Health of the Harbor:

The First Comprehensive Look at the State of the NY/NJ Harbor Estuary

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Hudson River Foundation

Prepared for the NY/NJ Harbor Estuary Program

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The First Comprehensive Look at the State of the NY/NJ Harbor Estuary

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2004

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Introduction

The New York/New Jersey (NY/NJ) Harbor Estuary is a remarkable place of surprising contrasts: abused but resilient, intensively developed but veined with natural treasures, a thriving port and a teeming estuary, a population center for people, fish and birds alike. As ships bring goods in and out of one of the largest ports in the country (and indeed the world) and commuters cross over and under the estuary's waters in ferries, bridges and tunnels every day, a parallel world just below the water's surface is conducting its business as well. Sturgeon commute upriver past the skyscrapers of Manhattan and the cliffs of the Hudson Highlands to spawn. Nutrients are shipped in and out of the estuary via the commerce of natural cycles. And all the while, ospreys soar overhead and blue crabs crawl along the bottom.

The core area (orange tint) of concern for the Harbor Estuary Program (Harbor Core Area)

The importance of the NY/NJ Harbor Estuary ecosystem was recognized by the US Environmental Protection Agency (EPA) when it was designated an Estuary of National Significance in 1987 and included in the National Estuary Program (currently 28 estuaries around the nation enjoy this status). The NY/NJ Harbor Estuary Program (HEP), a partnership of state, local and federal agencies, business interests, scientists, and concerned citizens has spent the past 15 years developing and implementing a plan to protect and restore the estuary: the Comprehensive Conservation and Management Plan (CCMP).

Because the estuary is so important, it is critical to understand the status of the estuary's health and whether it is getting better or worse. In order to assess these trends, a variety of monitoring programs are conducted, mostly by government agencies, to measure certain aspects of the estuary's ecology in the same way year after year. These data can then be analyzed over time to determine whether the estuary's health is improving. This type of analysis can help managers determine if environmental policies are having the desired effect and prioritize future actions and allocation of resources.

This report tracks progress in the environmental health of the NY/NJ Harbor Estuary through interpreting trends in a series of environmental indicators. The indicators were chosen in 1995 at a workshop attended by local environmental managers, scientists, advocates, and others whose charge was to design an environmental monitoring plan to accompany and support the HEP's CCMP. Indicators were chosen that would, when tracked, indicate whether the HEP's goals were being met, and whether HEP initiatives were making a difference in the environment. Of the approximately 40 indicators recommended by the workshop participants, 23 are examined in this report.

The remaining 17 indicators are not examined because appropriate data are lacking. The availability and accessibility of data are addressed for each indicator in this report in the form of a small bar graph at the beginning of each section. The two bars indicate the availability of relevant temporal and spatial data for that indicator. Analyses focus on data collected in the Harbor Core area (see map above), although the HEP's purview includes the entire watershed of the Harbor Estuary.

Generally, the news is good. Thanks to programs implemented under Federal and State environmental statutes, raw sewage and toxic materials are no longer discharged to the estuary to the extent they used to be. As a result, levels of contaminants in sediments and fish and concentrations of bacteria in the water have decreased over time. However, there is still room for much improvement. Consumption advisories against eating fish and shellfish caught in the estuary remain in effect because of unacceptable levels of contaminants in their flesh. Combined Sewer Overflows (CSOs) still contribute raw sewage to our waterways when it rains. And some shellfish beds have remained closed for decades. Private citizens, regulators and scientists still must work together to realize the HEP's vision: "a healthy and productive Harbor/Bight ecosystem with full beneficial uses."

This report is organized into sections corresponding to the modules of the HEP CCMP: Habitat and Key Species, Toxic Contamination, Pathogens, Floatable Debris, and Nutrients and Organic Enrichment. Within each section are chapters containing information about indicators relating to environmental trends in that subject area.

Use of Benchmarks

In presenting the spatial and temporal trends of the various indicators, this report employs the most widely used reference levels, or *benchmarks*, for each indicator. However, it is important to note that some of the benchmarks, particularly those related to toxic chemicals, are not universally accepted. Because of a number of factors, including our incomplete, though evolving, understanding of the human health effects of the contaminants of concern, these benchmarks will continue to be debated and updated in future years as new information is developed.

One example is the use of the *Effects Range* benchmark in the discussion of sediment contaminant concentrations. This measure has been endorsed by some agencies, criticized by others, and debated within the scientific community. Although it is widely used as guidance, it will likely be refined or perhaps even abandoned in the future as new research results become available.

Another example is the assessment of fish tissue chemical concentrations in terms of U.S. Food and Drug Administration (FDA) action limits. In this document these limits are used as reference points because they are the only numeric government enforceable standards in effect in this region. However, the action limit for PCBs – 2 parts per million (ppm) – is 20 years old and increasingly criticized for failing to take into account current information about PCB health effects, especially in relation to recreational fish consumption patterns. Recent health guidance developed by eight states bordering the Great Lakes, using more current science, sets guidelines for fish consumption at much lower concentrations than the standing FDA limits. EPA's recently published "Screening Values" for contaminant concentrations in fish consumed by recreational anglers include a value of 0.02 ppm for PCBs (see the section on PCBs in striped bass on page 40).

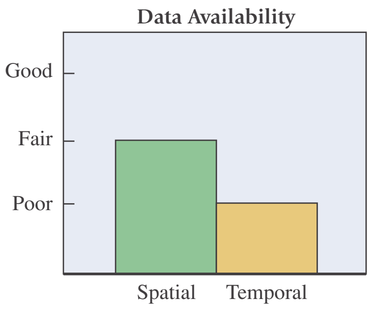
Therefore, the use of benchmarks in this report should not be viewed as endorsement of them by the authors or the HEP. Furthermore, they must not be interpreted as absolute threshold limits for triggering human health effects. It many instances, it is likely that effects can occur at levels below the benchmarks.

1 Habitat and Key Species

CHANGES IN HABITAT AREA

The Harbor Estuary is a mosaic of habitats for hundreds of species of fish, plants, birds, and other organisms. Salt marshes provide nursery areas for young fish. Uninhabited islands in the harbor are ideal nesting and feeding grounds for many species of aquatic birds. Mud flats are chock-full of shellfish. Rare and endangered plants can be found in the unique maritime habitats of Staten Island and New Jersey. The hard edges of the urban estuary— bulkheads, rip-rap, and pilings — even provide habitat for a rich community of invertebrates and other organisms.

Habitats are settings that provide crucial combinations of factors that support particular organisms. Many animals require multiple habitat types as they progress through different life stages. For example, striped bass spawning habitat is found upriver of the harbor core area in freshwater regions of the estuary. Once hatched, the young striped bass larvae progress downstream and grow through their first summer in the food-rich, protected shallow areas of Haverstraw Bay. In the fall they take up residence in the harbor off the shores of Manhattan, where temperature and salinity conditions are optimum for their overwinter survival. As adults, the striped bass will migrate between their oceanic feeding grounds and their upriver spawning habitat. All of these habitats are critical for healthy striped bass populations.



Many of the habitats of the estuary, particularly in the urban harbor core area, have been altered and destroyed over time. About 80% of the harbor's tidal wetlands and underwater lands (about 300,000 acres, roughly 1.5 times the size of the current area of New York City) have been lost because of filling, dredging, and other human activities. Shallow-water habitats have been filled since the beginning of European settlement; approximately 25% of the area of Manhattan is filled land which was previously shallow water habitat or wetlands. Canal Street in Manhattan used to be an actual canal, created by channelizing an existing portion of a salt marsh. Battery Park City is a more recent fill site. Although many of these activities are now banned, estuarine habitats continue to be threatened by development pressure and various types of pollution. As recently as 1990, a major oil spill in the Arthur Kill destroyed or damaged almost 200 acres of salt marsh (much of which has since been restored through the efforts of the Natural Resources Group of the New York City Department of Parks and Recreation).

The most straightforward way to track the health of estuarine habitats is to determine trends in numbers of acres of different habitats over time. Acreages of habitat types can be determined using aerial photography, accompanying surveys on the ground, and GIS (Geographic Information Systems) technology. This type of work is difficult and expensive, and so acreage data are somewhat limited, but existing data trends are described here. A harder thing to measure, but just as important as areal extent, is the *function* of existing habitats – whether those habitats are healthy overall and working the way they should. There is no program that monitors habitat function directly. However, one indirect way to determine whether habitats are functioning properly is to examine the population sizes of organisms that those habitats support. Trends in populations of some fish and bird species are described later in this report.

Wetland Acreage

Wetlands are among the most productive and important habitat types in the estuary, providing essential nursery, feeding, spawning, and nesting grounds for a variety of fish and wildlife species. Because of their high productivity, wetlands are crucial links in supporting the estuarine food web. Wetlands also filter sediment and associated contaminant and nutrient runoff from the land, thereby helping to protect water quality in the estuary. Finally, wetlands provide important flooding buffers for surrounding areas at times of high water and storm surges.

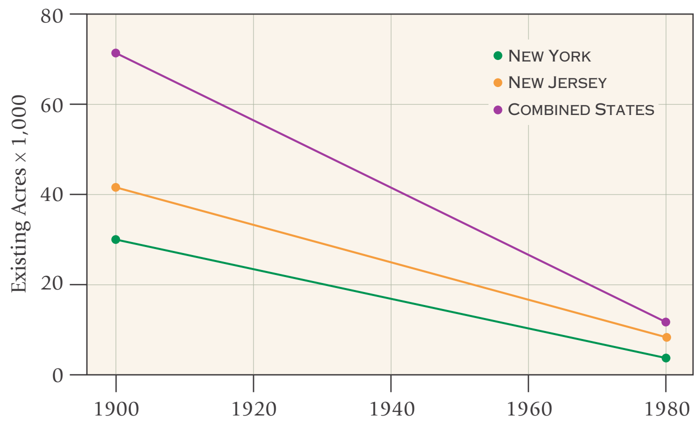


Figure 1 *Decreasing marsh acreage in the harbor core area in New York, New Jersey, and both states combined, 1900–1980 (Squires 1992).*

Unfortunately, since the time of European settlement in the region, the vast majority of wetlands in the Harbor Estuary have been destroyed or degraded by human activity, including bulkheading, filling, dredging, channelization, and inputs of toxic contaminants. Figure 1 depicts the changes in marsh acreage between about 1900 and 1980 in the harbor core area only. The sizeable loss of salt marsh in both states is clear. Figure 2 depicts the loss of wetlands in acres by county for the northern New Jersey counties that border the harbor from 1984 to 1995 (later in time than the data depicted in Figure 1). During that period of time, New Jersey lost approximately 2.5% of its natural wetlands statewide. The greatest losses in those 11 years occurred in Hudson County, where 432 acres of wetland, or nearly the area of 400 football fields, were destroyed between 1985 and 1995. It is likely that the losses were smaller in more urbanized areas such as Union and Essex Counties because by 1985 most of the historical wetlands in these counties were already gone. Between 1986 and 1995, nearly 11,000 acres of New Jersey wetlands were converted to urban lands.

Figure 2 *Coastal wetland losses in six New Jersey counties, 1985–1995. Losses are represented in acres (Rutgers University 2002).*

Figure 3 shows historic (1776–1777; in the pink colors) and modern (green shades) distributions of both freshwater and tidal wetlands in the harbor core area. The major losses around Jamaica Bay, New Jersey, and the Arthur Kill are apparent. There were also extensive wetlands fringing Little Neck Bay and other East River/Western Long Island Sound bays and in the southeast Bronx.

As of the mid-1980s and early 90s, there were approximately 200,000 acres of tidal marshes remaining in the entire state of New Jersey and about 25,000 acres in New York, the vast majority of which were outside of the urbanized harbor core area (the Hackensack Meadowlands being a notable exception). Approximately 20,000 acres of tidal wetlands now remain in the harbor core area (in both states), about 20–25% of the his-

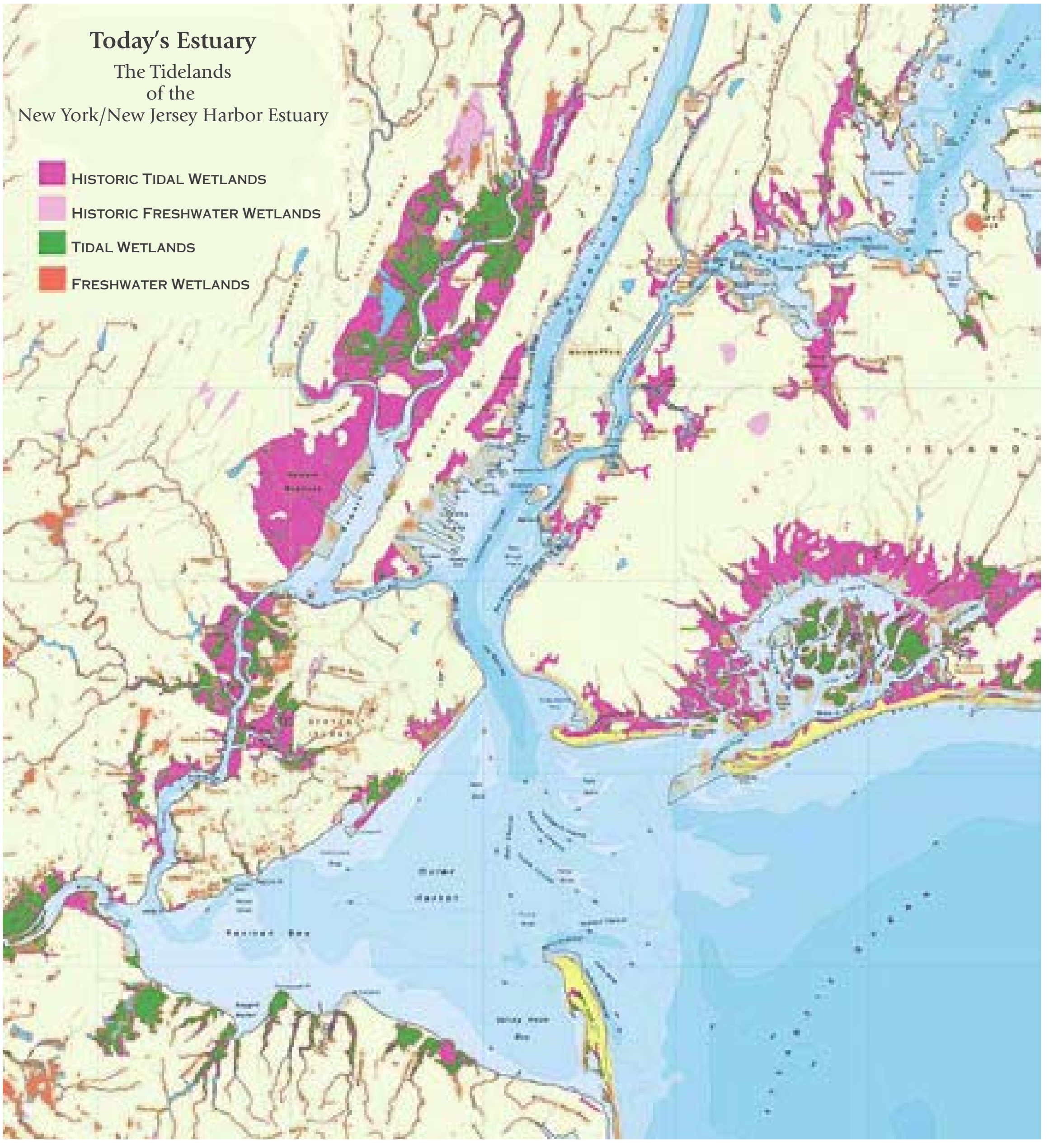


Figure 3 *Historic and modern tidelands in the NY/NJ Harbor Estuary. Historic lands based on the Ratzer Survey (1776–1777) and 19th century USGS, NJGS, and US Coast and Geodetic Survey topological maps and harbor charts (Cox 2003).*

torical marsh area in the harbor. Wetlands and other underwater lands were filled to expand the land mass of Manhattan and Brooklyn, to create the Newark and John F. Kennedy airports, to make room for railroad terminals, and to provide land for petroleum facilities along the Arthur Kill, among other uses. Also, most of the 224,000 acres of freshwater wetlands that existed in the urban core area in pre-colonial times are now lost.

Although loss of wetlands has slowed dramatically since the implementation of stricter wetlands protection laws, there are still many threats to wetlands in the estuary, most of them related to human activity (see the introduction to this section).

Changes in Newark Bay

One of the major ways in which humans have affected the estuarine environment, particularly in densely-populated areas like the NY-NJ metropolitan region, is by filling in coastal habitats. Marsh and open-water areas were filled for a number of reasons before the critical functions of wetlands were understood: to create more land for residential, commercial and industrial development, to dispose of waste in landfills, and to fill marshes that were considered merely mosquito-infested public health threats. Fill material ranged from cellar dirt to excavated rock to garbage. Hundreds of thousands of acres of marshes and open-water areas have been filled in the Harbor Estuary, beginning in the late 18th century. Some familiar landmarks that are built on filled land include the Fresh Kills landfill, much of Ellis Island, and Battery Park City. Large-scale filling activities are now severely restricted, in fact nearly eliminated, by wetlands protection legislation and other legal tools put in place in the early 1970s.

This history of rampant filling of aquatic habitats, followed by a virtual cessation of filling is typified in the Harbor Estuary by the history of the filling of Newark Bay. In order to follow the progression of fill activities in the Bay, trends in the area of the Bay were examined (Figure 4). About 2200 acres of marsh along the edges of Newark Bay were filled between 1913 and the early 1970s for the creation of Newark Airport and for the port facilities of Port Newark and Port Elizabeth, the busiest places in the Port of New York/New Jersey. That fill is reflected in the large decrease in the size of the Bay by about one third between 1855 and 1976. Between 1976 and 2000, as a result of restrictions on filling activities, there was virtually no change in the size of the Bay. These trends are shown graphically

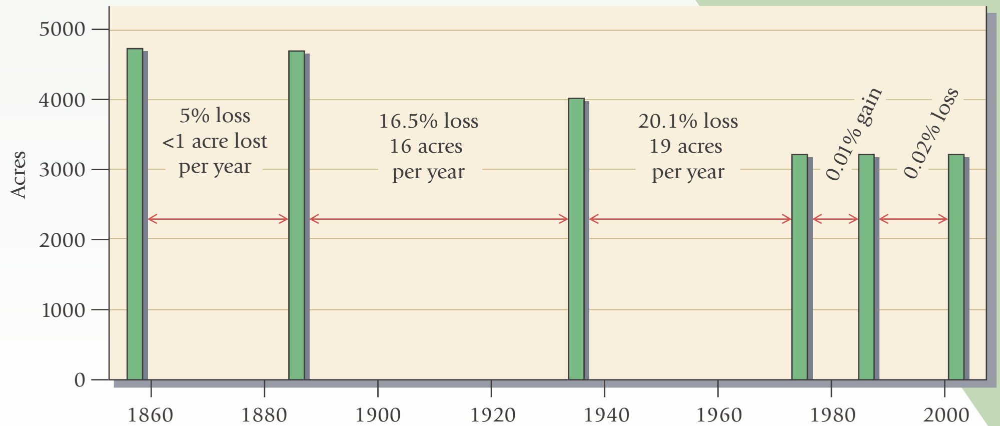


Figure 4 *Historic changes in the acreage of Newark Bay, 1855–2001 (Suszkowski 1978, NOAA 2001, NOAA 1985).*

in Figure 5, which traces the progression of fill in the Bay by depicting its shape over time. The blue areas are the surface area of the water in the Bay, while the red shows areas that were filled.

In addition to filling activities, dredging has changed the shape of Newark Bay as well. Although the Bay has become smaller, it has actually become deeper as a result of channel dredging. Other basins of the harbor have experienced the same trend: decreasing area due to fill but increased water volume because of dredging. For example, between 1845 and 1989 the area of the Upper Bay was reduced by 26% due to filling activities, but dredging channels increased the average depth from 20 to 31 feet over the same time period, expanding the volume of the Upper Bay by 15%.

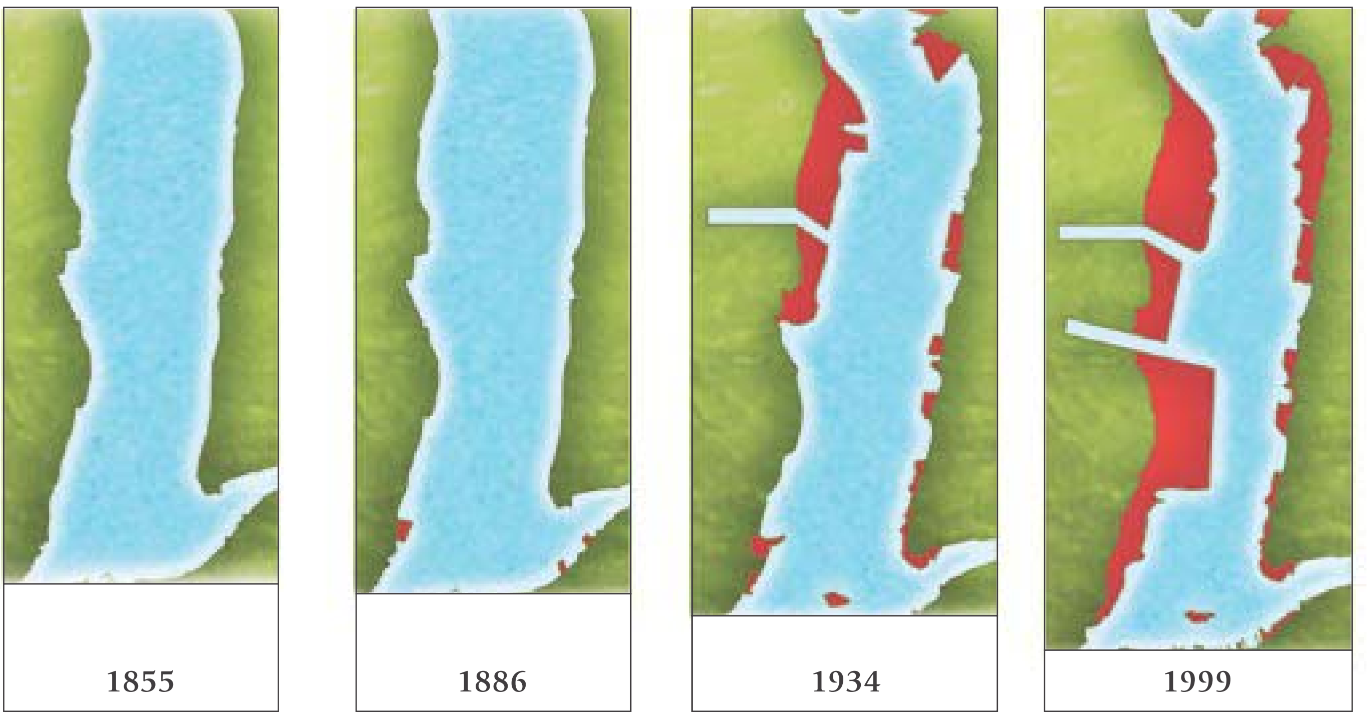


Figure 5 *Changes in the Newark Bay shoreline, 1855–1999. Red represents land created with fill. (Suszkowski 1978, NOAA 2001).*

Loss of Wetlands in Jamaica Bay

While filling and resulting loss of wetlands have been curtailed in the estuary in recent decades, there has been an alarming loss of tidal wetlands in Jamaica Bay, particularly the marsh grass islands that are scattered throughout the Bay. According to analyses of historical maps and aerial photographs conducted by the New York State Department of Environmental Conservation (NYSDEC), the size of tidal wetlands in Jamaica Bay remained nearly constant between 1857 and 1924. As shown in Figure 6, between 1924 and 1974, about 1300 acres of wetland were lost to fill and other human activities, at an average loss rate of about 10

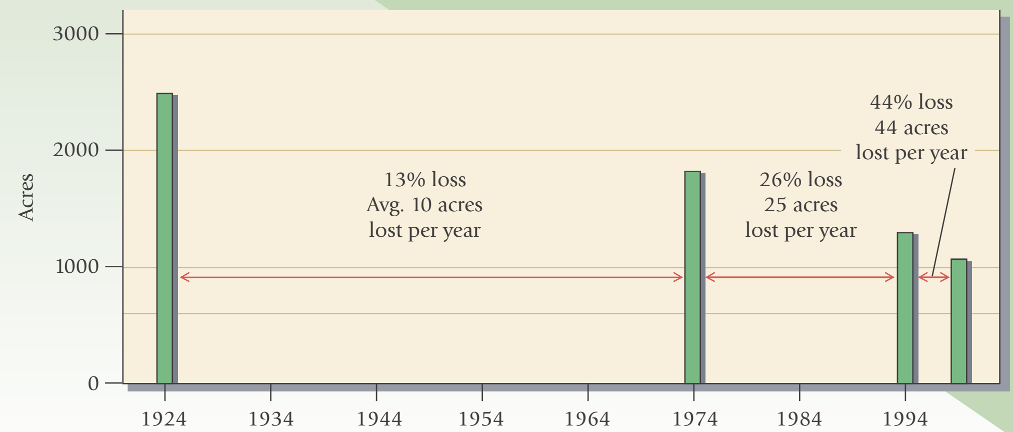


Figure 6 *Tidal wetland loss from Jamaica Bay islands, 1924–1999. Acreages were determined from aerial photography (Fallon and Mushacke 2002).*

acres per year. Since 1974, wetlands loss has occurred at an even greater average rate, currently about 44 acres per year. If loss continues at this rate and nothing else changes in the system, all of the marsh islands in the Bay will disappear by 2024. Figure 7 dramatically depicts the losses that are occurring at two representative sites in the Bay. Tidal marshes in these aerial photographs are shown in pink for Duck Point (7A) and Elders Point (7B) in 1974 and 1999. Duck Point marshes decreased in size from 103 acres to 38 acres, a loss of 63%, and Elders Point experienced a similar decline, from 97 acres to 21 acres (77% loss).

In 2001, a Blue Ribbon Panel was convened by the National Park Service to investigate the reasons for the marsh loss. A number of potential causes and contributing factors related to human impacts on the Bay were discussed: sea level rise due to global climate change; disruption of the sediment budget of the Bay which may prohibit the building of new marsh; increased wave energy and subsequent erosion in the Bay due to the existence of dredged channels; smothering of the marshes by blooms of sea lettuce; effects of contaminants leaching into the Bay from surrounding landfills or other sources; erosional loss of mussels that stabilize the edges of the marsh; the presence of an overabundance of mussels that may “dam” water behind them at low tide and contribute to breakdown of the marsh; and excessive consumption of the marsh grass by waterfowl. Clearly the issue is very complex, as marsh loss may be due to any or a combination of these factors. Consequently more research must be conducted in order to determine which (if any) are the most important causes. However, the Panel recognized that action must also be taken right away to stem the loss of marsh. Several pilot projects have been funded and are underway to determine the causes of the loss and the best ways to

For More Information about Habitat and Wetlands:

wetlands.fws.gov

www.epa.gov/owow/wetlands/vital/toc.html

www.dec.state.ny.us/website/dfwmr/marine/mhabitat.htm

www.dec.state.ny.us/website/dfwmr/marine/twloss.html

crssa.rutgers.edu/projects/lc/urbangrowth/index.html

Significant Habitats and Habitat Complexes of the New York Bight (report to the HEP, US Fish & Wildlife Service,1997)

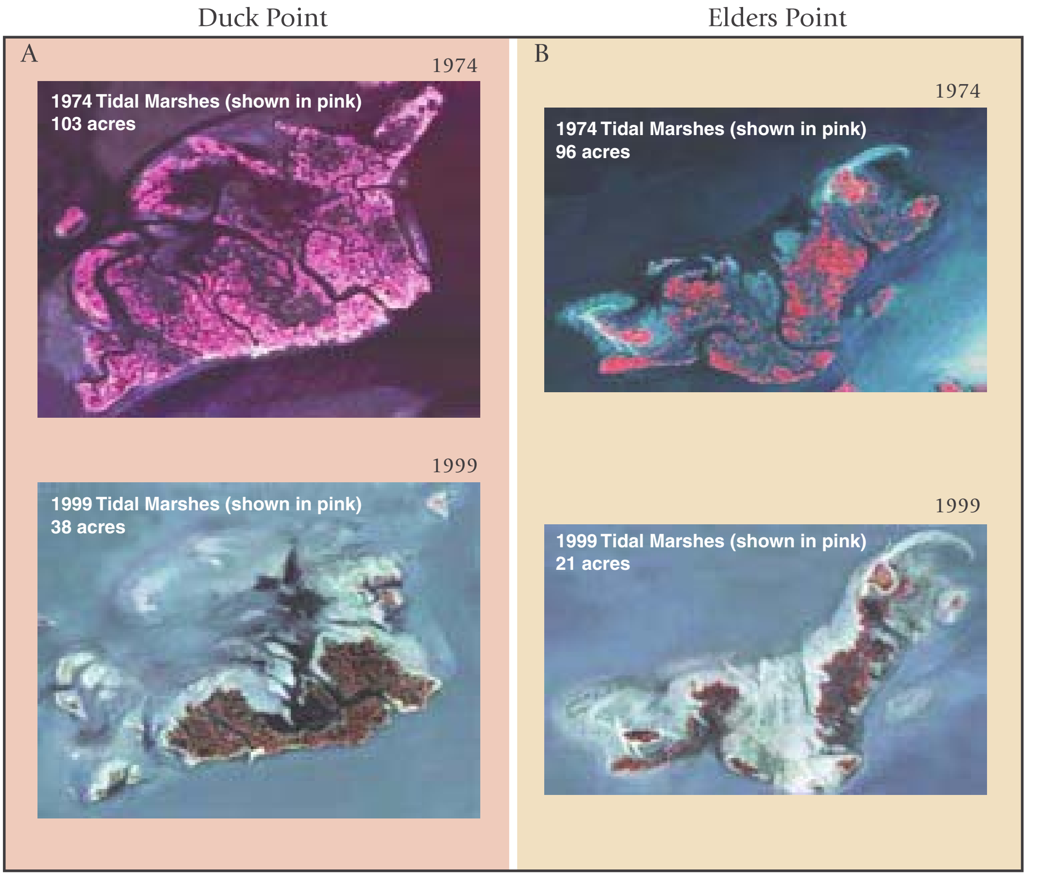


Figure 7 *Aerial photos depicting tidal wetland losses from two Jamaica Bay islands, 1974–1999. Figure 7A shows 65 acres lost at Duck Point; Figure 7B shows 75 acres lost at Elders Point. Tidal marshes are shown in pink (NYSDEC 2002).*

remediate the problem. These projects include monitoring the impact of foraging birds on the marsh grass and taking sediment cores around the Bay in order to examine patterns of deposition and erosion of sediments through time. Experimental planting of marsh grass will also be conducted, and a variety of additional actions are under consideration.

Habitat Loss in the Hackensack Meadowlands

The largest remaining tract of tidal wetlands in the harbor estuary system is the Hackensack Meadowlands in New Jersey. While many people think of the Meadowlands as a place to go to watch a football game, other equally exciting events occur there on a daily basis: Ospreys and herons capture fish to eat, fiddler crabs dig their burrows and search for mates, young fish eat and grow, and families of our own species canoe and kayak the winding waterways that criss-cross the marshes. As wild as the Meadowlands are today, however, they used to be even larger and wilder: originally a glacial lake (Lake Hackensack), over time the Meadowlands evolved into a succession of types of freshwater wetlands, and became brackish only after European settlers changed the hydrology of the area with dikes and dams in order to convert the wetlands to farmland. Over the past 100 years or so the Meadowlands have been drained and/or filled, first for agricultural purposes, then in misguided and ultimately fruitless attempts to control mosquitoes, and later for industrial and commercial uses and the creation of landfills. These changes destroyed valuable fish and wildlife habitat and altered the function of the areas that remain.

Figure 8 depicts the loss of Meadowlands tidal estuary acreage, including open water, mudflats and marsh, between 1890 and 1995. Total acreage has decreased from about 15,000 acres at the end of the 19th century to about 8,000 acres today, a total loss of approximately 47%. (Similarly, the US Fish and Wildlife Service states that the Meadowlands' historic 20,000 acres have been reduced to 8,400 acres today.) Particularly troubling is the fact that the rate of loss was higher between 1969 and 1995 than it was in the 79 year-period prior to 1969. Between 1890 and 1969 the rate was about 63 acres per year on average, while about 77 acres per year were lost from 1969 to 1995.

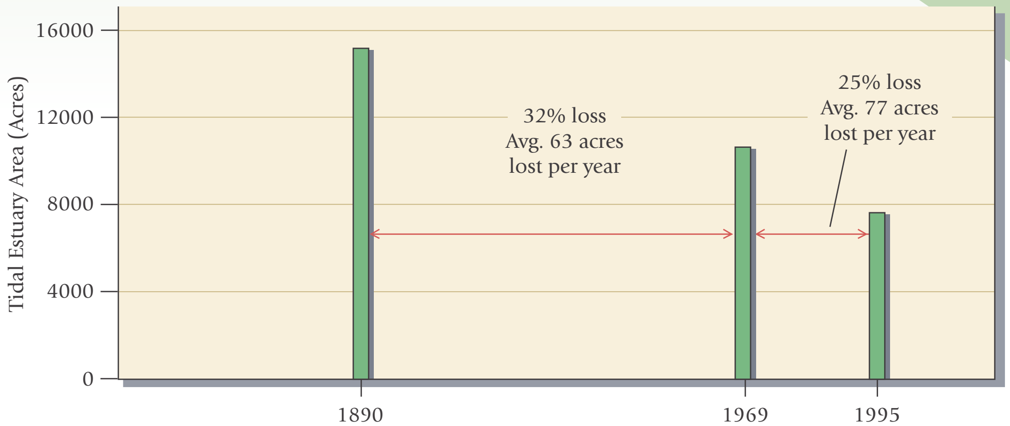
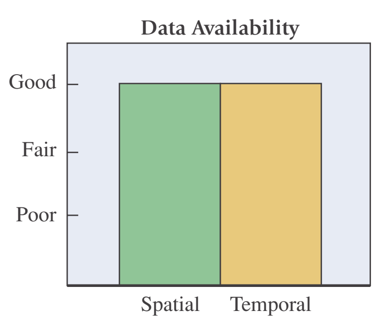


Figure 8 *Tidal estuary acreage, including open water, mudflats, and emergent marsh, in the Hackensack Meadowlands, 1890–1995 (Hartman 2002).*

ABUNDANCE OF WADING BIRDS



In the midst of the most urban part of the Harbor Estuary is a remarkable population of wading birds, consisting of a variety of species of herons, egrets and ibises commonly referred to as a group as the *Harbor Herons*. The Harbor Herons complex represents one of the most amazing comeback stories in the estuary. As recently as the 1960s there were virtually no wading birds in the harbor, their populations devastated by hunting (mostly for their decorative feathers), pollution, and lack of small fish for them to eat. As the environment of the harbor improved (hunting of these birds had been banned at the turn of the last century), their populations grew tremendously and they nested and foraged for prey in and around the uninhabited islands of the Arthur Kill, Kill van Kull, and East River. Currently the Harbor Herons constitute about a quarter of all of the nesting wading birds in New Jersey, New York and Connecticut.

For many years the New York City Audubon Society has monitored the population of the Harbor Herons with the help of trained volunteers. Their late spring surveys of North and South Brother Island in the East River and Shooter's and Prall's Island and the Isle of Meadows in the Kills count numbers of birds, numbers of nests, and other population parameters. Figure 9 depicts the numbers of individuals of various Harbor Heron species recorded on these islands by the Audubon survey between 1991 and 2001. These data indicate that the numbers of Harbor Herons birds, most notably the black-crowned night heron, cattle egret and glossy ibis, on these islands have generally been decreasing over the past decade. These declines could mean that these species are simply nesting elsewhere in the estuary or somewhere else along the East Coast, or could indicate that some disturbance or environmental factor is affecting their populations in the estuary. More research and coast-wide monitoring is needed in order to determine the actual causes for the declines.

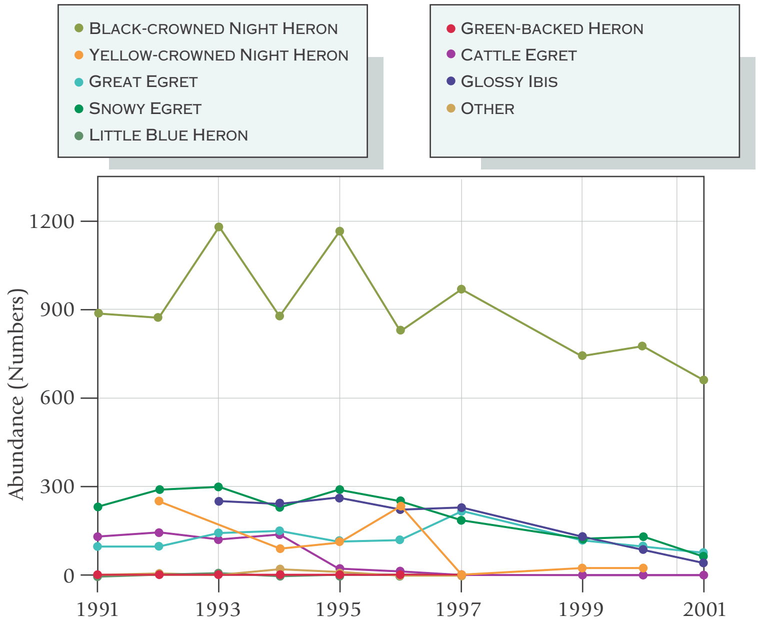


Figure 9 *Wading bird populations on five islands (Shooter's, Prall's, Isle of Meadows, North and South Brother) of the Harbor Herons Complex, New York Harbor, 1991–2001. Because the survey was conducted differently in 1998, that year's data are not included here. This data record is subsequent to the 1990 oil spill (see side bar) (Parsons and Wright 1991–1995, Kerlinger 1996–2002).*

The Audubon Society has observed nesting wading birds on other islands in the estuary in recent years, including Hoffman Island off Staten Island, Canarsie Pol in Jamaica Bay, Huckleberry Island in Long Island Sound and Goose Island in the Hutchinson River. Relocation may account for the declines on the islands described above. It has been well-documented that there was a large decline of wading birds on Shooter's Island after 1995, from 400 pairs of birds in 1995 to none in 1998. A similar decline has been observed on Isle of Meadows. However, during the same period the nesting populations of waders on other islands increased dramatically. Overall, Audubon reports that populations of many of these waders have decreased somewhat.

For More Information
about Birds in the Estuary:

Heartbeats in the Muck, by John Waldman (Lyons Press, 1999)

The Hudson: An Illustrated Guide to the Living River, by Stephen P. Stanne et al. (Rutgers University Press, 1996)

Before and After an Oil Spill: The Arthur Kill, by Joanna Burger (editor, Rutgers University Press, 1994)

www.nycas.org

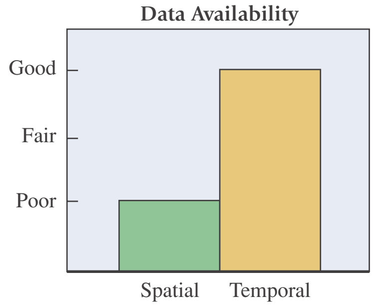
Chemical contaminants in the estuary may have a significant effect on wading and other birds, as the birds bioaccumulate contaminants that are present in their prey. For example, lead levels in the feathers of some terns in the area increased between 1988 and 1992 and were found in some individuals at levels that have been associated with behavioral impairment and retarded growth in laboratory experiments. However, decreases in DDT and other pesticides in the environment caused eggshell thickness in marine birds to increase from the 1970s to the 1990s (it is important for birds to maintain eggshell thickness so that the eggs do not break during incubation).

The 1990 Arthur Kill Oil Spill

New York Harbor is both the largest oil port in the country and a productive and diverse ecosystem. These two aspects of the estuary clashed in January 1990 when a large oil spill (actually a leak from a nearby refinery and storage facility) in the Arthur Kill threatened the ongoing recovery of the estuary. During the night of January 1-2 more than 560,000 gallons of No. 2 fuel oil leaked into the Arthur Kill. Some of the organisms that were most directly and immediately affected by the spill were the birds of the Kills. Because the spill occurred during the winter, migratory species that reside in the estuary only in the summer were not directly harmed. Birds are particularly affected by oil spills because the oil destroys the insulating and waterproof properties of their feathers, causing them to die from hypothermia or prohibiting them from diving to collect food. In addition, they can ingest or respirate the oil, with lethal consequences, and the oil can destroy critical nesting and foraging habitat.

About 600 dead birds (mostly gulls and a few small waterfowl) were found in the estuary immediately after the spill, but what long-term effects would the oil spill have? Fortunately, scientists had been collecting data about the populations of birds in the Arthur Kill before the spill, so they were able to compare that information with information collected after the spill in order to determine the impact of the spill on birds. Although it is difficult to differentiate between oil spill impacts and natural population fluctuations, a sharp decline in the number of gull nests in the Kills was observed in the summer of 1990, and a smaller decline was noted in 1991. In 1992 the numbers started to climb again, but virtually no gulls now nest on the islands of the Arthur Kill. (NYC Audubon believes that this absence is due to changes in habitat on the islands that have eliminated grassy areas that are suitable for gulls to land and take off.) Changes in feeding behavior and declines in reproductive success of many bird species were observed in the two years after the spill as well. Most species seem to have returned to normal only a few years after the spill (wading birds returned to pre-spill reproductive success three years after the spill, for example). However, the long-term effects of the spill on birds and other species in the estuary are still not known.

ABUNDANCE OF FISH AND CRUSTACEANS



In his classic book about the Hudson River (*The Hudson River: A Natural and Unnatural History*), Robert Boyle writes "For fishes, the lower Hudson is a kind of Times Square." Because the estuary is such a productive ecosystem and provides protective and food-rich nursery habitat for young fish in particular, it is teeming with a diverse fish community. Species ranging from marine bluefish to freshwater sunfish are found there. Migratory fishes such as striped bass, sturgeon and shad spend most of their lives at sea but come through the estuary on their way to freshwater spawning grounds, a life cycle called *anadromy*. Once spawned, the offspring of these species spend their first summer eating, growing and hiding from predators in the estuary. American eels, which employ the opposite strategy (*catadromy*), move into the Hudson after hatching somewhere in the Sargasso Sea. Add to this mix the occasional stray fish from deeper or warmer waters, and a highly diverse and dynamic fish community results. All in all, more than 100 species of fish call the Harbor Estuary home for some or all of their life cycles. Many of these species are important in commercial and recreational fisheries on the East Coast or in the estuary itself. It is estimated that about 75% of the nation's (and 32% of the Northeast Atlantic's) commercially-caught fish depend on estuaries at some point in their lives. Anglers covet the wily striped bass and acrobatic bluefish,

Other Birds in the Estuary

Besides wading birds, there are many other bird species that live in the estuary for all or part of the year. Figure 10 depicts trends in some of the waterbird species that are found in the harbor, again from the Audubon Society's survey program. Gulls are one of the most familiar avian residents of the estuary. The Audubon Harbor Herons survey has noted a drastic decline in the herring gull population in the harbor in recent years, while the great black-backed gull population has remained stable. Double-crested cormorants, often seen drying out their wings around the harbor, have experienced a large population boom, and have been expanding the number of harbor islands on which they nest.

While Canada geese seem to be everywhere in the harbor region, their numbers seem to be declining as well. Other waterfowl populations seem to be fairly stable. One bird that seems to be increasing in number is the osprey, a fish-eating type of raptor that likes to nest on pilings and other structures around the estuary. As profiled in Rachel Carson's well-known and important book, *Silent Spring*, populations of these birds were severely depleted because they were susceptible to the effects of the pesticide DDT, use of which is now banned in the United States. The resurgence of the osprey is a good indication that the estuary itself is cleaner and healthier than it used to be.

The harbor is also an important stopover for what are called "neo-tropical migrants," small songbirds that travel between North American and tropical regions in Central and South America. The harbor, particularly parts of Jamaica Bay and Raritan Bay, provides spectacular birding when these brightly colored birds come through in the spring and fall.

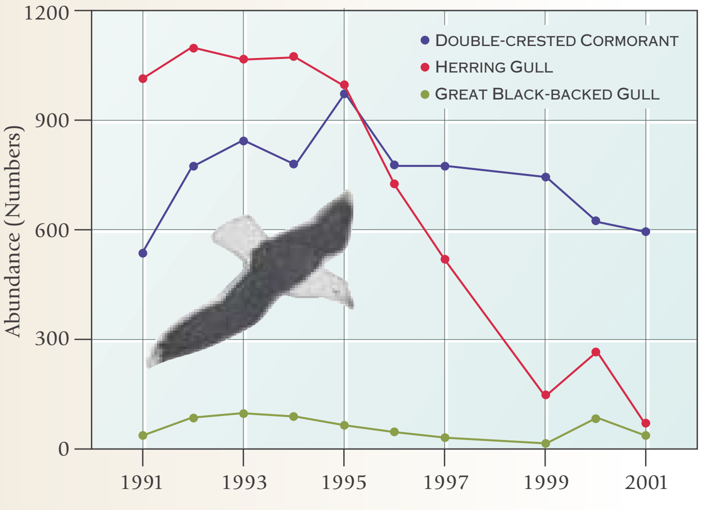


Figure 10 *Colonial water bird populations on five islands (Shooter's, Prall's, Isle of Meadows, North and South Brother) of the Harbor Herons Complex, New York Harbor, 1991–2001 (Parsons and Wright 1991–1995, Kerlinger 1996–2002).*

while commercial fishers target shad and blue crab within the Harbor Estuary in the shadow of skyscrapers.

It is a key goal of estuarine protection programs to ensure that populations of native fish and crabs are thriving. In turn, abundances of fish and crabs provide a measure of the overall health of the estuary in terms of habitat quality and ecosystem function. In order to determine the health of fish and crustacean populations in the estuary, measures of abundance of eight representative species are depicted in the following pages. Because there are no reliable long-term studies of fish populations in the harbor core area of the HEP, two other sets of data in the estuary were used for these analyses: one in Haverstraw Bay slightly north of the harbor core area, and one in Jamaica Bay. Because some of the species discussed in the following pages do not occur regularly in Jamaica Bay, the Jamaica Bay data are not shown for those species.

Because it is very difficult to determine the absolute number of a given species in the estuary, indices of abundance (rather than an exact count of abundance) are generally used. An index of abundance is generated by using standard sampling methods over a set period of time to examine population size. These measures can provide a basis for comparison of one year to another, show trends in abundance over time, and tell us whether a particular year was a "good" year for that species or a relatively poor year. They do not provide an absolute number of any given species present in the estuary in a given year.

It is important to note that determining the cause of changes in abundance of fish and crab species from year to year is also very difficult. Virtually all species experience natural fluctuations in population size over time, the reasons for which are usually complex and often unclear. Perhaps an environmental factor is controlling the population in a given year – a dry spring or a cold winter can have a large impact on young fishes' survival. Human-induced changes, including pollution, habitat destruction and overfishing can affect fish and crab populations as well. Some species spend substantial amounts of time outside the boundaries of the estuary, so conditions that they encounter elsewhere also will affect their numbers in the estuary proper. Interactions among fish species can affect abundance — for example, high numbers of predatory young bluefish in a particular year can result in lower numbers of their prey fish, including young striped bass and shad. In order to determine if a species is actually experiencing a significant population decline, as opposed to a natural shift in abundance, it is critical to examine as many years of data as possible to be able to determine long-term trends. The data sets used for these analyses are reasonably long-term and continuous.

While the following discussions focus on the patterns in abundance observed for individual species, it is also important to look at changes in the fish community over time. One study in Haverstraw Bay has found that the *diversity* (a measure of the number of species along with their relative abundances found in a given area) of the fish community in Haverstraw Bay has declined over time (Hurst et al. in review).

Striped Bass

If the Harbor Estuary had a mascot, it would likely be the striped bass. In his book, *Heartbeats in the Muck,* John Waldman calls striped bass "... the harbor's symbol, a pin-striped tough guy that transcends its surroundings." Volumes have been written about this popular fish, thousands of hours and millions of dollars have been spent on researching its ecology and biology, and anglers go to great lengths to fish for it along the entire east coast (and parts of the west coast where it was introduced in the late 1800s from Hudson River stock). While striped bass are a very popular quarry for recreational anglers, the commercial fishery in the river and estuary is closed because of public health concerns about the levels of PCBs in their flesh. Health advisories are also in effect regarding eating recreationally-caught fish throughout the Hudson River and harbor as well.

Striped bass enter the estuary in the spring on their way to freshwater reaches of the Hudson between the Highlands and Kingston to spawn. The eggs and larvae drift downstream, and after hatching, most of the young striped bass spend their first summer congregated mainly in and around Haverstraw Bay. In the fall, most of the adults will migrate back out to sea, while the young of the year will spend their first winter in the lower river off Manhattan's shoreline. Adults can be quite large, growing to more than three feet in length and 50 pounds in weight.

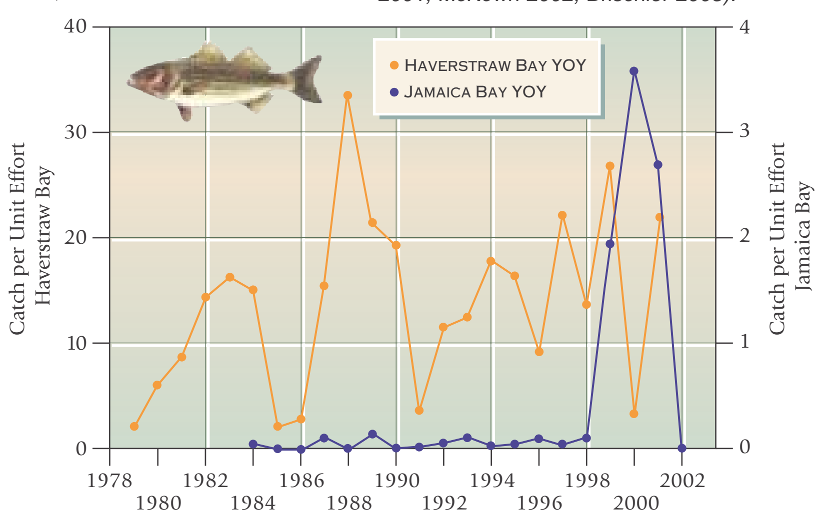
Striped bass have undergone a remarkable recovery after a huge coast-wide decline attributed largely to overfishing. Coastal commercial landings declined precipitously starting in the mid-1970s, and heavy fishing restrictions, including a closure of the commercial fishery in Maryland and Delaware, were put into place. These policies seem to have worked: striped bass have increased in numbers since that time, and are again abundant throughout their range. The fishery restrictions have since been eased (but note, as stated above, that the commercial fishery in the Hudson River remains closed because of concerns about PCBs).

The New York State Department of Environmental Conservation (NYSDEC) has conducted a summer and fall population survey of the "young-of-the-year" (YOY) striped bass (those hatched in the spring and therefore not yet one year old) every year since 1979 in the Haverstraw Bay region of the Hudson. From the data collected for this survey, an index of YOY striped bass abundance is calculated to provide a relative measure of the size of that year's population. This index is plotted in Figure 11 from 1980 to 2001. There is no clear directional trend in the index in the years shown; rather, it varies widely from year to year. However, the peak years in the index indicate stock recovery by revealing increases in the number of individuals present in the system. The 2001 index was among the highest during the entire history of the survey. It is likely that environmental factors such as salinity and temperature have a large impact on the yearly variation in the index.

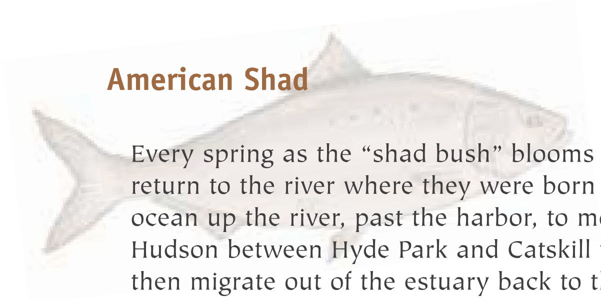
The Hudson River population stayed fairly stable throughout the time that the coastal stock was in decline as described above, because the coastal stock is comprised mostly of Chesapeake Bay fish (approximately 75% Chesapeake, 15% Hudson fish, and 10% Delaware Bay fish) and the Hudson population did not experience the precipitous decline that occurred in Chesapeake Bay.

Figure 11 also shows NYSDEC survey measures of abundance of YOY striped bass in Jamaica Bay for the years 1984–2002. Note that usually there are far fewer young striped bass in Jamaica Bay than in Haverstraw Bay, but that in 2000, when the index of abundance was very low in Haverstraw Bay, the index was the highest recorded in these years in Jamaica Bay.

Figure 11 *Catch per Unit Effort (CPUE) of young-of-the-year striped bass in Haverstraw Bay (1979–2001) and Jamaica Bay (1984–2002). CPUE values are geometric means. Note different scales of the two Y axes (Hurst 2002, Hurst and Conover 2001, McKown 2002, Brischler 2003).*



The reason for this pattern is not known. Perhaps conditions were better in Jamaica Bay for striped bass that year so they congregated there rather than in the Hudson. It appears that numbers of striped bass were high in both bays in 2001.



American Shad

Every spring as the "shad bush" blooms along the Hudson, American shad return to the river where they were born to spawn. They migrate from the ocean up the river, past the harbor, to more freshwater portions of the Hudson between Hyde Park and Catskill where they spawn. The adults then migrate out of the estuary back to the ocean. Unlike some species such as west coast salmon, shad do not die after spawning, but return to spawn again for as many as 5 additional years. The just-hatched shad reside in the river, moving generally downstream over the course of the summer. They migrate out to the ocean in the fall, where they live for four to seven years until it is their turn to return to the river and spawn.

These silvery relatives of herring, which can reach 10 pounds, constitute the most important commercial fishery remaining in the estuary. Using much the same technique that has been used for centuries, shad fishers from the George Washington Bridge to Haverstraw Bay place their nets in the estuary every spring. Shad roe is a delicacy that appears annually in local fish markets, and the flesh of the shad, once the difficult task of de-boning it is accomplished, lives up to the shad's Latin name, *Alosa sapidissima* -- "herring most delicious."

For the most part, shad are not subject to the strict health advisories issued by the states for most other edible species in the estuary because they do not feed while on their spawning runs and therefore do not appreciably bioaccumulate contaminants.

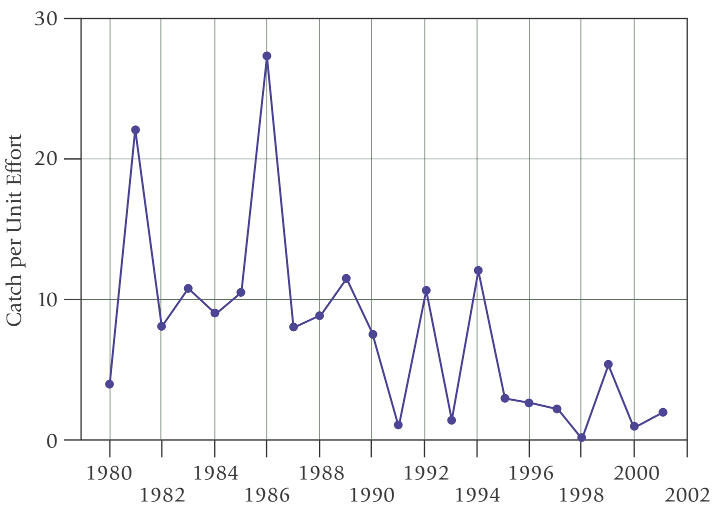


Figure 12 *Catch per Unit Effort of young-of-the-year American shad in Haverstraw Bay, 1980–2001 (Hurst 2002, Hurst and Conover 2001).*

New York State conducts two annual surveys from which shad abundance can be determined. Figure 12 shows measures of abundance for "young-of-the-year" shad (fish just hatched in the spring, counted in the summer and fall, and therefore not yet one year old) in Haverstraw Bay, counted as they migrate out to sea. These data indicate that young shad numbers have been declining since the mid-1980s in the Hudson River. Other related fish species in the Hudson River, such as alewife and blueback herring, exhibit similar declines over this time period.

Figure 13, which shows the abundance of adult shad caught in the commercial fishery in the Hudson River, indicates a declining trend similar to the pattern for the young of the year. This decline could be due to a number of factors, including loss of spawning habitat, overfishing in the river, effects of pollution, or simply natural but poorly-understood variations in population size over time. The ocean intercept fishery for shad, which caught large numbers of shad in the ocean before they entered their respective estuaries to spawn, may have had a significant effect on shad populations as well; this fishery is currently being phased out. Very large fluctuations in shad abundance have occurred historically: from very high numbers in colonial times the fishery experienced a decline in the mid-1800s, spiked at the end of the 19th century, and crashed in 1916. Commercial landings edged up again in the 1930s and continued to increase to record levels in 1942. They declined again in the 1960s and are now experiencing a further decline.

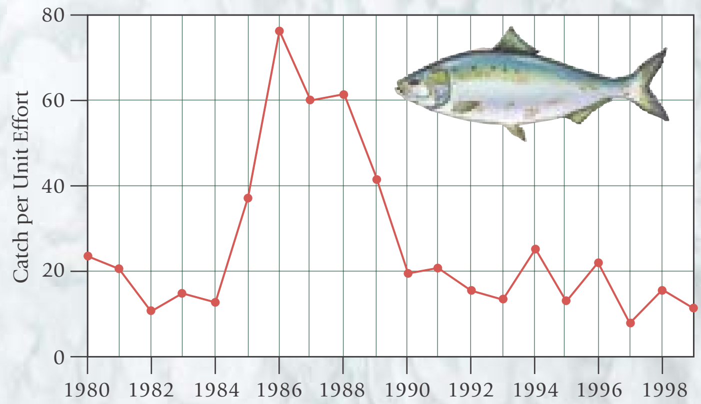


Figure 13 *Catch per Unit Effort of American shad in the Hudson River commercial shad fishery, males and females combined, 1980–1999 (Hattala 2001).*

Winter Flounder

One of the most popular sport fish in the NY/NJ region is the winter flounder, another part-time estuary resident. In fact, it is so popular with anglers that in most years recreational catches of winter flounder exceed commercial landings in New York waters.

Winter flounder get their name from the fact that they move into the estuary in the fall and spawn there in late winter and early spring. They move offshore to colder, deeper waters in the summertime (although it has also been speculated that some stay in the estuary but bury themselves deep in the sediment during the summer months). The young spend their first year in the estuary before taking up the migratory patterns of the adults. Because winter flounder live in close contact with the sediment in often-contaminated east coast estuaries and feed on small organisms in the sedment, concern has been raised about the impact of pollution, particularly in contaminated sediment, on this fish. Many studies have been done on the impact of pollution on winter flounder; results of these studies indicate that organic chemical contamination can cause reproductive, developmental, and other problems in winter flounder. In addition, flatfishes in general seem to be more susceptible to pollution-related disease than other fishes. However, contaminants do not seem to bioaccumulate in the muscle tissue that we eat, so eating flatfishes generally should result in less contaminant intake than consuming other species, according to available data.

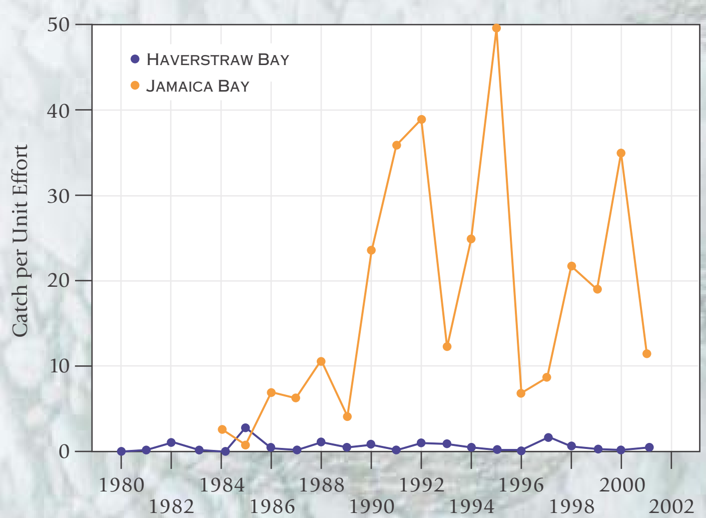


Figure 14 *Catch per Unit Effort of young-of-the-year winter flounder in Haverstraw Bay (1980–2001) and Jamaica Bay (1984–2001) (Hurst 2002, Hurst and Conover 2001, McKown 2002).*

Figure 14 depicts the relative abundance of winter flounder in Haverstraw Bay and Jamaica Bay as measured by two NYSDEC yearly surveys. In Haverstraw Bay, the data indicate a small and fluctuating population not obviously increasing or decreasing over time. In Jamaica Bay, the population seems to have increased, appearing to be larger in the 1990s compared to the 1980s. Abundance of winter flounder is higher in Jamaica Bay than in the Hudson River, presumably because winter flounder prefer more saline waters.

Although they are heavily fished, there is some evidence that habitat loss and degradation may be as influential as fishing pressure on the population dynamics of this species. Because winter flounder spend a portion of their life cycle outside of the estuary, both estuarine and ocean conditions must be considered in understanding the controls on their abundance.

Summer Flounder

More commonly known to anglers as fluke, summer flounder are another popular sportfish in the estuary. Like other flounders, summer flounder spend most of their time in and on the bottom sediments of the estuary and ocean, but they are active predators, often chasing prey fish all the way to the surface. Summer flounder spawn in the open ocean, outside of the estuary, in the fall and winter, and move into the estuary in the spring, staying through the spring and summer. The newly-hatched larvae probably enter the estuary in the late winter and spend their first spring and summer there. The following fall, they migrate out of the estuary again, slightly after the adults do. They overwinter on the outer portions of the Continental Shelf. Summer flounder can grow to be 30 inches or more in length.

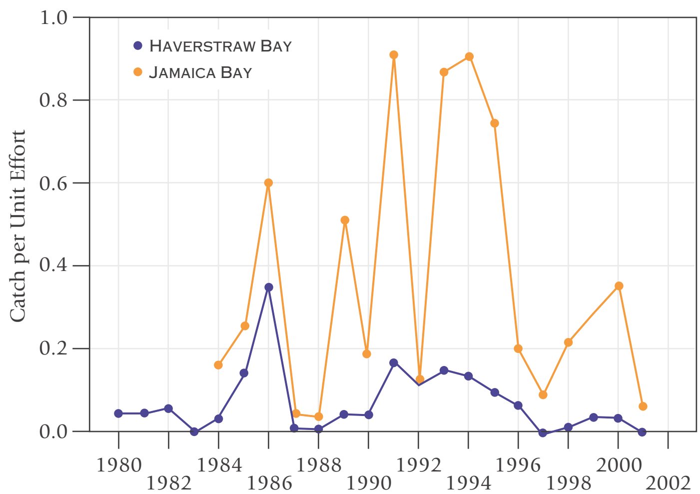


Figure 15 *Catch per Unit Effort of young-of-the-year summer flounder in Haverstraw Bay (1980–2001) and Jamaica Bay (1984–2001) (Hurst 2002, Hurst and Conover 2001, McKown 2002).*

Summer flounder undergo an amazing transformation common to all flatfish species. When the larvae are first hatched, they swim upright and have eyes placed symmetrically on either side of their head, like a typical fish. As they age, their right eye migrates over their head until both eyes are on the left side of the fish, its right or "bottom" side loses its pigmentation, and it takes up a bottom-dwelling existence.

Figure 15 shows relative abundances of summer flounder in Haverstraw Bay region and Jamaica Bay from the 1980s to 2001. Note that populations of this fish appear to fluctuate widely. Like other fish species discussed in this report, it is difficult to determine what controls summer flounder abundance, but the factors could include fishing pressure, pollution, and habitat availability.

White Perch

White perch are smaller (about 8 inches long as adults) but numerous relatives of striped bass. There is virtually no commercial fishery for white perch in this estuary (although Chesapeake Bay recorded commercial landings of 1 million pounds as recently as 1973, and there are still active commercial white perch fisheries today in Delaware and Chesapeake

Bays). Recreational fishing for them is small compared to estuarine and coastal sportfish such as striped bass and bluefish. White perch are of ecological interest because, unlike striped bass, they generally remain in the estuary year-round for their entire life cycle, rather than migrating out to the ocean.

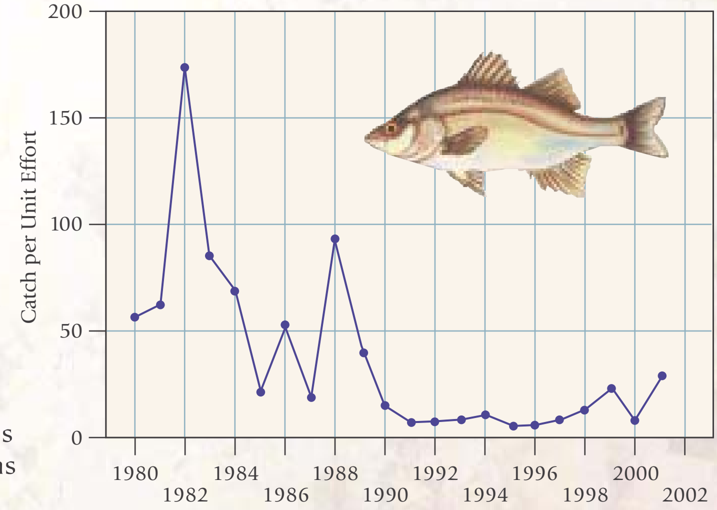


Figure 16 *Catch per Unit Effort of young-of-the-year white perch in Haverstraw Bay, 1980–2001 (Hurst 2002, Hurst and Conover 2001, McKown 2002).*

Figure 16 shows the relative abundance of white perch collected in a New York State survey in the Haverstraw Bay region. Abundance of white perch has been declining in the river survey since the early 1980s (with the exception of a spike in abundance in 1988), and uniformly low in the 1990s, extending a declining trend that began in the late 1970s. Although the exact reasons for this decline are not certain, it is likely that conditions within the estuary itself have a large impact on white perch because of their year-round residency. There has been significant concern about the impact that entrainment and impingement in the cooling systems of Hudson River power plants have on their population. It is also possible, as suggested by scientists who looked at white perch abundance in the 1970s and 1980s, that it has become harder to measure accurately white perch abundance over time because coverage of invasive dense vegetation in the Hudson, which white perch may use as habitat, has increased. Similar declines have been observed in other species that are full-time residents of the estuary, including tomcod, hogchoker, and four-spine stickleback.

American Eel

The slippery, snake-shaped American eel is another familiar fish that resides in the Harbor Estuary for part of its life cycle, exhibiting a catadromous life history opposite that of anadromous striped bass and shad. Instead of coming into the estuary and river to spawn, eels spawn about 1,000 miles away from the Hudson River in the Sargasso Sea near the Bahamas in the Atlantic Ocean (or at least, evidence suggests that is where they spawn – no one has actually ever captured an adult American eel there or seen them spawning!). Eels have strange larvae, called *leptocephali,* that resemble transparent willow leaves. The leptocephali drift in ocean currents for up to a year before heading toward coastal areas where they metamorphose into “elvers,” which more closely resemble small adult eels except that the elvers remain transparent. The elvers undergo another transformation to the so-called “yellow eel” phase which lasts for a number of years, all of which are spent in the estuary. Finally, the yellow eels transform into the familiar adult eel. Adult eels are probably the most broadly distributed fish in the Hudson system, inhabiting all reaches and basins of the estuary from salt water to fresh. After residing in the estuary for 7 to 19 years, they undergo a final transformation, then migrate to the Sargasso Sea, spawn, and die.

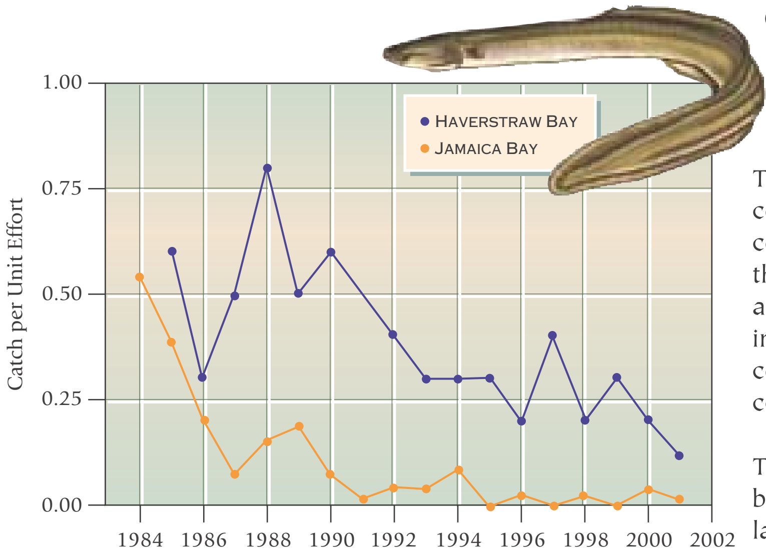


Figure 17 *Catch per Unit Effort of young-of-the-year American eel in Haverstraw Bay (1985–2001) and Jamaica Bay (1984–2001) (Hurst 2002, Hurst and Conover 2001, McKown 2002).*

One reason why eels are of great interest ecologically is that they spend most of their time in the sediments at the bottom of the estuary and exhibit a high degree of "site fidelity," meaning that they tend to stay in one area and do not move very far. These traits mean that it is likely that the health and contaminant burdens in eels reflect the environmental conditions, particularly the sediment conditions, of the site where they are captured. They are hardy fish, and exhibit some of the highest levels of contaminants in the harbor core area, particularly in areas where contaminants in the sediments are found in high concentrations.

There is still a small eel fishery, both for food and bait, in some parts of the estuary. Eels are a popular food fish in Europe. In the 1980s, 6 to 7 million pounds of eels (a high percentage of which were the juvenile "glass eels") were shipped to Europe and beyond from the east coast each year (only 300,000 pounds were sold in the US per year during the same time period). Eels have seemed to decline over time, and in Raritan Bay, by 1991, only two eel fishermen were still able to make a living.

Figure 17 shows trends in eel abundance in NYSDEC seine surveys in the Haverstraw Bay region and Jamaica Bay from the mid-1980s to 2001. Over that time period, the population of eels in both areas has declined dramatically. This trend is particularly worrisome because eels are generally very hardy - they usually seem to be able to survive under conditions that would be detrimental and even lethal to other species. The reason for this population decline is unknown; however, overfishing is one likely cause.

For More Information about Fish in the Estuary:

Heartbeats in the Muck, by John Waldman (Lyons Press, 1999)

The Fisheries of Raritan Bay, by Clyde L. MacKenzie, Jr. (Rutgers University Press, 1992)

The Inland Fishes of New York State, by C. L. Smith (New York State Department of Environmental Conservation, 1985)

The Hudson River: A Natural and Unnatural History, by Robert H. Boyle (W. W. Norton and Co., 1979)

The Hudson: An Illustrated Guide to the Living River, by Stephen P. Stanne et al. (Rutgers University Press, 1996)

www.dec.state.ny.us/website/dfwmr/marine/hudson/index.html

Forage Fish

Forage fish, sometimes referred to as baitfish, is a generic term for small fish of numerous species that are preyed on by larger fish, forming an important link in the estuary's food web. Healthy forage fish populations are critical to sustaining populations of commercial and recreational fish such as striped bass and bluefish. In the Harbor Estuary, three of the most important forage fish species are the bay anchovy, Atlantic silverside and killifish. Anchovies and silversides, both about 4–6 inches full grown, are spawned in estuaries in the spring, spend their first summer in the estuary, and then migrate out of the estuary to the ocean in the fall. These two species are two of the most abundant fish in the mid-Atlantic. Killifish, or mummichog, are smaller and chubbier little fish that are common year-round in northeast estuaries. "Killies" are important food sources for both fish and bird predators.

Figure 18 shows measures of population size of bay anchovies, Atlantic silversides and killifish as determined by NYSDEC surveys in Haverstraw Bay and Jamaica Bay (Jamaica Bay only for killifish). While there is no clear trend in populations of any of these species, there is a slight indication of an increase in silversides in Haverstraw Bay, and perhaps a decline in anchovies in Haverstraw Bay. All of these species' populations are known to be highly variable from year to year, and could be substantially affected by a variety of factors, including salinity, temperature, river flow, presence of predators, and food availability. In addition, there has been some concern over the impact of power plants along the Hudson River on anchovy populations – in some years the cooling water intakes at the plants entrain (draw in) or impinge (trap on their intake screens) potentially significant numbers of anchovy.

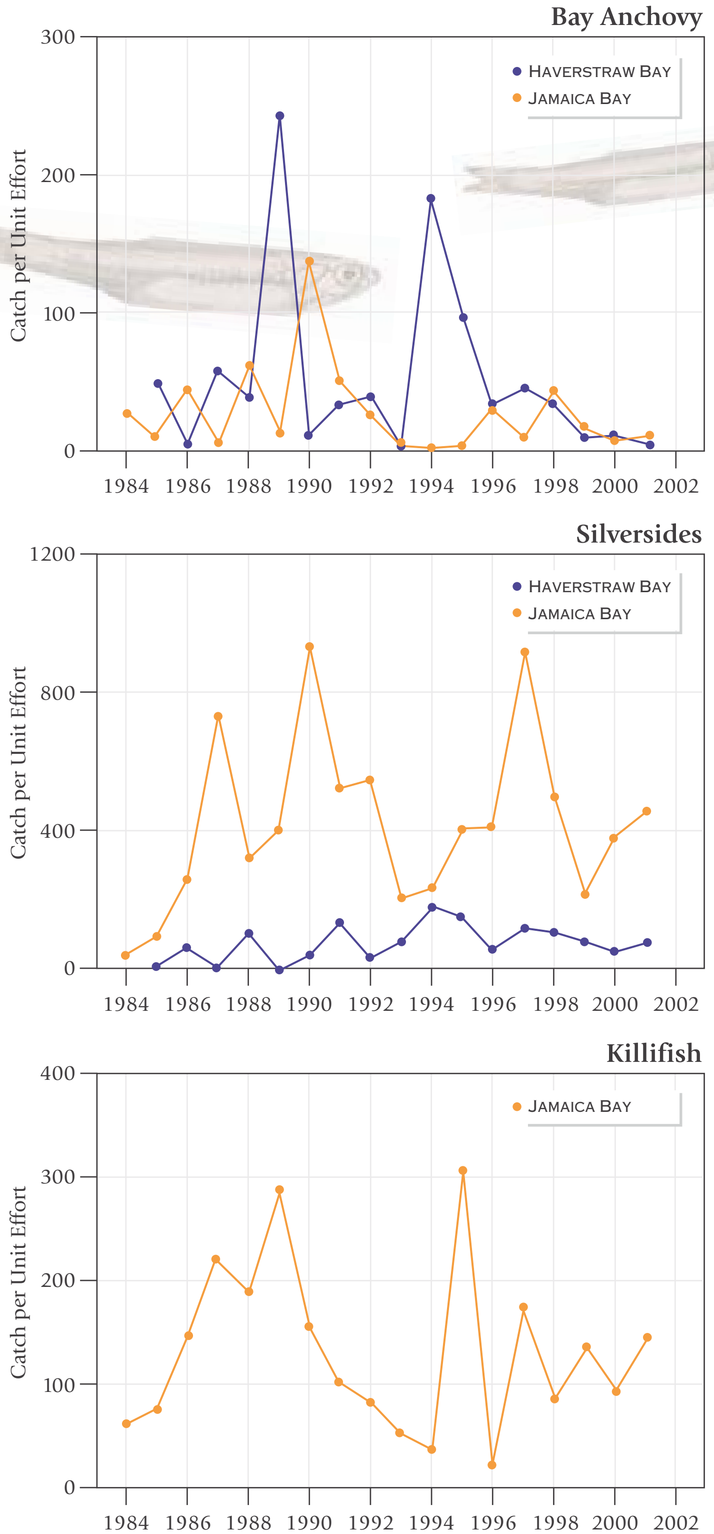
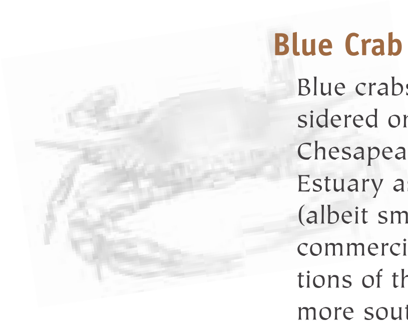


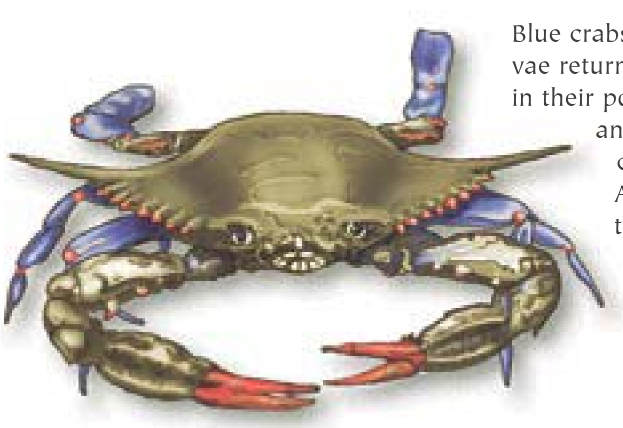
Figure 18 *Catch per Unit Effort of three species of forage fish in Haverstraw Bay (1985–2001) and Jamaica Bay (1984–2001). Note there are no Haverstraw Bay data for killifish. Note the different Y-axis scales for the three species (Hurst 2002, Hurst and Conover 2001, McKown 2002).*



Blue Crab

Blue crabs, sometimes referred to locally as blue claw crabs, are considered one of the prime symbols of another mid-Atlantic estuary, the Chesapeake Bay. These crabs are found in abundance in the Hudson River Estuary as well; in fact, blue crabs constitute one of the few remaining (albeit small) commercial fisheries in the estuary. Blue crabs are harvested commercially and recreationally in both the New York and New Jersey portions of the estuary, but the total landings are much smaller here than in more southern estuaries such as the Chesapeake because the Hudson is close to the northern limit of the species' distribution. Historically, blue crabs were harvested in great numbers in Raritan Bay, particularly in the 1920s and 1930s. In those days, street vendors in Red Bank sold great numbers of soft-shelled crabs in the summer months for 10 cents each.

Figure 19 shows a record of blue crab abundance as measured in a seining survey conducted every year for the past 20 years in the Haverstraw Bay region on the Hudson River and for the past 15 years in Jamaica Bay. These data indicate that blue crab abundance has remained fairly stable over the length of the survey in Haverstraw Bay, with a large spike in abundance in the late 1990s. Commercial landing statistics for blue crabs from the late 1800s to 1970 show a similar stability in abundance with occasional spikes. The numbers of crabs in Jamaica Bay have been much more variable from year to year than in Haverstraw Bay.



Blue crabs release their eggs offshore and then the microscopic crab larvae return to the estuary by riding on shore-bound currents. Fluctuations in their population can therefore be caused by many factors both within and outside of the estuary, making it very difficult to determine the causes of the changes in blue crab abundance from year to year. An increase in abundance in the early 1970s may be attributable to the cessation of production and use of the pesticide DDT, which had a large impact on aquatic crustacean populations. However there is no direct evidence for this explanation.

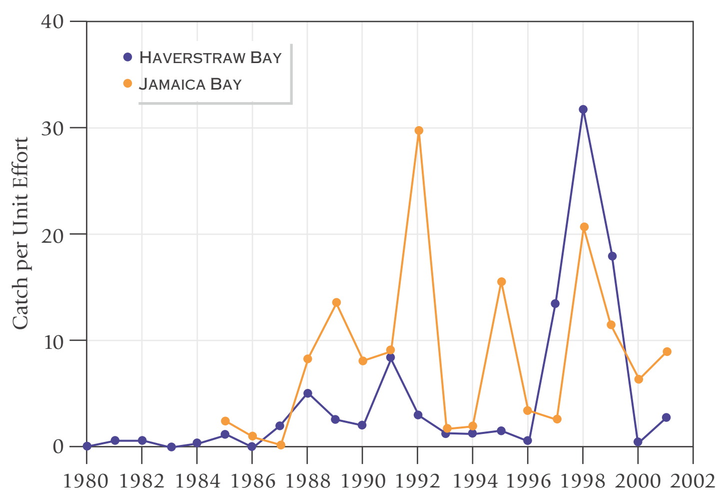
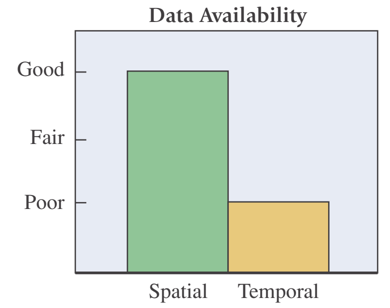


Figure 19 *Catch per Unit Effort of blue crabs in Haverstraw Bay (1980–2001) and Jamaica Bay (1985–2001) (Hurst 2002, Hurst and Conover 2001, McKown 2002).*

BENTHIC COMMUNITY HEALTH

Animals and plants associated with the sediments at the bottom of the estuary, called *benthic* organisms, are particularly susceptible to the effects of contamination because they live and feed in and on the sediments which are final receptacles for much of the chemical contamination in the estuary, and because many of them are not mobile enough to escape unfavorable or toxic conditions. The structure of the benthic community – the number of species, the number of individuals of each species, and the number of pollution-tolerant vs. pollution-intolerant species there are – can be an accurate indicator of the health of a given site. It is also important to monitor the health of the benthic community because these organisms are important links in the estuarine food web, and they perform critical functions with respect to nutrient cycling.



A monitoring program conducted by the EPA called the Regional Environmental Monitoring and Assessment Program (R-EMAP) has conducted a comprehensive survey of the benthic communities of the harbor core area, and concurrent measurements of sediment contamination and toxicity, in order to characterize the sediment quality of the harbor. In 1993 and again in 1998 R-EMAP collected samples of the benthic macroinvertebrates (larger benthic organisms without backbones, such as clams, worms, and amphipods) at sites throughout the harbor. At the same locations the program measured concentrations of contaminants in the sediments and determined whether the sediments at those sites were toxic to test organisms (the program collected data in 2003 as well, which are still undergoing analysis). By combining a number of measurements of characteristics of the benthic community (number of species, number of organisms, biomass, the fraction of pollution-sensitive organisms present, and the fraction of pollution-tolerant organisms present), R-EMAP has developed an index of benthic community health based on community characteristics at stressed and pristine reference sites throughout the harbor and elsewhere. Applying this index to both the 1993 and 1998 data, EPA characterized the percentage of the benthic community in each of the R-EMAP subbasins in the harbor considered "impacted," or of degraded quality.

Figure 20 depicts the percentage of sampling sites within different basins of the harbor that were considered "impacted" in 1993 and 1998 (this analysis was not done for Long Island Sound or the Bight Apex in 1998). One of the most interesting results is that for all basins, the percentage of impacted sites decreased between 1993 and 1998. For example, in 1993 42% of the sites analyzed in Raritan Bay were considered impacted, while only 18% were impacted in the 1998 survey. It is also interesting to note that the sites with impacted benthic communities were also the sites where high sediment contamination levels and the most toxic sediments were recorded in the other analyses conducted by R-EMAP (see pages 33 and 34 in this report). Of the sites with impacted

For More Information
about Benthic Communities:

www.csc.noaa.gov/lcr/nyharbor/html/background/intro.html

www.dec.state.ny.us/website/imsmaps/benthic/webpages/biblio.html

www.chesapeakebay.net/info/benthos.cfm

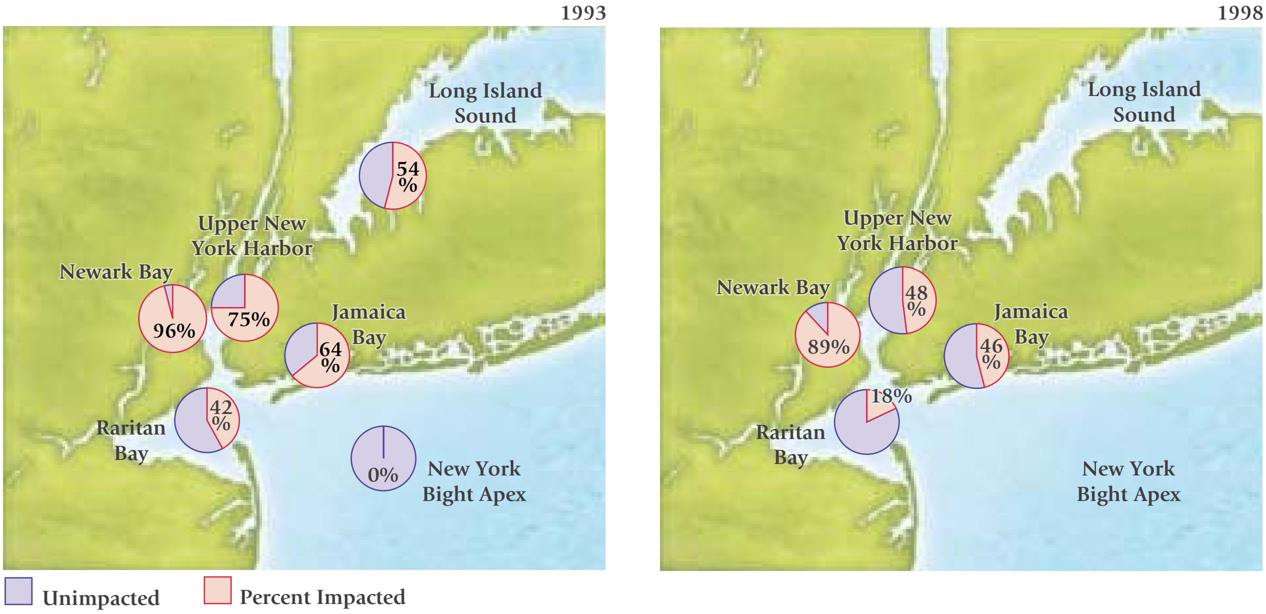
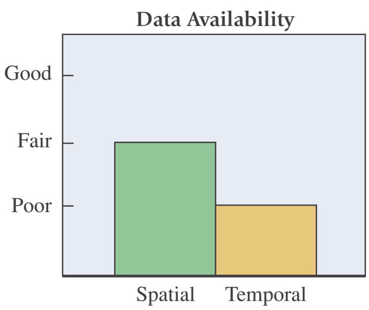


Figure 20 *Percentage of benthic communities impacted and unimpacted in sub-basins of the Harbor Estuary in 1993 and 1998. Note that there are no data for Long Island Sound and the New York Bight Apex in 1998 (Adams 2002).*

benthic communities, in 1993 86% had either high concentrations of contaminants in the sediments or high sediment toxicity, and 66% exhibited both high contamination and high toxicity.

The smaller number of impacted sites in 1998 is encouraging. The differences between the years in three of the basins are statistically significant (significantly fewer of the basin sites were impacted in 1998 than in 1993 for the Upper Harbor, Lower Harbor and Jamaica Bay but not for Newark Bay). However data from just two years do not constitute a trend. More data like these must be collected in future years in order to determine if a pattern of decreasing impacted benthos is actually occurring.



SEDIMENT LOADING

Many people assume that because the waters of the Harbor Estuary are not crystal clear like those of the Caribbean or a mountain stream, the estuary is hopelessly polluted. But the Hudson River and New York Harbor are naturally turbid waters, partially because they carry and move around so much *suspended sediment*. Much of this sediment load begins as soil, sand and mud on the land that is washed into the estuary somewhere in the watershed of the harbor. It can then travel downriver until it settles out in a more quiescent area of the estuary. Sometimes the journey of a particle does not end there – particles of sediment can be resuspended during tidal or storm events and redeposited elsewhere.

Although it is normal for a river/estuary system to carry suspended sediment, human activities can cause sediment loads to increase, with serious environmental consequences. Much of the suspended sediment load of the Harbor Estuary consists of very small particles – mud rather than sand. Molecules of chemical contaminants preferentially attach themselves to these smaller particles and then hitch a ride from their source to the estuary. High sediment loads also settle in the harbor, clogging shipping channels and making dredging of these often-contaminated sediments necessary in order to keep the port open. Because the sediments are contaminated, disposal options are limited, contentious and frequently expensive. Finally, in those areas where heavy sedimentation is induced, suspended sediment can settle out onto the bottom and smother sensitive habitats such as oyster reefs and sea grass beds.

Land use has a tremendous impact on sediment load. Dense trees and other vegetation of forested lands "grip" the soil tightly, preventing erosion and resulting sediment runoff to local tributaries. Land cleared for agriculture is more prone to erosion and therefore is a proportionally higher source of sediment to the estuary. Land clearing and earth moving for urban development is potentially an even greater source of sediment to waterways than agricultural land clearing. Further, paved suburban and urban lands retain less sediment on land than vegetated areas, and paved areas can channel the flow into adjacent streams and cause erosion.

Researchers have used information about land use and weather patterns to construct a mathematical model that calculates what sediment loading to the Hudson River might have been in the past under historical land uses. Figure 21 shows the modeling results as sediment flux, a relative measure of sediment loading compared to today, which is set as 1. The figure shows sediment loads from the Lower Hudson River, Upper Hudson River, and Mohawk Rivers combined. The graph shows the progression from pre-colonial forested land to the peak of agriculture in the Hudson Valley in the 1870s to the present-day situation. These results indicate that because much of the land once used for agriculture has today reverted to forested lands, sediment loading on a large scale has actually decreased between the late 19th century and today.

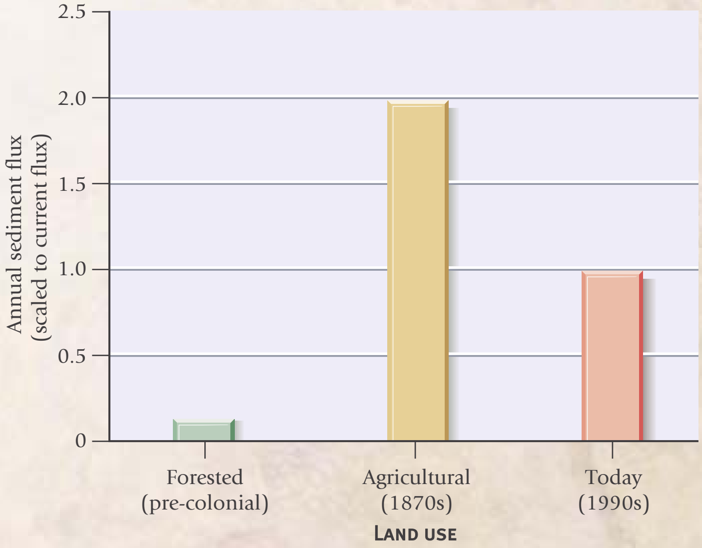


Figure 21 *Calculated annual sediment loadings to the Hudson River under three land use/time period scenarios. Loadings include calculations for the Upper and Lower Hudson and the Mohawk River (Swaney et al. 1996).*

Figure 22 shows estimates of current sediment loadings to the harbor, based on data collected for use in the mathematical modeling activities of the Contamination Assessment and Reduction Project (CARP) of the HEP. These estimates are based on data collected by the US Geological Survey (USGS). Figure 22A shows the percentage of the total sediment load that comes from a variety of sources; note that the largest source of sediment to the harbor is the tributaries (the rivers entering the estuary). Figure 22B breaks down the 82% pie slice of tributary load into specific rivers. The vast majority of sediments entering the harbor come from the Hudson (Upper and Lower) and Mohawk Rivers.

It is important to note that the pie charts in Figure 22 for 1988–89 reflect average conditions in the estuary. Sediment loadings to the harbor were calculated for two other years (1994–95 and 1999–2000) and the results demonstrated that the loads can vary substantially from year to year. For instance, loads calculated for 1999–2000 are more than three times the amount estimated for 1994–95. The amount of rainfall, along with the duration and intensity of storms, strongly influences the amount of sediment that washes into the estuary.

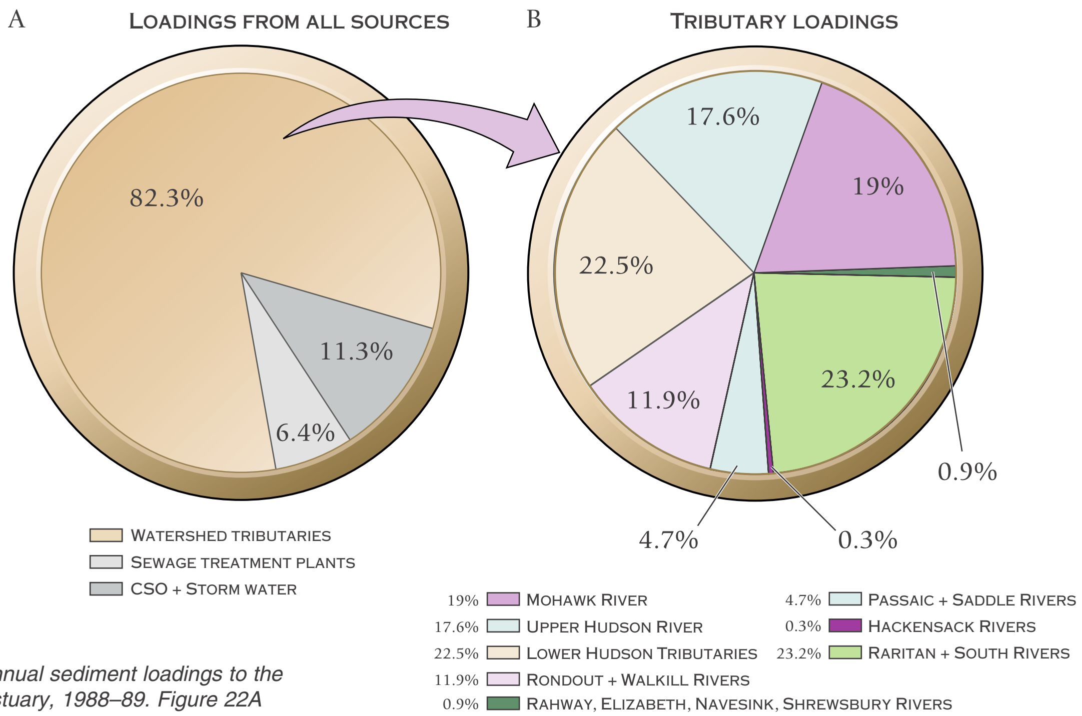


Figure 22 *Annual sediment loadings to the NY/NJ Harbor Estuary, 1988–89. Figure 22A shows loadings from three sources: tributaries, sewage treatment plants, and CSOs and storm water. Figure 22B breaks down the tributary source category into individual tributaries (Miller 2003).*

For More Information about Sediment Loading:

ny.water.usgs.gov/projects/poused/

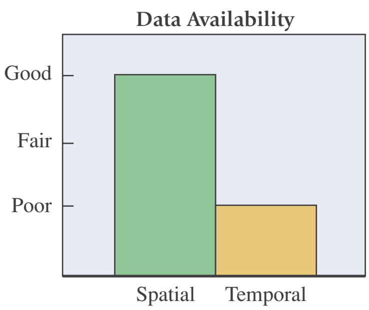
ny.water.usgs.gov/pubs/wri/wri964065/WRIR96-4065toc.htm

www.carpweb.org

2 Toxic Contamination

Contaminant Loadings and Levels in Sediment

One of the most challenging and serious problems facing the estuary is contamination of its sediments with a variety of organic and inorganic toxins, including PCBs, dioxins, mercury and other heavy metals, pesticides such as DDT, and polycyclic aromatic hydrocarbons (PAHs, derivatives of petroleum products). While some of these contaminated sediments are vestiges of the pre-Clean Water Act industrial harbor, there are still active sources of contaminants, including industrial discharges, leaks and spills, landfills and inputs from sewage treatment plants, combined sewer overflows and tributaries. These persistent contaminants



can cause a number of ecological and economic problems. One of the main pathways for contaminants to accumulate in the tissue of fish and shellfish, including edible species, is through the food chain: Contaminants build up in the bottom-dwelling organisms that feed in the sediments, which can then be consumed by blue crabs, striped bass, or any of the other estuary residents that we would like to eat. Another problem is that the disposal of contaminated sediment, dredged from the harbor to ensure that the port is navigable, is expensive and contentious.

Figures 23 through 26 show trends over time in sediment concentrations of mercury, PCBs, dioxin and DDT (a pesticide), four contaminants which are of concern in the harbor. These data were generated by taking cores – intact columns – of sediment from areas in the estuary where sediment is deposited in a uniform way, and not eroded over time. By looking at contaminant concentrations at different depths in the core, which correspond to particular years or spans of years, a history of sediment contamination at a site can be generated.

During the past 30 years levels of most of these contaminants have decreased on average by about an order of magnitude (10-fold). This decrease is due mainly to the implementation of a number of control measures required by the Clean Water Act, in particular a strict permitting system for the discharge of these chemicals into our waterways, and improved sewage treatment. In addition, DDT and PCBs are now banned from production in the United States, so there are few active discharges of these chemicals (although leaks and spills of stored material are still potential continuing sources to the estuary, as are by-products of various industrial processes). The horizontal red line on each of the plots in figures 23–26 indicates the ER-M (effects range - median; see box on page 35) for that contaminant. In almost all cases declining contaminant levels in all areas are approaching or below that level. PCBs in the Arthur Kill and Newark Bay still exceed the ER-M in this analysis, as does mercury in many of the basins studied. DDT levels are high in the Lower Passaic River and just above the ER-M in Newark Bay and the Arthur Kill. Levels of some other important contaminants, notably PAHs, have not decreased at the same rates and are still of concern in the harbor.

Figures 27–32 show surface sediment concentrations of a variety of contaminants as measured by R-EMAP in 1993 and again in 1998. In both years, the R-EMAP program measured the levels of

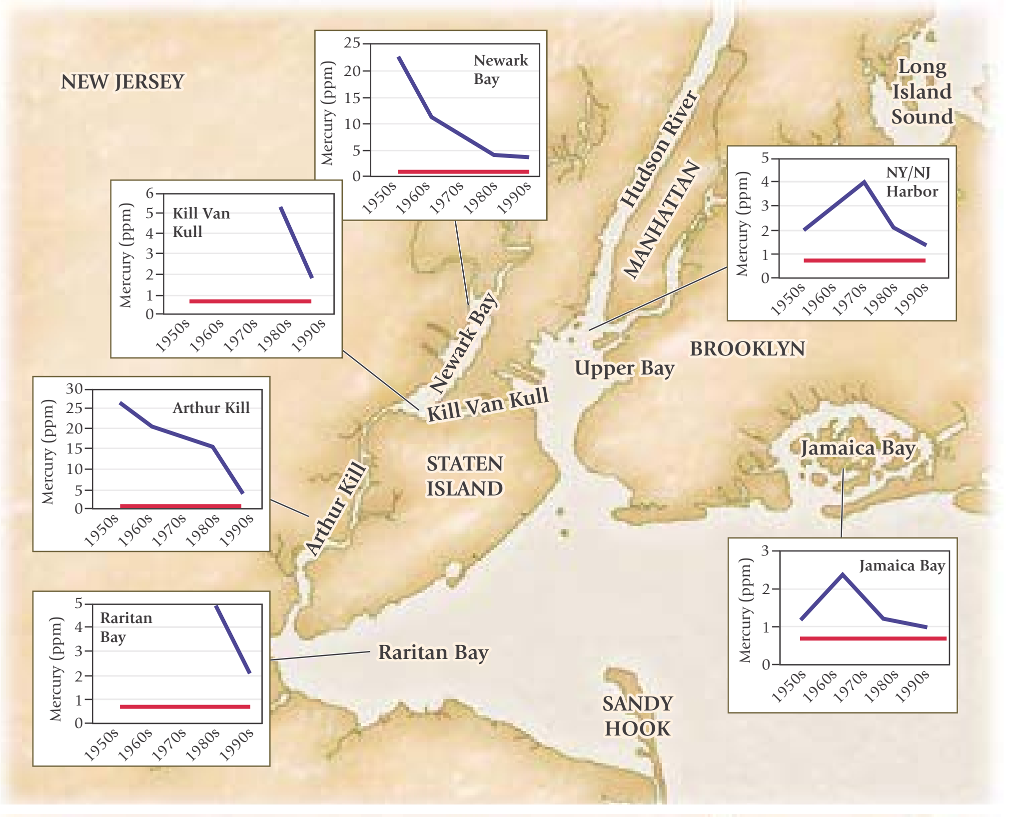


Figure 23 *Mercury concentrations in NY/NJ Harbor Estuary sediments over multiple decades. Red line on graphs indicates ER-M for mercury (see sidebar on ER-Ms) (Bopp 2000).*

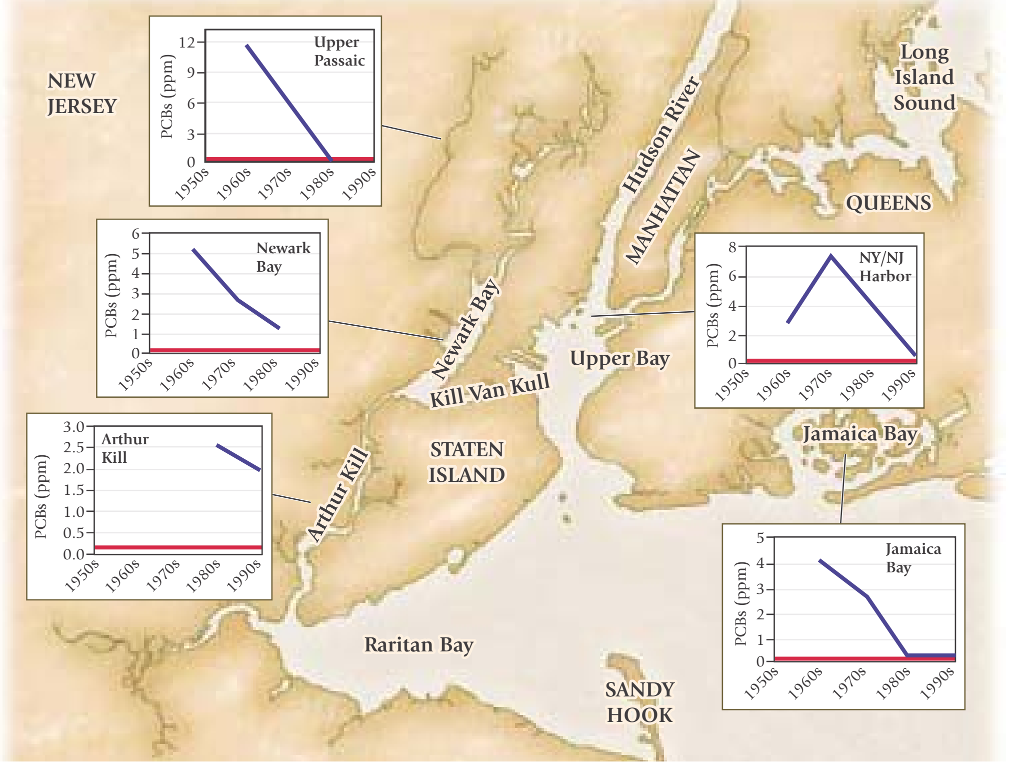


Figure 24 *PCB concentrations in NY/NJ Harbor Estuary sediments over multiple decades. Red line on graphs indicates ER-M for PCBs (see sidebar on ER-Ms) (Bopp 2000).*

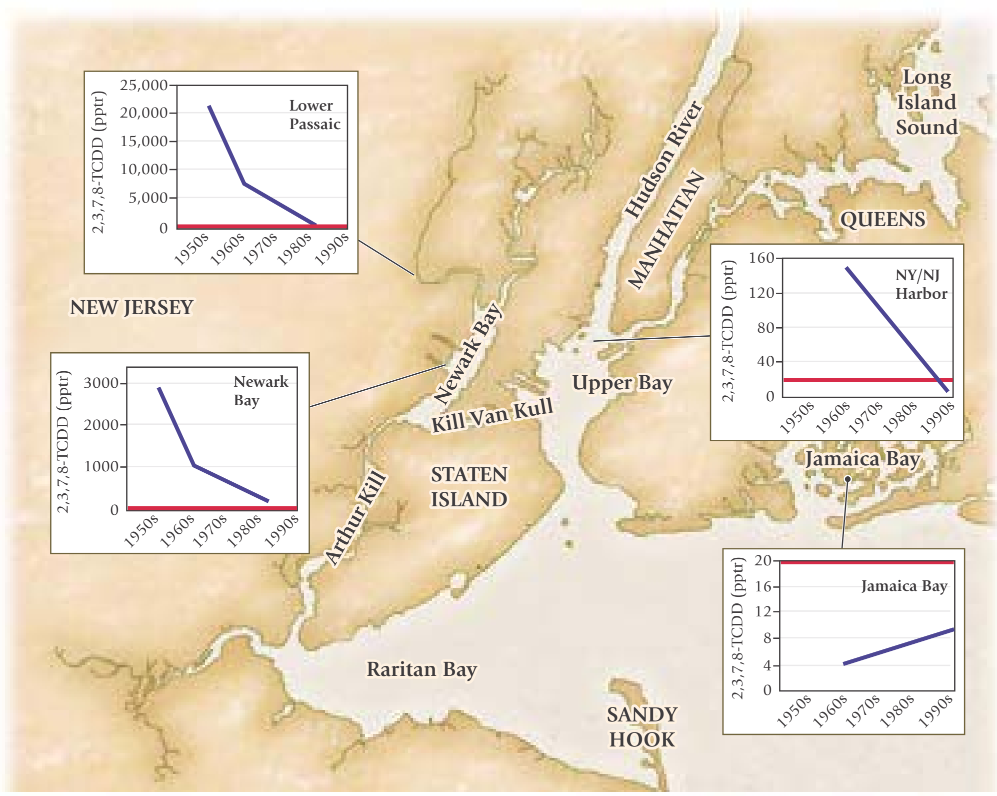


Figure 25 *Dioxin concentrations in NY/NJ Harbor Estuary sediments over multiple decades. Red line on graphs indicates EPA Guidance Value for dioxin (see sidebar on ER-Ms) (Bopp 2000).*

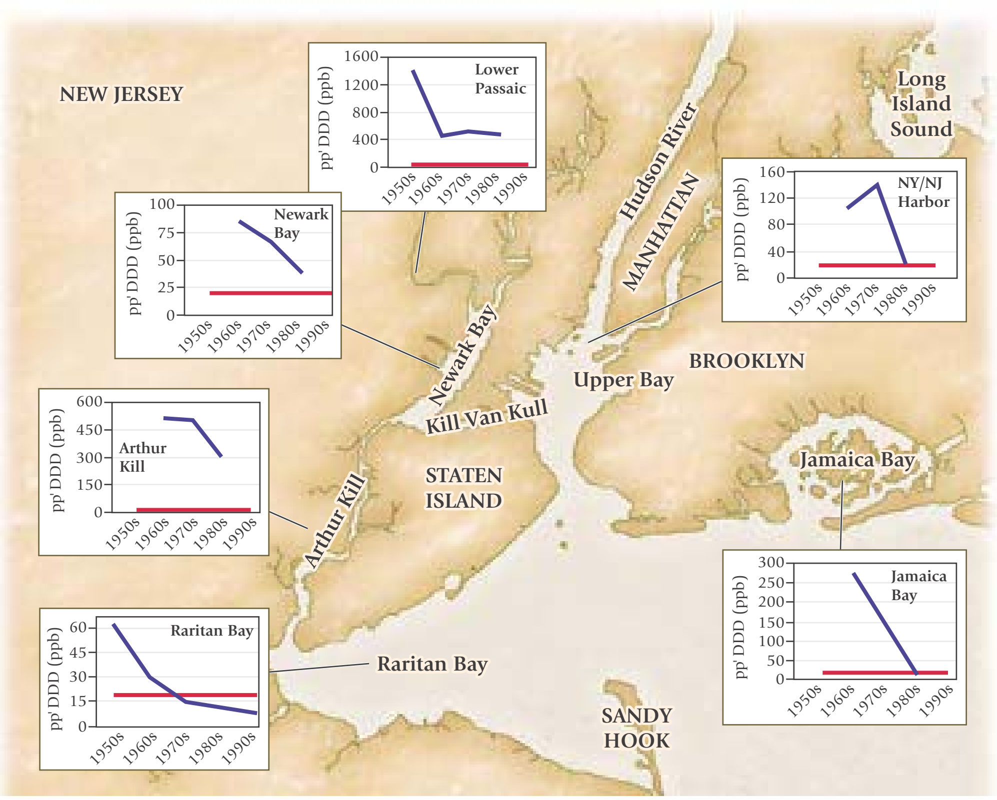
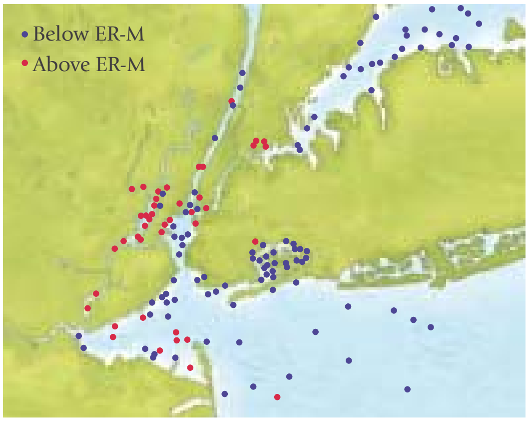


Figure 26 *DDT concentrations in NY/NJ Harbor Estuary sediments over multiple decades. Red line on graphs indicates ER-M for DDT (see sidebar on ER-Ms) (Bopp 2000).*

Mercury in Sediments (R-EMAP 1993–94)



Mercury in Sediments (R-EMAP 1998)

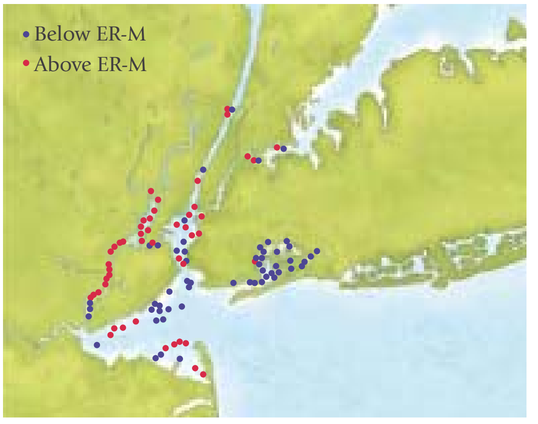
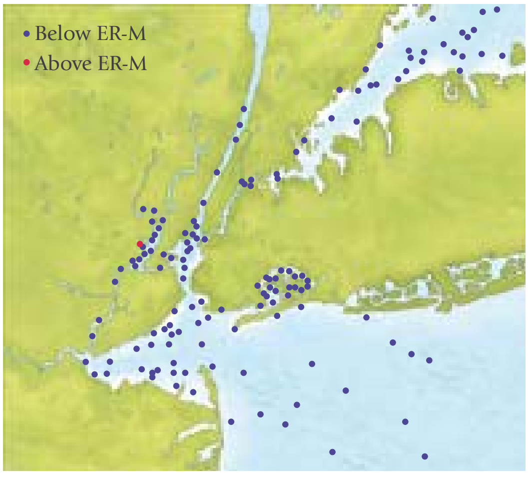


Figure 27 *Levels of mercury in NY/NJ Harbor Estuary sediments as compared to the ER-M value in 1993 and 1998 (US EPA 1998b, Adams 2002).*

Cadmium in Sediments (R-EMAP 1993–94)



Cadmium in Sediments (R-EMAP 1998)

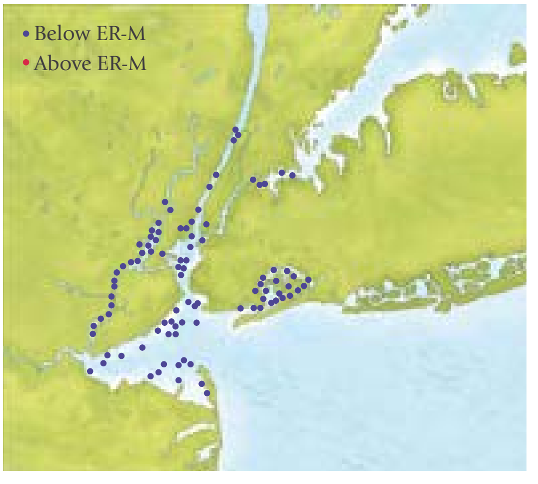
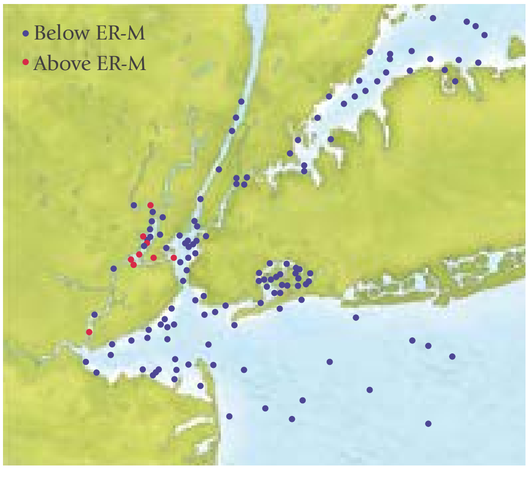


Figure 28 *Levels of cadmium in NY/NJ Harbor Estuary sediments as compared to the ER-M value in 1993 and 1998 (US EPA 1998b, Adams 2002).*

Nickel in Sediments (R-EMAP 1993–94)



Nickel in Sediments (R-EMAP 1998)

Figure 29 *Levels of nickel in NY/NJ Harbor Estuary sediments as compared to the ER-M value in 1993 and 1998 (US EPA 1998b, Adams 2002).*

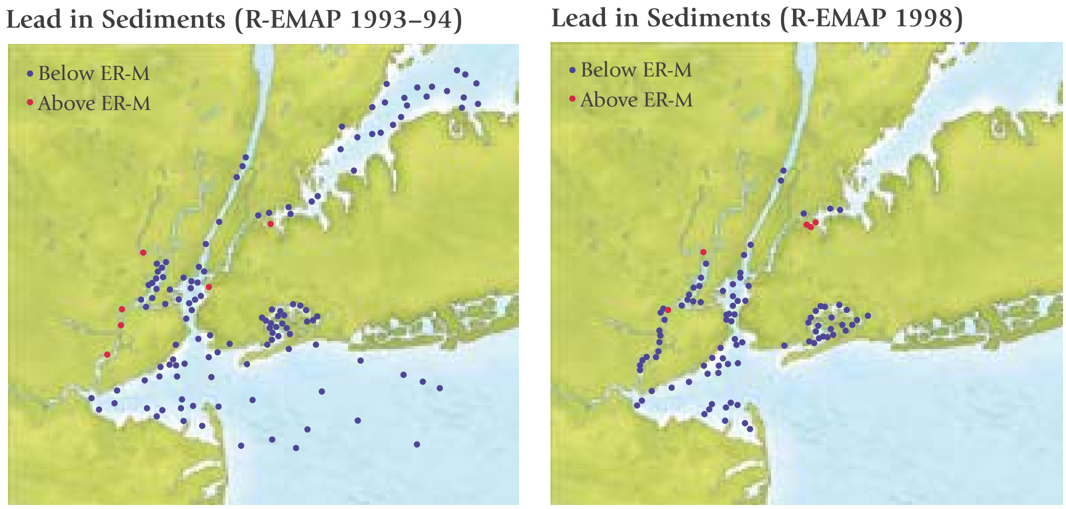


Figure 30 *Levels of lead in NY/NJ Harbor Estuary sediments as compared to the ER-M value in 1993 and 1998 (US EPA 1998b, Adams 2002).*

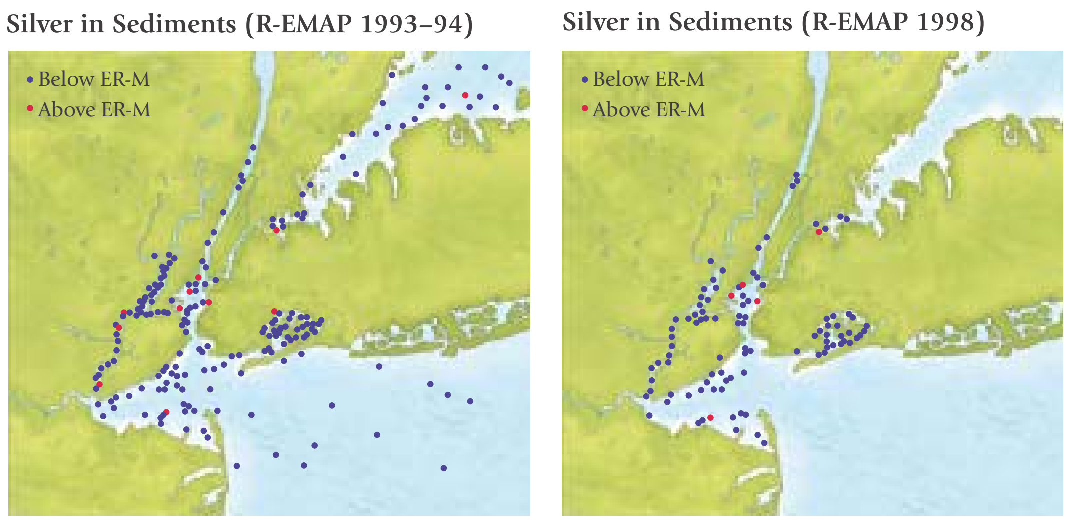


Figure 31 *Levels of silver in NY/NJ Harbor Estuary sediments as compared to the ER-M value in 1993 and 1998 (US EPA 1998b, Adams 2002).*

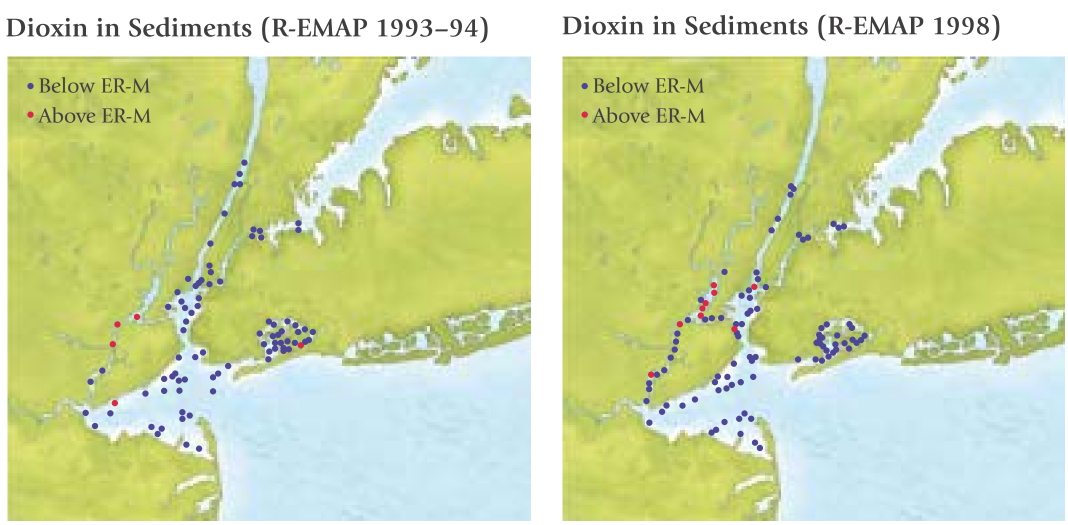


Figure 32 *Levels of dioxins in NY/NJ Harbor Estuary sediments as compared to the ER-M value in 1993 and 1998 (US EPA 1998b, Adams 2002).*

these contaminants (and others) in surface sediments at the sites represented by the dots on the maps. The red dots indicate stations where the contaminant in question is above the ER-M (effects range - median; see box below for an explanation) for that chemical, while the blue dots indicate stations where the concentration is below the ER-M for that chemical. It appears that not much change has taken place between 1993 and 1998 with respect to the location of the more contaminated sites. For example, levels of mercury, cadmium, nickel and lead in all of the basins are not statistically different in 1998 and 1993. For silver, the only significant difference is in Newark Bay, where sediment concentrations of silver were significantly higher in 1993 than in 1998. Newark Bay and the Kills stand out as problem areas in both surveys, and one or two stations in the East River/Western Long Island Sound exceed the ER-M for some contaminants. There was not much overall change in dioxin levels in the estuary between 1993 and 1998. Note that stations in Long Island Sound and the Bight were not sampled in the 1998 survey.

Water column measurements of heavy metals show patterns similar to those observed in sediments. In the mid- to late 1990s, scientists measured levels of copper, cadmium, nickel, zinc, mercury, silver, lead and other contaminants dissolved in the water throughout the estuary and compared them to similar measurements that had been made in the 1970s. They found that most metal concentrations decreased significantly in those 25 years, some as much as 90%. They attributed the declines to decreased industrial and sewage treatment plant discharges. However, they pointed out that current sources of many of these metals are not so easy to control, as they seem to be coming from non-point sources such as reservoirs of contaminants in watershed soils and estuarine sediments.

Another important parameter is the amount of a given contaminant entering the estuary at the current time, rather than the concentration present in the sediment already. This parameter is called the contaminant loading. Loadings are notoriously difficult and expensive to measure, and as a result, very few measurements of loadings have been made. A comprehensive contaminant moni-

What is an Effects Range–Median?

The ER-M is a number used to correlate sediment contamination with observed effects in organisms and biological communities. It was originally developed by scientists at the National Oceanic and Atmospheric Administration. An ER-M for a particular contaminant is the median sediment contaminant concentration at which adverse biological effects have been observed (the median is the value in a data set that has an equal number of values on either side of it, and is typically different from the mean, or average). Results from a variety of studies of the given contaminant are usually combined to develop the ER-M. These values are not regulatory guidelines and they indicate only a correlation, rather than a causal relationship. However, they are among the only guidance numbers available in examining the potential effects of sediment contamination on organisms. For dioxin, the EPA guidance value is slightly different from the ER-M and represents the sediment concentration at which there is high risk to mammalian wildlife consuming food contaminated with dioxin.

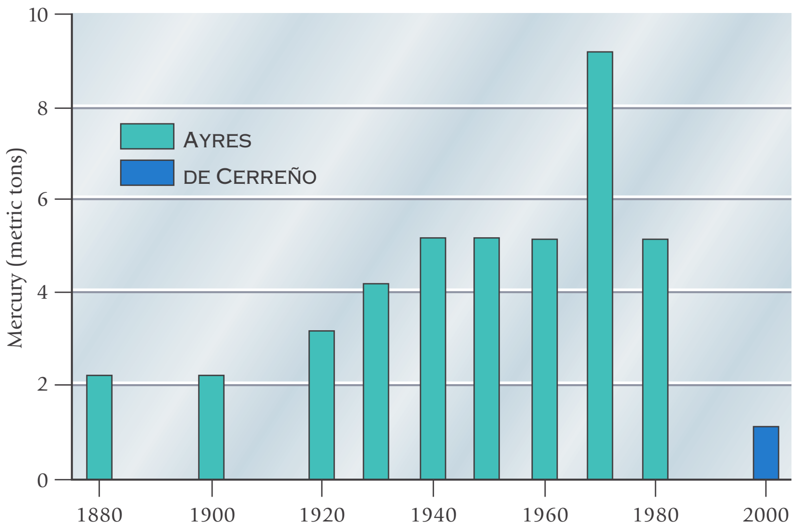
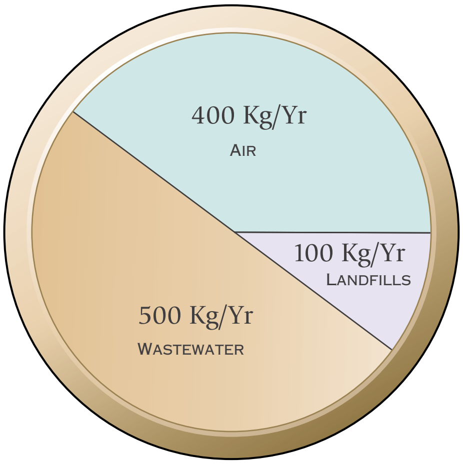


Figure 33 *Mercury loadings to the Harbor Estuary, 1880–2000 (Ayres and Rod 1986, de Cerreño et al. 2002).*

toring program, the Contamination Assessment and Reduction Project (CARP), is currently conducting an assessment of all of the loadings to the estuary of a large suite of chemicals. A few other measures of contaminant loadings are available now. Figure 33 shows estimated loadings of mercury, a toxic heavy metal, to the harbor between 1880 and 2000. Most of these estimates were generated from industrial and other records of mercury use and disposal in the Hudson-Raritan basin. The last bar on the graph, colored blue, was generated more recently using a similar approach. The pattern indicates a trend of increasing loadings through the 1970s, and a decrease from the 1970s to 2000 due to the implementation of a number of environmental laws and more stringent pollution prevention initiatives undertaken by dischargers in the 1970s.

The pie chart in Figure 34 depicts the three key sources of the current (2000) loading of mercury to the watershed of the Harbor Estuary: wastewater, deposition from airborne mercury, and landfills. Of the approximately 1000 kg of mercury that enters the Harbor Estuary yearly, the most important vehicle is wastewater. The table in Figure 34 lists the most important individual contributors to each of those sources. Dental facilities contribute the most mercury to both the wastewater and landfill pools; other important sources include hospitals, automobile switches, furnaces, and thermostats.



Source	Most Important Contributors
Wastewater	Dental Facilities Hospitals Laboratories
Air	Utilities: Furnaces Industrial/Commercial Furnaces Automobile Switches Incineration of Fluorescent Lamps Automobile Fuel Combustion Households (Furnaces, Thermometers, etc.)
Landfills	Dental Facilities Hospitals Automobile Switches Thermostats

Figure 34 *Estimated mercury loadings to the Harbor from air, wastewater, and landfills. Table shows the most important contributors to each of those three pools (de Cerreño et al. 2002).*

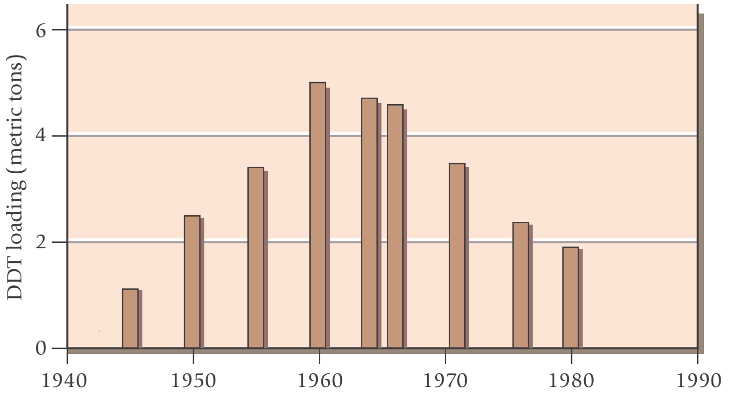


Figure 35 *Estimates of DDT loading to the Harbor Estuary (mid-1940s–1980) (Ayres and Rod 1986).*

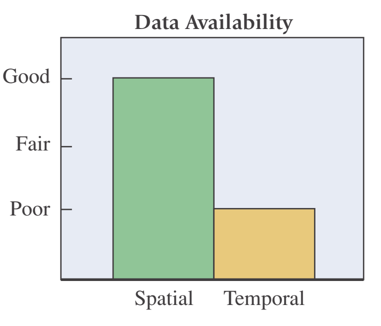
Figure 35 shows the estimated loadings of DDT to the estuary between the mid-1940s and 1980. More current estimates of loadings will be provided by the CARP program described above. Because DDT use was banned in the U.S. in 1973, loadings to the estuary have been declining for decades. However, remnant DDT in the estuary's sediments, as well as loads from leaks and spills of stored DDT, is still a problem.

For More Information
about Toxic Contaminants:

www.dec.state.ny.us/website/dow/carpintro.htm
www.rpi.edu/locker/69/000469/dx/harbor.www/harbor.html
www.epa.gov/emap/remap/index.html
www.epa.gov/hudson
www.nan.usace.army.mil/business/prjlinks/dmmp/prevent/
www.nyas.org/scitech/harbor/
www.carpweb.org

SEDIMENT TOXICITY

Sediment toxicity testing is one way to determine the quality of marine sediments. Typically, test organisms are exposed to test and reference sediments for a proscribed number of days and then the survivors are counted. The results of these tests can tell us about the impacts of sediment quality on the health of the marine environment, but they do not indicate the impact of these sediments on human health.



One program that has generated sediment toxicity data is R-EMAP (described previously on page 25). This program exposed amphipods for 10 days to sediment samples from 28 different sites in six basins (New York Bight Apex, Jamaica Bay, Western Long Island Sound, Newark Bay, Raritan Bay and the Upper Harbor/East River) and to clean reference sediments. The results are expressed as amphipod survival as a percentage of the survival observed in the reference tanks, such that if the same number of amphipods survived in the test sediments and the reference, the score would be 100%. A score below 80% is considered toxic, and a score below 60% is considered highly toxic. Figures 36A and 36B show the results of these tests in 1993 and 1998. Close-ups of Jamaica Bay are included for both years for clarity since some points are overlapping and obscured on the maps of the entire harbor.

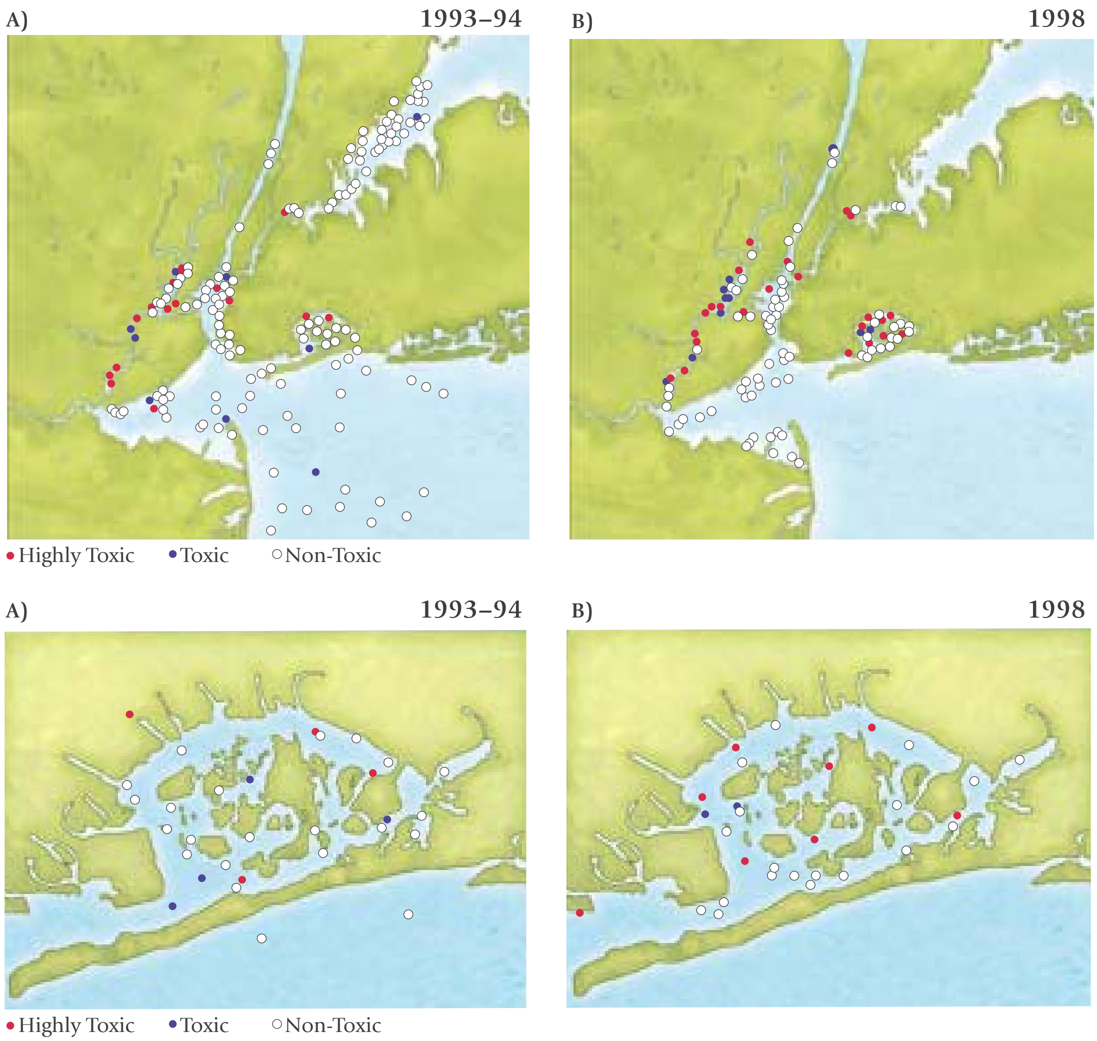


Figure 36 *Toxicity levels of NY/NJ Harbor Estuary sediments, 1993 (A) and 1998 (B). The bottom two maps show enlargements of Jamaica Bay in each year (US EPA 1998b, Adams 2002).*

A comparison of the 1993 and 1998 data reveals that the number of highly toxic sites increased from 15 sites (9% of the sites sampled) in 1993 to 23 sites (21% of the total number of sites sampled) in 1998. The geographical distribution of "problem spots" also changed somewhat. The area of highest concern in 1993 – Newark Bay and the Kills – remained so in 1998 but Raritan Bay exhibited fewer toxic sites, and two highly toxic sites were revealed in western Long Island Sound. Jamaica Bay is an area of serious, increasing concern. Four sites in the Bay were considered highly toxic in 1993, and seven sites were determined to be highly toxic in 1998.

It is important to note that while the difference between the two years suggests that things may be on the wrong track, the differences are not statistically significant for any of the basins or for the harbor overall, so the data do not indicate a significant trend in a particular direction. More years of data need to be collected in order to determine if sediment toxicity is really getting better or worse in the estuary.

Figure 37 *Results of four sediment toxicity testing methods. Red dots show sites where significant toxicity was observed in at least one of the four tests. See text for test descriptions (NOAA 1995).*

For More Information
about Sediment Toxicity:

Magnitude and Extent of Sediment Toxicity in the Hudson-Raritan Estuary, by Ed Long et al. (NOAA Tech Memo NOS ORCA 88 1995)

www.epa.gov/emap/remap/index.html

www.cerc.usgs.gov/pubs/sedtox

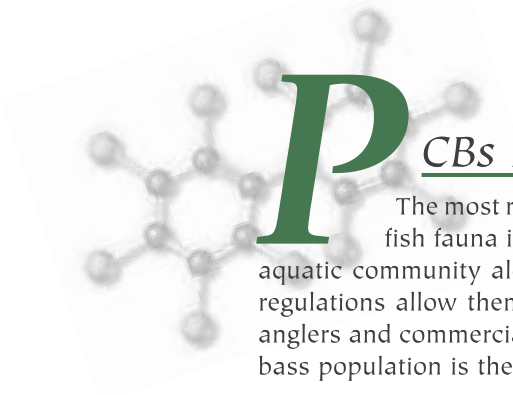
response.restoration.noaa.gov/cpr/sediments/sediment.html

Toxicity tests do not determine causes of the observed toxicity. An individual chemical or a combination of chemicals could cause the problem. Sediment Toxicity Identification Evaluations (TIEs) are tests that can isolate the cause or causes of sediment toxicity; more of this type of work needs to be conducted in the estuary.

The National Oceanic and Atmospheric Administration (NOAA) conducted a variety of types of sediment toxicity testing throughout the harbor in 1991. The four types of tests were (1) the amphipod toxicity test used by R-EMAP, (2) measuring the mortality rates and (3) development of clam larvae, and (4) examining the amount of bioluminescence (light production) exhibited by a certain species of bacteria. Figure 37 shows sampling stations where statistically significant toxicity was observed in at least one of the four tests. Each circle represents a mean of three stations at that location.

Like the R-EMAP results, this analysis shows Newark Bay and the Kills to be areas of concern with respect to sediment toxicity. However, the East River and Sandy Hook Bay also appear as toxic in this analysis. Jamaica Bay was not sampled in this program.

Taken together, the R-EMAP and NOAA surveys suggest that there is some concern about sediment toxicity in most parts of the harbor. The sites with the most significant toxicity are generally those with consistent patterns of surface sediment concentrations of many contaminants (see the discussion of sediment contamination on pages 29–37). NOAA also measured concentrations of a variety of contaminants in the sediments at their toxicity testing sites and found correlations between the amount of toxicity observed and contaminant concentration. For example, there was a strong relationship between amphipod survival in the toxicity tests and the concentration of total PCBs in the sediments. However, these analyses and correlations are not enough to prove that these sediment contaminants caused the observed toxicity. The relationship between toxicity and contaminant concentration is, thus far, *correlative* and not *causal*. In order to determine what exactly is causing the toxicity, whether it is a single contaminant or the additive effects of multiple contaminants or other stressors, TIEs must be performed.



PCBs IN STRIPED BASS

The most recognizable representative of the Hudson River Estuary's fish fauna is probably the striped bass, a prominent member of the aquatic community along the entire East Coast. Wherever it is found — and regulations allow them to be harvested — you can be sure that enthusiastic anglers and commercial fishers are not far behind. The Hudson River's striped bass population is the second largest on the East Coast.

Unfortunately, as with many other fish and crustacean species in our estuary, the flesh of striped bass is contaminated with a variety of organic chemicals, including PCBs. PCBs, or polychlorinated biphenyls, are a class of organic compounds used in a variety of consumer products and industrial applications from the 1940s to the 1970s, most notably in the production of capacitors and other electronic equipment by General Electric in the towns of Fort Edward and Hudson Falls, NY. During those decades, approximately 1.3 million pounds of PCBs were discharged to the river from the GE facilities, where they spread down-stream and were found in unacceptably high levels in the flesh of resident and migratory fishes. Consequently, a ban on all fishing was instituted in a portion of the upper river (subsequently modified to catch-and-release regulations in 1995), the commercial fishery for striped bass was closed, and health advisories on consumption of striped bass and other species were issued throughout the estuary.

In addition to the GE facilities, there are sources of PCBs in the harbor itself, which are in the process of being quantified by the HEP's Contaminant Assessment and Reduction Project. Research suggests that about half of the loading of PCBs to New York Harbor comes over the Troy dam from the GE site and half is from local sources in the harbor complex.

Figure 38 shows that levels of PCBs in striped bass greatly exceeded 2 parts per million, the Food and Drug Administration action limit for commercial sale of fish (the red line on the graph), when data were collected in the mid-1970s. As PCBs were no longer being actively discharged to the river, levels declined in striped bass throughout the 1970s and 1980s. In 1991, PCB levels increased again because of documented releases of PCB-bearing oil after the collapse of

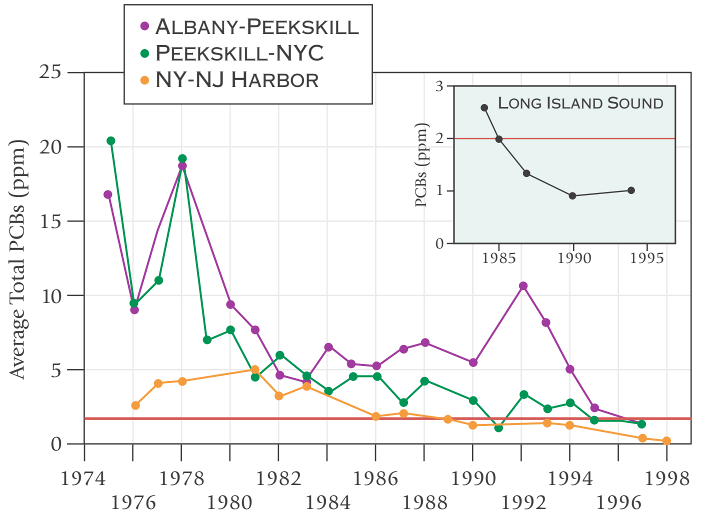
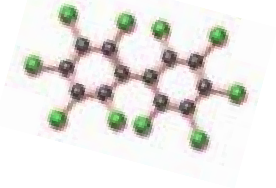


Figure 38 *PCB concentrations in Hudson River and Harbor Estuary striped bass tissue, 1975–1998. Red line indicates FDA guidance value of 2 ppm for commercial sale. Inset shows PCB levels in Long Island Sound striped bass (Sloan 1995, Sloan 1999, Sloan and Hattala 1991).*



an abandoned mill structure adjacent to a GE facility. This increase is evident in the "Albany-Peekskill" line in Figure 38. Data from Long Island Sound fish are shown in the inset of Figure 38 for comparison purposes. Note that levels in Long Island Sound fish have also been decreasing over time, and are much lower than the 2 ppm level.

Levels in the Harbor Estuary have continued to decrease since the early 1990s, and in the lower estuary average concentrations are now below the FDA guideline of 2 parts per million. These recent lower levels have prompted New York State to begin an evaluation of whether the current ban on the commercial harvest of striped bass can be lifted. Both New York and New Jersey continue to issue health advisories on the consumption of striped bass caught in the estuary. For a more complete discussion of fish consumption advisories, see the "Contaminants in Fish Tissue" section of this report (page 42) and the sidebar on consumption advisories.

PCB levels in striped bass still exceed other guidance values. For example, the EPA has issued a Screening Value (a level at which there are potential concerns for human health) for levels of PCBs in fish consumed by recreational anglers of 0.02 ppm, 100 times lower than the FDA standard. Calculation of this Screening Value takes into account current trends in fish consumption, combined risk through consuming multiple contaminants, and other pathways through which people can be exposed to contaminants.

A special intensive study of levels of a variety of contaminants in fish species in the harbor was conducted under the auspices of the HEP in 1993. Figure 39A shows the results of that study for PCB levels in striped bass. Generally, levels of PCBs were found to be higher upriver and decrease downstream to the lower levels

For More Information
about PCBs and PCBs in Striped Bass:

www.epa.gov/hudson

www.epa.gov/toxteam/pcbid/defs.htm

www.dec.state.ny.us/website/dfwmr/habitat/nrd/index.htm

contaminants.fws.gov/restorationplans/HudsonRiver.cfm

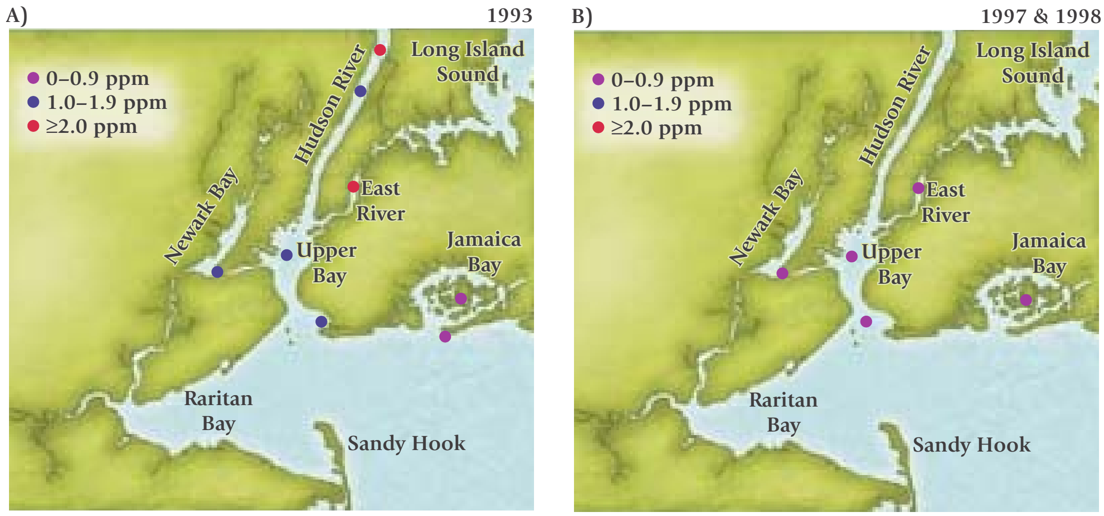
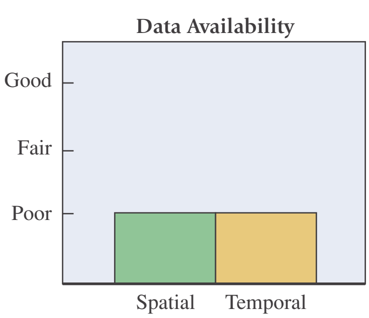


Figure 39 *Levels of PCBs in striped bass tissue in the Harbor Estuary in 1993 (A) and 1997/1998 (B) (Sloan et al. 1995, Sloan 1999, Sloan and Hattala 1991).*

observed in the New York Bight and Jamaica Bay. A later study, the results of which are shown in Figure 39B, found all levels in the lower estuary to be below 0.9 ppm, indicating improvement between 1993 and 1998.

CONTAMINANTS IN FISH TISSUE

High concentrations of contaminants in fish and shellfish tissue in the estuary cause the states of New York and New Jersey to issue consumption advisories for most estuarine species caught in sportfishing activities. The effects of these contaminants on the fish themselves are not well understood, but could include adverse impacts on reproduction, growth and development. Figures 40 through 44 show the means and ranges of levels of a variety of contaminants in fish and shellfish species in the estuary, as measured in 1993. In most plots, the vertical line represents the level at which the US Food and Drug Administration limits commercial sale of fish; the states generally use this level as well as other considerations when conducting risk assessments on which their health advisories are based (see pages 45–46 for a more complete discussion of health advisories). The mean value measured for the given contaminant in that species is indicated by the green box on the plot, and the range of values measured is indicated by the horizontal line and circles. If the range of observed concentrations of a given chemical does not exceed the established guideline (the vertical line) in a particular species, there is less cause for concern than if the observed range does exceed the limit *(but it does not mean that consumption of fish below those levels is risk-free)*. Note that the states have not issued health advisories for the flounder species (see table on page 46). Flounders tend to be lower in contaminant



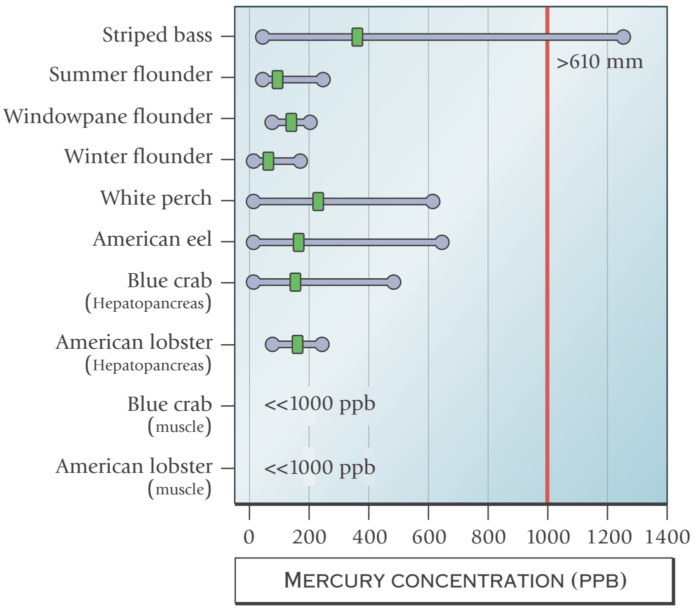


Figure 40 *Mercury levels in selected finfish and crustacean species for all areas of the estuary combined. Red line indicates FDA guidance value of 2 ppm for commercial sale. Green box indicates mean, grey lines and circles indicate range of values measured. (Skinner et al. 1996).*

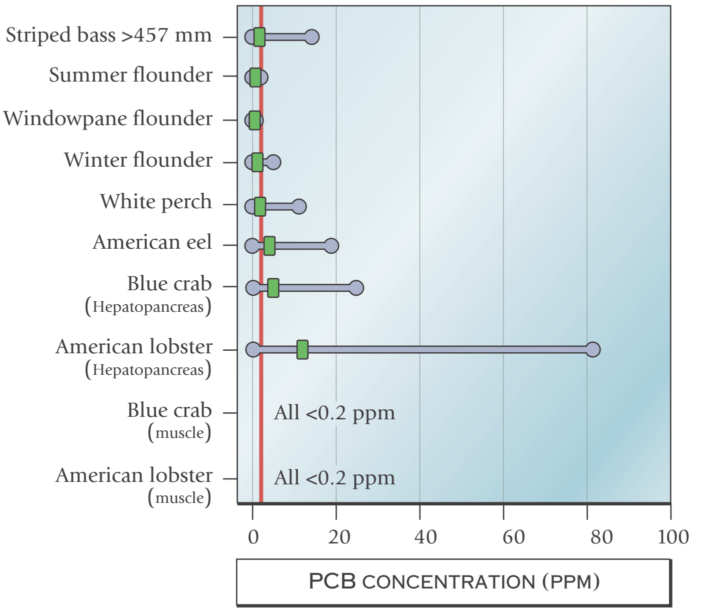


Figure 41 *Total PCB levels in selected finfish and crustacean species for all areas of the estuary combined. Red line indicates FDA guidance value of 2 ppm for commercial sale. Green box indicates mean, grey lines and circles indicate range of values measured. (Skinner et al. 1996).*

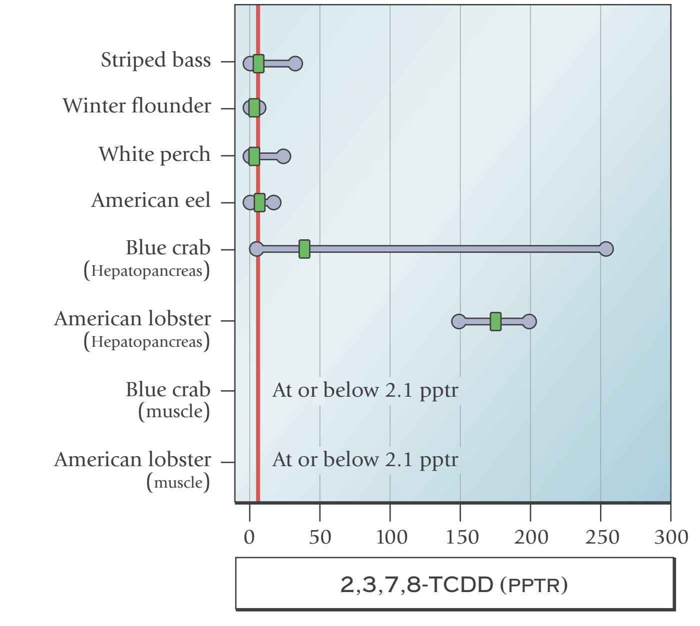


Figure 42 *Dioxin (2,3,7,8-TCDD) levels in selected finfish and crustacean species for all areas of the estuary combined. Red line indicates NYS DOH limit for imposition of health advisories. Green box indicates mean, grey lines and circles indicate range of values measured. (Skinner et al. 1997b).*

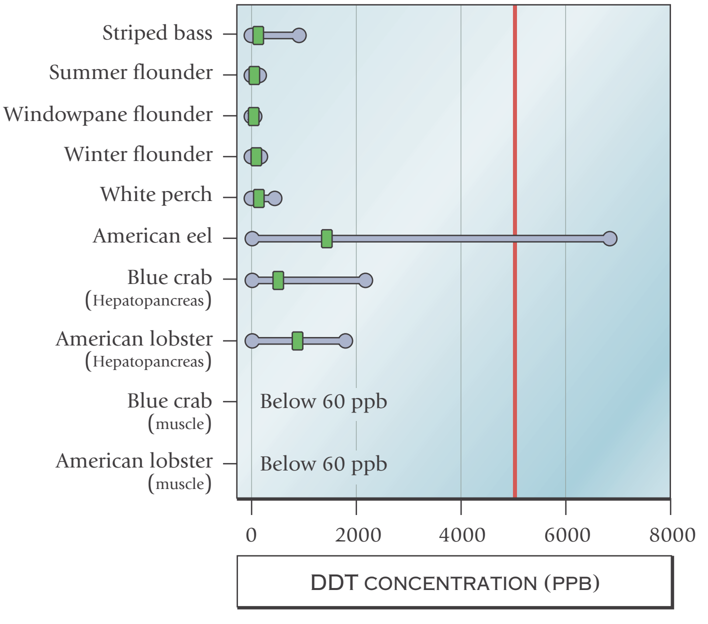


Figure 43 *Total DDT levels in selected finfish and crustacean species for all areas of the estuary combined. Red line indicates FDA guidance value of 2 ppm for commercial sale. Green box indicates mean, grey lines and circles indicate range of values measured. (Skinner et al. 1996).*

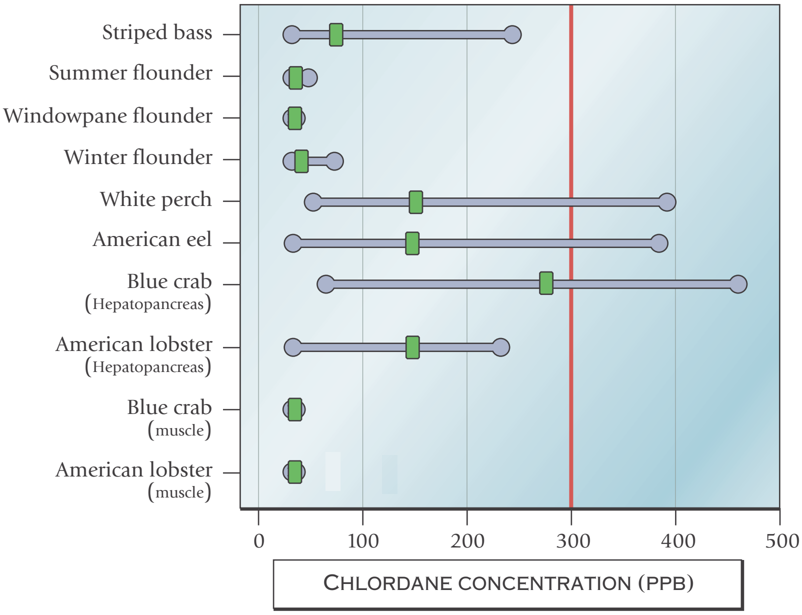


Figure 44 *Total DDT levels in selected finfish and crustacean species for all areas of the estuary combined. Red line indicates FDA guidance value of 2 ppm for commercial sale. Green box indicates mean, grey lines and circles indicate range of values measured. (Skinner et al 1996).*

For More Information about Contaminants in Fish and Crustaceans:

www.epa.gov/ost/fish
www.health.state.ny.us/nysdoh/fish/fish.htm
www.state.nj.us/dep/dsr/njmainfish.htm
www.carpweb.org

For Full Health Advisories GO TO

www.health.state.ny.us/nysdoh/fish/fish.htm
(New York advisories) and
www.state.nj.us/dep/dsr/njmainfish.htm
(New Jersey advisories)

levels, probably in part because they spend more of their time in the relatively clean Lower Bay and Bight rather than in the more contaminated areas of the harbor.

Almost all of the mean observed concentrations (the boxes on the plots) fall below the action limit for that chemical, with the notable exceptions of dioxin (2,3,7,8-TCDD) and PCBs in blue crab and lobster hepatopancreas (the green substance commonly known as "tomalley"). The ranges of some contaminant concentrations still indicate some cause for concern in the cases of chlordane (a pesticide) in white perch and blue crab hepatopancreas, mercury in striped bass larger than 610 mm, dioxin in striped bass and white perch, and PCBs in striped bass larger than 457 mm, winter flounder, and white perch. PCB ranges for summer flounder and windowpane flounder are also close to the action level. American eel exceed all of the guidelines except for mercury, most likely because as benthic species they live in constant close association with contaminated sediments and they do not migrate very far outside a very small home range. As a result, eels that live in contaminated areas tend to accumulate high levels of contaminants and do not depurate by migrating to cleaner areas. Note that while the levels of contaminants in crab and lobster hepatopancreas are high, the muscle tissue levels, the parts that are usually eaten, are too low to be detected. Consequently, it is advisable not to eat the hepatopancreas of local crabs or lobsters.

Table 1 summarizes the data on these contaminants in fish and shellfish by geographic area within the estuary. An open circle in this figure means that no species are above the FDA (or New York State Department of Health) tolerance levels for that chemical in that basin, a half-filled circle means that one species is above the action limit and a filled circle means that two or more species are above the limit for that chemical in that basin. The geographic area in which the most exceedances were observed was the Newark Bay/Kills complex, while the Bight Apex had the fewest exceedances. The table also indicates that while PCBs and chlordane are of widespread concern throughout the estuary, DDT and mercury are not of major concern in terms of levels in fish, and dioxin is of concern in a few areas (although it has

	Upper Bay	Harlem East River	Kills/ Newark Bay	Jamaica Bay	Lower Bay	NY Bight Apex
PCBs	●	●	●	◐	●	◐
Chlordane	◐	●	●	●	◐	○
DDT	○	○	◐	○	○	○
Dioxins	●	ns	●	○	ns	◐
Mercury	○	◐	○	○	○	○

○ No species above action limit ◐ 1 species above action limit ● 2 or more species above action limit ns = Not sampled

Table 1: *Incidence of contaminant levels in fish and crustaceans. Species included in this analysis are blue crab, American lobster, white perch, striped bass, American eel, winter flounder and windowpane flounder. Health advisories are in effect in all of the estuary segments in the table. (Skinner et al. 1997a, 1997b).*

not been measured in fish from all basins of the estuary). These results are consistent with the patterns in the levels of contaminants in the sediments in these basins (see pages 29–34).

Taken as a whole, these results indicate that while the levels of contaminants in fish and shellfish are generally starting to decrease, reflecting the reduction in loadings of these chemicals to the environment, there are still some species, chemicals, and areas that are causes for concern with respect to human health. Health advisories issued by the two states should be followed, and steps can be taken in the preparation of fish and shellfish that will reduce the risk associated with consumption of these species. However, even in those species where average contaminant levels are below the action levels, body burdens of contaminants may still pose a health risk to people if the fish are eaten, and may adversely affect the animals themselves. In other words, an action limit is not a "magic" level below which there is no impact on humans or the ecosystem. In fact, as discussed on page 41, EPA has developed a Screening Value for levels of PCBs in fish tissue for consumption by recreational anglers which is much lower than the FDA value.

Fish Consumption Advisories in the NY/NJ Harbor Estuary

Because of the elevated levels of contaminants in fish and shellfish in the estuary, the states of New York and New Jersey both issue consumption advisories for many recreationally-caught species of fish and crustaceans.

The states consider a variety of factors in formulating their health advisories. One is how the levels of PCBs and other contaminants in the fish flesh compare to the US Food and Drug Administration action levels, by which the FDA regulates the commercial sale of fish. For a variety of reasons it is not appropriate to use only this level as a determining factor in devising health advisories for sportfish consumption. Other factors must also be considered, including the potential additive effects of multiple contaminants in the fish, the vulnerability of different types of individuals to disease caused by the fish, known hot spots of contamination, and the consumption rates of anglers, which are generally greater than others' rates.

The state advisories therefore provide guidance about the amounts and kinds of fish, caught in specific areas, that can be consumed safely. In addition, both New York and New Jersey advise that women of childbearing age, infants and children under the age of 15 should not eat any of the species from any water bodies for which there are advisories.

Table 2 on the next page outlines some of the fish consumption advisories issued by New York and New Jersey for estuary waters in 2003.

Table 2 *Fish Consumption Advisories NY and NJ*

Area	Species (note: not all species under advisories are listed here)	New York Advisory	New Jersey Advisory (for 1/10,000 cancer risk)*
East & Harlem Rivers**	American eel	Eat none	N/A (not applicable)
East & Harlem Rivers**	Bluefish, striped bass	No more than one meal per month	N/A
Jamaica Bay	Bluefish, American eel	No more than one meal per week	N/A
Jamaica Bay	Striped bass	No more than one meal per week	N/A
Hudson River downstream of Catskill, Upper Bay, Kills**	American eel	No more than one meal per month	No more than one meal per year
Hudson River downstream of Catskill, Upper Bay, Kills**	Bluefish	No more than one meal per month	fish > 6 lbs.: No more than 4 meals per year fish < 6 lbs.: No more than one meal per month
Hudson River downstream of Catskill, Upper Bay, Kills**	Striped bass	No more than one meal per month	No more than 4 meals per year
Newark Bay, Hackensack River, Kills**	Striped bass	Kills: No more than one meal per month	Eat none
Newark Bay, Hackensack River, Kills**	Bluefish	Kills: No more than one meal per month	fish > 6 lbs.: No more than 4 meals per year fish < 6 lbs.: No more than one meal per month
Arthur Kill, Kill van Kull**	Blue crab	No more than 6 crabs per week; do not eat hepatopancreas	Eat none
Hudson River downstream of Catskill, Upper Bay, Kills**	Blue crab	No more than 6 crabs per week; do not eat hepatopancreas	No more than 6 crabs per week; do not eat hepatopancreas
Lower Bay	Bluefish, American eel	No more than one meal per week	Bluefish > 6 lbs.: No more than 4 meals per year Bluefish < 6 lbs.: No more than one meal per month eels: No more than 4 meals per year
Lower Bay	Striped bass	No more than one meal per month (women of childbearing age and and children under 15: Eat none)	No more than one meal per month
Newark Bay, Hackensack & Passaic Rivers	Blue crab	N/A	Eat none
Passaic River downstream of Dundee Dam	All species of fish and shellfish	N/A	Eat none
Raritan Bay, Raritan River, Sandy Hook Bay	Bluefish	N/A	fish > 6 lbs.: No more than 4 meals per year fish < 6 lbs.: No more than one meal per month
Raritan Bay, Raritan River, Sandy Hook Bay	Striped bass	N/A	No more than one meal per week
Raritan Bay, Raritan River, Sandy Hook Bay	Blue crab	N/A	No more then 6 crabs per week: do not eat hepatopancreas

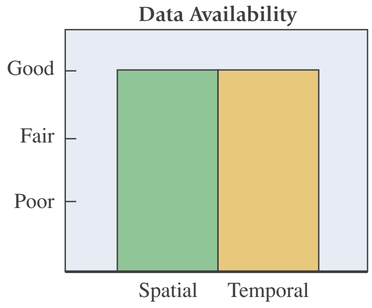
*In Addition to the 1/10,000 cancer risk advisories summarized here, New Jersey issues separate, more restrictive advisories for a lifetime cancer risk of 1/100,000, as well as for high risk individuals (infants, children, pregnant women, nursing mothers and women of childbearing age). Please go to their web site (www.state.nj.us/dep/dsr/njmainfish.htm) for more deailed health advisories.
**NYSDOH stresses that in addition to the warning for women of childbearing age, infants, and children under 15 (see below), other people are advised to eat no more than one meal per week of unlisted species in these (NY) waters.

In addition to these recommendations, both New York and New Jersey advise that women of childbearing age, infants and children under the age of 15 should not eat any of the species from any water bodies for which there are consumption advisories.

3 Pathogens

ACRES OF OPEN SHELLFISH BEDS

For more than 200 years, from the time of European settlement of this region, clams, mussels and oysters were a critical part of the harbor's economy and of the diets of locals. Oysters in particular were so large and plentiful in the harbor area that until the mid-1800s a major industry in the harbor region was the processing and export of oysters. The meats of "Rockaways," "Jamaicas," and "Amboys" were eagerly consumed, and the shells were used in construction materials. Hardshell and softshell clams were also important fisheries, particularly in Raritan Bay. As the human population increased in New York City and the surrounding region, pollution and development began to take



For More Information about Shellfish and Shellfish Beds:

Heartbeats in the Muck, by John Waldman (Lyons Press, 1999)

The Fisheries of Raritan Bay, by Clyde L. MacKenzie, Jr. (Rutgers University Press, 1992)

www.harborestuary.org/pdf/hepshellfish.pdf

www.state.nj.us/dep/fgw/shelhome.htm

www.dec.state.ny.us/website/dfwmr/marine/shellfish

www.hsrl.rutgers.edu

www.nynjbaykeeper.org/oyster_garden.htm

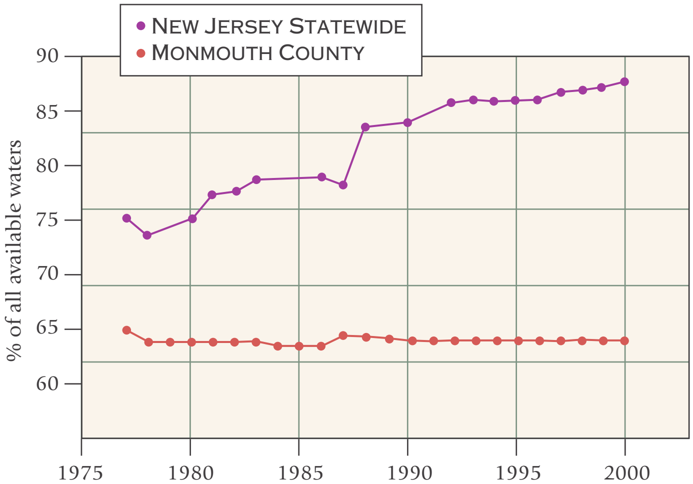


Figure 45 *Percent of available shellfish beds open for harvest in New Jersey, statewide and in Monmouth County alone, 1977–2000 (Eisele 2000, NY/NJ HEP 2002b).*

their toll on the harbor's water quality and on local shellfisheries. Although overharvesting and low dissolved oxygen levels in the water due to discharge of raw sewage to the harbor caused the decline of shellfish populations in the estuary, ultimately the industry was devastated when cases of typhoid in the region were linked to contaminated oysters in 1924.

With the major improvements in sewage treatment and water quality that have occurred over the past 30 years, some areas are once again available for either direct shellfish harvest or relay (harvested shellfish are placed in clean waters to purge themselves of contaminants before being sold or consumed) or depuration (harvested shellfish are placed in tanks of cleaned treated seawater to remove contaminants from the shellfish before they are sold). State and local governments now assess the suitability of shellfish beds for harvest on the basis of a variety of factors, primarily levels of coliform bacteria found in the water. Other factors, such as historical water quality problems or presence of other pollutants, also influence these decisions. In New York, "administrative closures" (based not on bacterial measurements but on circumstances known to cause shellfish to become contaminated) are maintained year-round near sewage treatment plants and near marinas in the boating season. Administrative closures are also issued in some areas after heavy rainfalls; bacterial sampling is conducted in these cases in order to determine when a bed should be reopened. Although there are small differences in the ways in which the two states determine whether shellfish beds should be closed to harvest, both states follow the National Shellfish Sanitation Program guidelines established at the federal level for monitoring shellfish beds.

Figure 45 shows the percent of available shellfish bed area open to harvest in the state of New Jersey from the mid-1970s to 2000. The increasing trend in open acreage statewide can be attributed to better water quality, mostly due to improved sewage treatment. Open bed acreage in Monmouth County (Navesink and Shrewsbury Rivers, Sandy Hook and Raritan Bays) has remained fairly stable over the period shown. Many of the continuing closures are due to a variety of general environmental concerns (presence of CSOs, historical chemical contamination) in addition to poor water quality (for example, having characteristics such as low dissolved oxygen or high concentrations of coliform bacteria). Some areas are closed permanently (for example, parts of the Shrewsbury and Navesink Rivers) for administrative reasons, such as insufficient Conservation Officers to patrol and enforce regulations in those areas. There are several success stories in New Jersey waters, including the reopening of areas of the lower Navesink in 1997, after having been closed to shellfishing for 25 years.

Figure 46 shows the percent of available shellfish bed area open for harvest in three New York water bodies: New York Bight, Western Long Island Sound, and the estuary from Peekskill to the harbor. Because of concerns about persistent water quality problems and other pollution problems, direct harvest (i.e., without relay or depuration) of shellfish is not allowed anywhere in the harbor itself. Over the time period depicted, the acreage of shellfish beds open has remained fairly stable.

Figure 47 shows the size of the relay fisheries in each state: the Raritan-Sandy Hook Bay fishery in New Jersey from the 1980s to the late 1990s and the Staten Island hard clam relay fishery from the late 1970s to 2001. For New York, the orange portion of the line shows bushels of clams that were depurated, or harvested from the environment and then placed in tanks on land to cleanse themselves for 48 hours. The depuration process was not used after 1983 for economic reasons. Starting in 1987 (the green portion of the line), clams have been harvested from Raritan Bay and relayed to areas in Long Island Sound and Peconic Bay for a minimum 21-day cleansing period. Over time, the amount of clams annually transplanted from Staten Island has risen from about 5,000 bushels to more than 80,000 bushels. In New Jersey, the amount of clams depurated and relayed has grown from 20,000 bushels to about 120,000 bushels.

Generally speaking, as water quality has improved, more harvesting, particularly under the relay/depuration program, has taken place in both states, either because it has become safer to consume shellfish from the estuary or because improvements in water quality have led to increases in shellfish populations and increases in the number of people harvesting shellfish commercially.

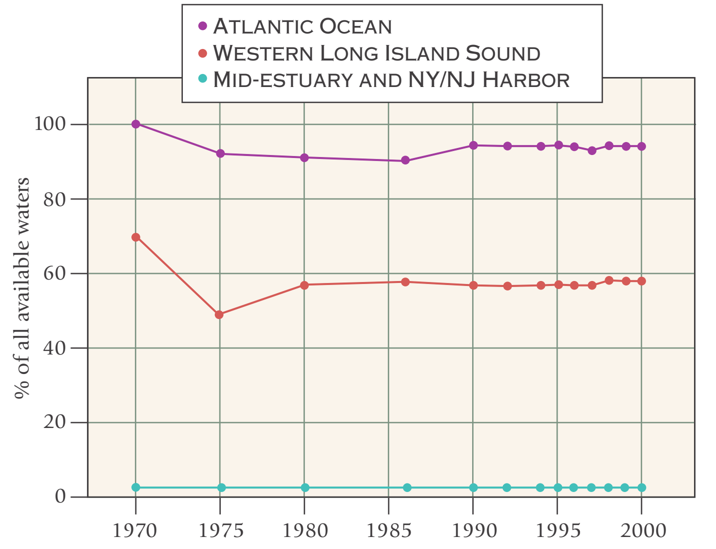


Figure 46 *Percent of available shellfish beds open for harvest in New York in three areas, 1970–2000 (Lewis 2000, Barnes 2000).*

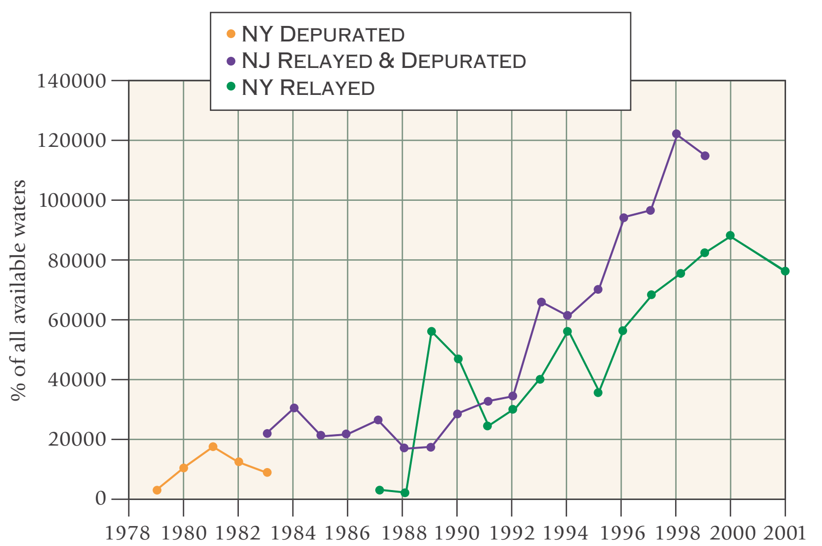
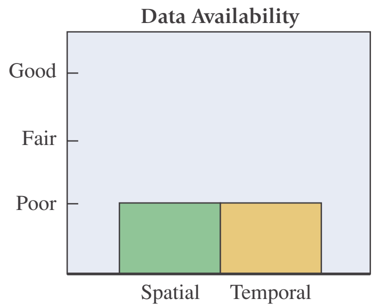


Figure 47 *Relay and depuration clam fisheries in New York and New Jersey, 1978–2001 (see text for explanation of these practices) (Eisele 2000, Lewis 2000, Barnes 2000, NY/NJ HEP 2002b).*



DISEASE LINKED TO CONTAMINATED SHELLFISH

The decline of the shellfishing industry in the harbor, particularly the oyster fishery, was hastened when outbreaks of typhoid in the area were linked to consumption of contaminated oysters (see the section on shellfish beds, page 47). In 1924 a typhoid outbreak was traced to oysters harvested from Raritan Bay. This outbreak caused 1500 illnesses and 150 deaths. As a result, the Surgeon General of the U.S. established the National Shellfish Sanitation Program (NSSP) in 1925 to classify shellfish waters, inspect shellfish dealers, and address the public health issues associated with shellfish harvest.

Most of the shellfish that people eat are filter feeders, meaning that they pump water through their system to filter out phytoplankton (microscopic plants) as their food source. In polluted waters they may also filter and accumulate contaminants such as disease-causing bacteria and viruses. These disease-causing organisms, which usually come from human sewage sources such as combined sewer overflows, illegal sewer bypasses, sewage treatment plant malfunctions, and boat discharges, can become concentrated in the guts of the shellfish and ultimately cause a variety of illnesses in humans. These illnesses include typhoid fever and cholera (caused by bacteria) and viral gastroenteritis and hepatitis (caused by viruses). With the advent of advanced sewage treatment in the past 30 years, sources have been greatly reduced, as has the risk of becoming sick from eating shellfish grown in harbor waters.

It is important to keep in mind that even shellfish harvested from seemingly pristine waters, if consumed raw, can cause disease if they have been feeding on disease-causing organisms or if they are mishandled and contaminated after they are harvested. Consumption of any raw shellfish, regardless of where it was harvested, carries some risk which can be reduced, but not necessarily eliminated, by cooking.

Figure 48 shows the history of occurrence of two of the most serious shellfish-associated diseases, typhoid and hepatitis, caused by consumption of shellfish in New York and New Jersey from the early 1900s until 1988. In many cases the source of the shellfish was unknown, but was often suspected to be from New York, New Jersey or Connecticut. The last known typhoid case was in 1954, and the cases of hepatitis (the first known appearance of which was in 1962) have been few.

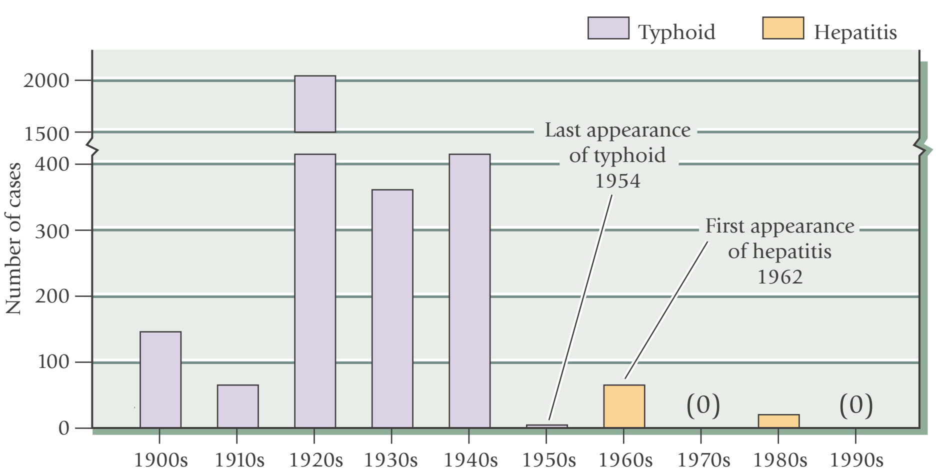


Figure 48 *Incidence of typhoid and hepatitis traced to the consumption/handling of contaminated shellfish likely from New York, New Jersey or Connecticut, 1900s–1990s (Horn 1990, Wolf 2001).*

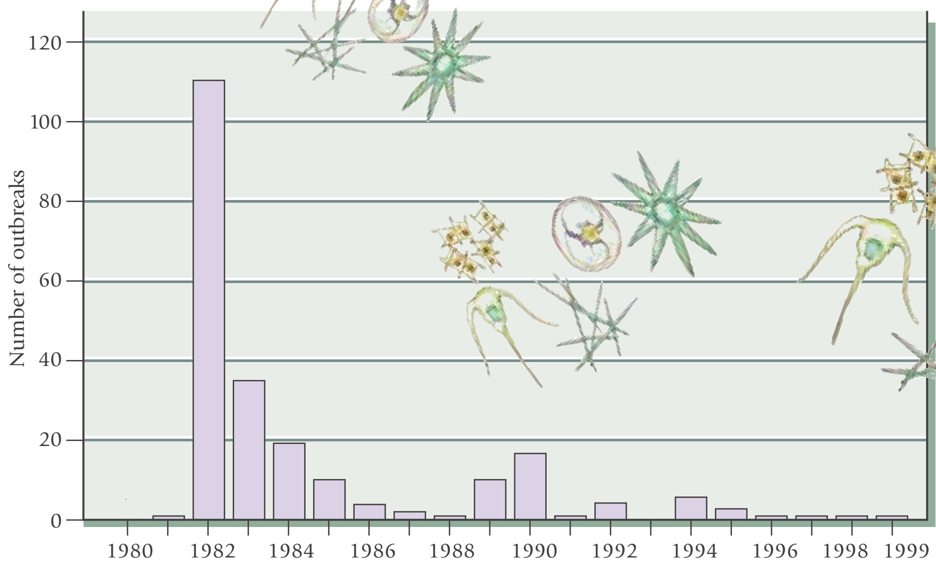


Figure 49 *Incidence of shellfish-related illness in New York State, 1980–1999 (Holcomb 2000).*

Figure 49 summarizes another data set compiled by the New York State Department of Health on shellfish-associated illness (most commonly gastroenteritis) recorded in New York State from 1980 to 1999. The sources of the shellfish that induced these outbreaks is frequently unknown, and may not be local in many cases. Most of the 1989 outbreaks resulted from consumption of Long Island clams, and the source of the illnesses in 1982 was most frequently traced to Rhode Island shellfish. The 1998 outbreak was traced to shellfish from Oyster Bay, Long Island. The incidence of reported illness has dropped markedly since its peak in 1982. Decreases in shellfish-associated disease could be due to a number of factors, including better sewage treatment leading to reductions in concentrations of disease-causing microorganisms, more restrictions on harvest of shellfish from contaminated areas, and more awareness among the public as to the risks associated with consuming raw shellfish.

One important caveat about the data presented here: Shellfish-related illness is probably under-reported and is likely to be misdiagnosed when it is reported, because the symptoms are non-specific. While the incidence of shellfish-associated disease is much lower in recent years as compared to the 1980s and previous years, it may be that the absolute numbers of cases in each year are higher than reported.

Although shellfish beds are monitored carefully for pathogenic contamination, the levels of chemical contaminants in shellfish are not as well-studied.

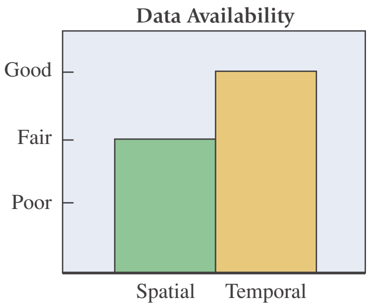
For More Information about Shellfish and Disease:

Heartbeats in the Muck, by John Waldman (Lyons Press, 1999)

www.cfsan.fda.gov/~mow/chap37.html

www.cdc.gov

www-seafood.ucdavis.edu



LEVELS OF COLIFORM BACTERIA

Bacteria are all around us - in the air, in the water, and even in the food we eat. Most bacteria encountered on a daily basis are harmless, or even beneficial and necessary to sustain life. However, the presence of some bacteria, namely fecal coliform bacteria, in estuary waters, is an indicator of fecal waste and therefore suggests that other, more dangerous pathogens may be present. These pathogens can be a threat to human health if we eat shellfish that have been ingesting them (see the discussion of shellfish bed closures beginning on page 47) or sometimes if we swim in sewage-contaminated waters. The most common result of exposure to these pathogens is gastroenteritis, but more serious conditions can also result from exposure to sewage (see the discussion of shellfish-related illness on beginning page 50).

Before there were sewage treatment plants, raw sewage was disposed of directly into our waterways, and fecal coliform and other pathogen levels were very high. Now that sewage treatment plants have been constructed and upgraded, the main source of coliform bacteria to the estuary is combined sewer overflows. CSOs route a mixture of raw sewage and street runoff directly into the estuary during and immediately after rain events when the processing capacity of the sewage treatment plants is exceeded. Other sources include illegal sewage connections, sewage treatment plant bypasses (which sometimes are due to plant malfunctions or construction at plants), some inputs from the plants even when they are functioning properly, storm water outfalls, non-point sources such as storm runoff and leaking septic tanks, and in some areas, excessive wildlife waste.

Figure 50 shows the mean concentration of fecal coliform bacteria in the harbor as measured during four years by the New York City Department of Environmental Protection (NYCDEP). The progressive improvement in coliform levels is clear from these four time periods, which represent four phases in sewage treatment plant upgrades and improvements in New York City. In 1974, many sewage treatment plants in the New York/New Jersey area were not yet upgraded to secondary treatment, meaning that raw sewage continued to be discharged in some locations, and disinfection was sporadic. At this time, most areas exceeded bacterial standards for either fishing or bathing. In 1985, some upgrades had been made to existing plants, but two of the City's plants were not yet built (North River and Red Hook). In 1988, the large improvements due to the operation of those two plants (which ended the discharge of approximately 210 million gallons per day of untreated sewage from Manhattan and Brooklyn) can be seen. Further improvements to the plants, significant reductions of illegal discharges and increased maintenance of the sewerage system caused mean coliform levels to drop even further, as shown in the 1998 panel.

Figure 50 *Summer geometric means of fecal coliform concentrations in Harbor surface waters in four selected years (NYC DEP 1998).*

Figure 51 shows a more detailed record of fecal coliform densities for 1989–1999 for three coastal sites in New York and three in New Jersey outside of the harbor core area. Concentrations of coliform at these coastal sites were uniformly lower than concentrations in the harbor (see Figure 50), and varied only slightly from year to year. Fecal coliform concentrations along the coast are influenced by several factors: concentrations in waters flowing out of the harbor, local storm water discharges, runoff from the land, contributions of bird and other animal wastes, occasional sewage treatment plant malfunctions, and discharges related to rainfall when fecal coliform gets washed into local waters. Levels of coliform at these sites generally decreased between 1989 and the mid-1990s, then increased again in some areas, most notably Rockaway Point, NY and Manasquan Inlet, NJ. In no year at any of the sites did the density of coliform approach the States' guideline used in making beach closure determinations of 200 fecal coliform cells per 100 ml of water.

While fecal coliform is the most commonly monitored indicator of fecal contamination, it has certain limitations. For example, it cannot distinguish between human and animal contamination sources, but it is generally believed that human fecal contamination poses a much greater human health risk to bathers and shellfish eaters than animal waste. The presence of fecal coliform also does not correlate well with the levels of human fecal viruses, which may be more of a concern with respect to disease than bacteria. For these reasons, NJDEP has conducted research into the utility of monitoring an alternate indicator, coliphages, which are viruses that infect one species of coliform bacteria. The results of this work are promising, but more research needs to be done before this method becomes widely used. Recent federal legislation, the Beaches Environmental Assessment and Coastal Health (BEACH) Act, will require coastal states to monitor enterococcus bacteria, a more reliable and sensitive indicator, as the primary indicator for swimming waters within three years; New Jersey is already examining this indicator, but it is not yet used to determine whether beaches should be closed.

For More Information about Coliform Bacteria:

NYCDEP annual Harbor Survey report, available from DEP at 212-860-9339 or www.ci.nyc.ny.us/html/dep/home.html

www.epa.gov/region02/desa/nybight/

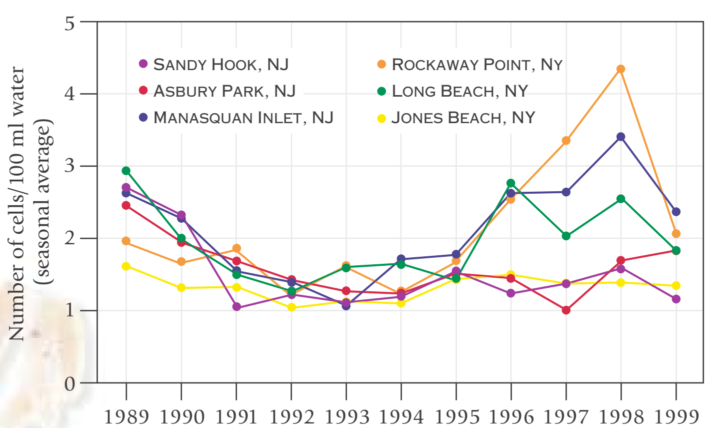
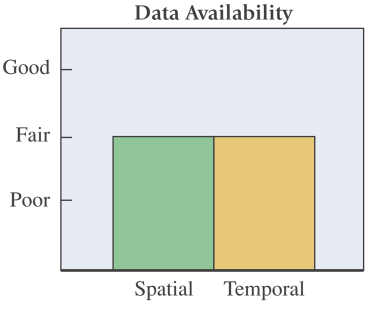


Figure 51 *Average fecal coliform concentrations at sites on Long Island, NY and the New Jersey Coast, 1989–1999 (US EPA Region 2 1989–1999).*

BEACH CLOSURES

If you say that you are "going to the beach" in the New York/ New Jersey region, most likely you mean you are heading to the Jersey Shore, to one of the well-known Long Island South Shore beaches such as Jones Beach, or perhaps to Long Island Sound. Except for Coney Island, New York City and the harbor generally are not considered prime bathing destinations. However, there are several beaches in and near the estuary that, with water quality improvements, are becoming more attractive as conveniently accessible swimming holes. After having been closed for decades because of water quality concerns, some New York City beaches, notably Seagate Beach on Coney Island and South and Midland Beaches on Staten Island, have opened again for swimming in recent years. Some people have been swimming off Pier 26 in the Hudson River in recent years, and there has been discussion of the feasibility of creating swimming beaches or floating pools at other points along the Hudson in Manhattan.



Responsibility for monitoring the water quality of bathing beaches in the estuary lies with a number of agencies, all of whom use different tests, criteria, and advisories in their monitoring programs. New Jersey has one of the most comprehensive beach monitoring programs in the country: all 127 miles of ocean and bay beaches are monitored for fecal coliform once per week during the summer. It is the only state to have a statewide mandatory beach protection program that includes a bacterial standard, testing protocol and mandatory closure requirements. New Jersey's beach monitoring protocols have been the same since 1986. New York does not have a mandatory beach monitoring program, but the Departments of Health of all coastal counties in New York, including New York City, do conduct routine bacterial testing at all public beaches. In many areas, automatic preemptive closings are also issued after heavy rainfall.

What makes it unsafe to swim at a closed beach? Most beach closures are due to pathogen-contaminated storm water runoff or combined sewer overflows, which release untreated sewage into our waterways when it rains. Pathogens, including viruses, from raw sewage or runoff can cause gastroenteritis (which is actually an umbrella name for a variety of illnesses that cause vomiting, stomach ache, or related symptoms) or other infectious diseases such as hepatitis and salmonellosis. A few beach closures have occurred for other isolated reasons, such as sewer line breaks and oil spills. Although some ocean beaches in New York and New Jersey were closed after wash-ups of medical waste in the late 1980s, these incidents are extremely rare and the risk to swimmers of any kind of infection from them is extremely small (see the Floatables indicator discussion, page 57).

Figure 52 shows the total number of beach closures at ocean and bay beaches of Monmouth County, New Jersey from 1989 to 1999. Figure 53 shows beach

For More Information about Beach Closures:

www.epa.gov/OST/beaches/technical.html
www.nrdc.org/water/oceans/ttw/titinx.asp
www.nj.gov/dep/beaches/
www.harborestuary.org/pdf/hep_beaches_03.pdf

closures and advisories for some New York City boroughs and Westchester and Nassau Counties, New York. Note that New York City has a standing rainfall advisory for all Bronx, Queens and Staten Island beaches which are not included in the totals on the graph. There does not appear to be a clear trend in the number of beach closures for either state over the time period shown here, most likely because so many factors combine to influence bacterial concentrations, and because advisory standards change over the years – the number of beaches monitored or the required duration of an advisory can change, for example (although as noted above, New Jersey's monitoring protocols have been the same since 1986).

The BEACH Act, described on page 54, will require all coastal states to implement consistent and rigorous beach monitoring, closure and public notification programs based on monitoring levels of enterococcus bacteria. Enterococci have been more closely correlated with gastroenteritis in swimmers than fecal coliform, and thus will be a better indicator of health risk. Not only will beach monitoring protocols become more consistent and stringent, but the BEACH Act also requires EPA to maintain a national database of beach water quality information, so tracking this indicator should become easier in the coming years.

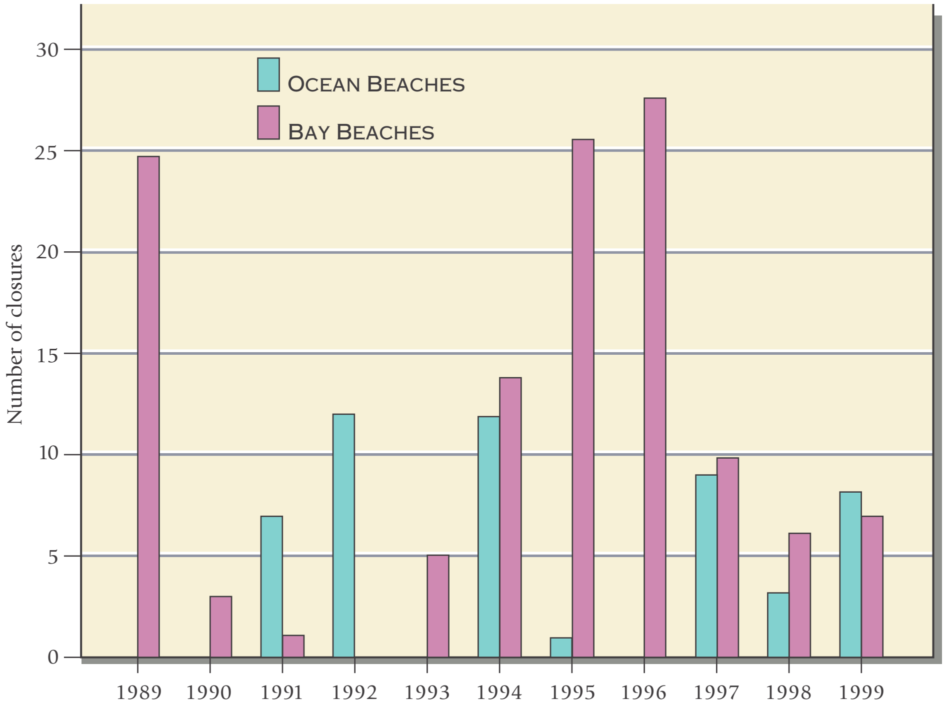


Figure 52 *Numbers of ocean and bay beach closures in Monmouth County, NJ, 1989–1999 (NRDC 1991–1999).*

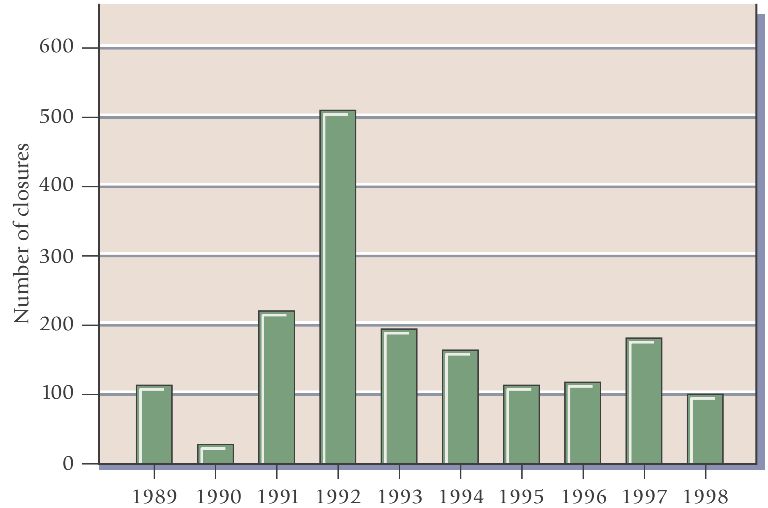
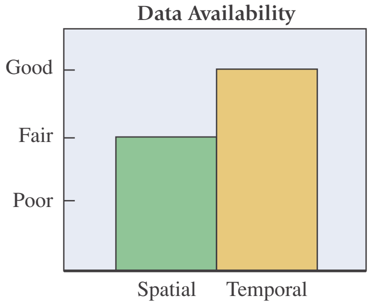


Figure 53 *Number of beach closures in New York City and Westchester and Nassau Counties, NY, 1989–1998. Decrease in 1993 closures was largely the result of decreased rainfall levels and changes in NYC's rainfall advisory program, which included fewer beaches and reduced the duration of advisories from 48 to 12 hours (NRDC 1991–1999).*

4 Floatable Debris

FLOATABLE DEBRIS

Although debris in our waterways and on beaches (often called “floatables”) rarely poses an immediate public health threat, trash in the environment is unsightly, offensive and affects our quality of life. The perceived health threat posed by some floatables, such as the medical waste found on area beaches in 1987 and 1988, can have tremendous economic impact: the economic losses due to the New York and New Jersey beach closures in 1987 and 1988 are estimated to have been between $900 million and $4 billion in New Jersey and $950 million and $2 billion in New York. In addition, floatables can pose hazards to navigation if boats hit large objects or suck smaller ones into



engines and propellers, and to wildlife, which can become entangled in fishing gear or can die from ingesting some kinds of debris.

Where does this debris come from? The main sources of estuary floatables are combined sewer overflows and storm water, both of which flush debris into local waterways when it rains. Prevailing currents can carry this debris to the Jersey shore beaches (and less frequently to New York beaches). Other sources include beach litterers and discharges from boats.

Table 3 shows the top ten constituents of trash removed from New York beaches by the American Littoral Society-sponsored volunteer Coastal Cleanup in 1994–1999 (conducted on a single day in September every year), and the occurrence of medical waste (syringes only) for comparison. Note that syringes comprise only a tiny portion of what is found in these beach cleanups.

Most Common Debris Items Found on New York City Beaches, 1994–1999

Debris item	Percent (%) of Total Items
Cigarette butts	8.2
Plastic food bags/wrappers	7.5
Plastic caps/lids	6.2
Plastic beverage bottles	6.0
Foamed plastic pieces	5.2
Plastic straws	5.0
Glass pieces	4.9
Glass beverage bottles	4.2
Plastic pieces	3.7
Plastic cups/utensils	3.2
Medical waste (syringes only)	0.2

TABLE 3 *Debris on NYC beaches (American Littoral Society 1999).*

Figure 54 shows the amount of debris removed from New York (New York City, Long Island and upstate) and New Jersey shores per mile cleaned in 1989–1999. The New York beaches were cleaned by American Littoral Society volunteer crews in the Coastal Cleanup. The yearly variability in the New York data could be due to a number of factors, including how many volunteers participated in a given year, the meteorological conditions that year, and even the weather on the day of the beach cleanup. Nasty weather can deter even the most enthusiastic volunteers! New Jersey shorelines were cleaned by the New Jersey Department of Environmental Protection's Clean Shores program; note that the amount removed per mile of shoreline has decreased over the years for which we have data. The EPA uses helicopter surveys to determine the number of "slicks" or aggregations of floatables in the harbor, those data are shown in Figure 55 for 1992–1998. Observations of slicks have been decreasing since 1994 (they increased from that year over previous years because of an expansion of the program area).

Prior to the HEP, the New York Bight Restoration Program initiated a Floatables Action Plan in the harbor in the late 1980s to prevent debris from getting into the waterways and to remove it from waterways when it gets there. This program includes the operation of "skimmer vessels" by the US Army Corps of Engineers and the New York City Department of Environmental Protection that cruise the harbor removing floating debris. Figure 56 shows the tons of debris removed by those efforts (the NYCDEP program was initiated in 1994) from 1988–1997; there does not seem to be a directional trend in this data. However, EPA considers the Floatables Action Plan to be very successful, as it has eliminated beach closures due to floatables in New Jersey and Long Island and has instituted a better mechanism for notifying beach operators of potential wash-ups of floating debris.

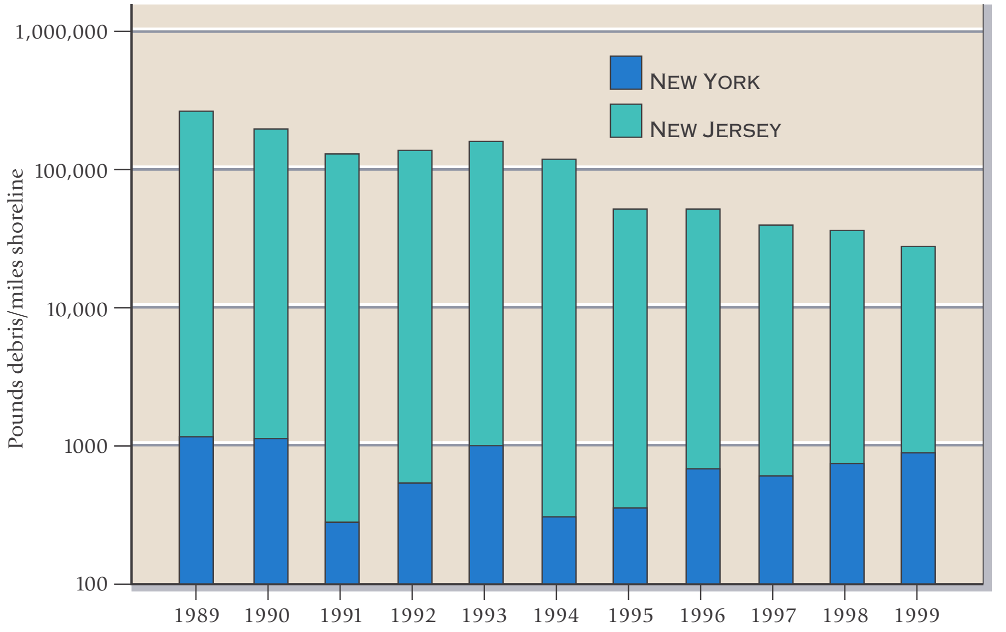


Figure 54 *Amount of debris removed from NY and NJ shorelines, 1989–1999. NY beaches include those in all boroughs of New York City and Nassau, Suffolk, Westchester and upstate counties (American Littoral Society 1999, NJDEP 2000).*

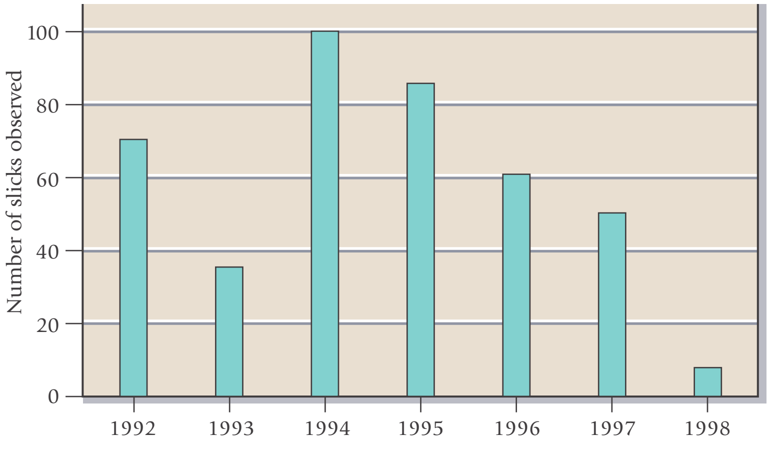


Figure 55 *Observations of floatables slicks in NY Harbor, 1992–1998. A "slick" is defined as an "aggregation of floating debris of indefinite width and a minimum length of approximately 400 meters." Note: in 1994, surveillance areas were increased, resulting in the large increase in that year (US EPA 1999).*

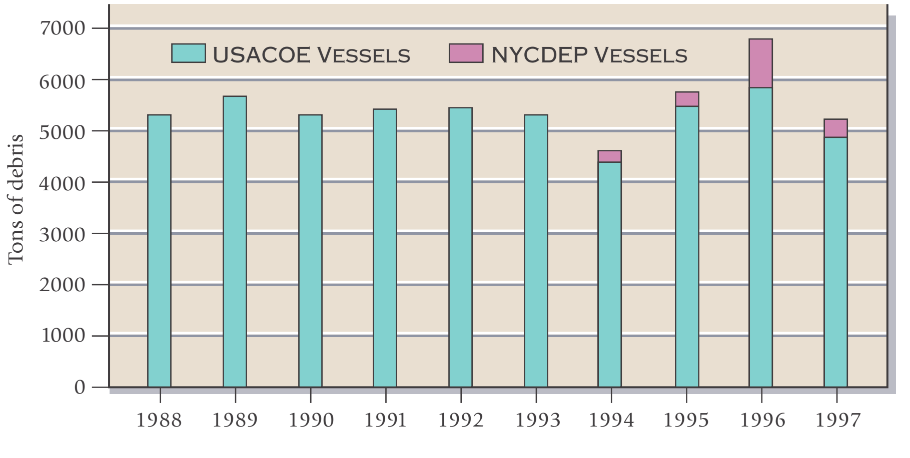


Figure 56 *Amount of floatable debris removed from the Harbor by NYCDEP and USACOE skimmer vessels, 1988–1997. NYCDEP's skimmer vessel collection program was initiated in 1994. USACOE program uses 3 vessels, NYCDEP's program uses 5 vessels (US EPA 1998a).*

For More Information about Floatable Debris:

www.alsnyc.org

www.oceanconservancy.org/dynamic/issues/threats/debris/debris.htm

www.epa.gov/owow/oceans/debris

www.nyc.gov/html/dep/html/float.html

To volunteer for beach clean-ups:

In NY: Contact the American Littoral Society at 800-449-0790 or 718-471-2166. or visit their web site at www.alsnyc.org

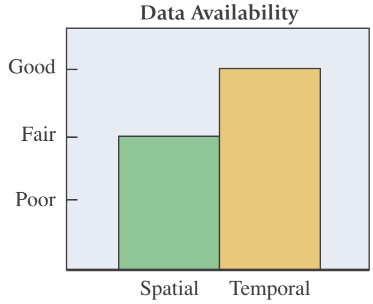
In NJ: Contact Clean Ocean Action at 732-872-0111 or vistit their web site at www.cleanoceanaction.org

5 Nutrients and Organic Enrichment

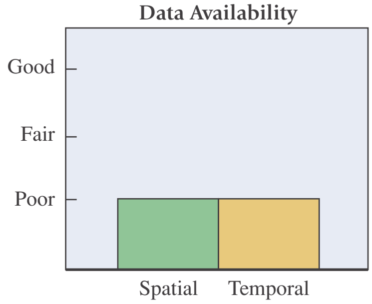
NUTRIENT LEVELS AND LOADINGS

Nutrients such as nitrogen and phosphorus are essential for the growth of all organisms. In the marine environment, these nutrients can come from a variety of sources, including recycling of nutrients from dead organisms, runoff from the land, and gaseous nitrogen in the air. However, as human populations around waterways increased, a number of new *anthropogenic* (human-caused) sources of nutrients began loading into waterways, often resulting in "too much of a good thing" for those waters. If too much nitrogen or phosphorus is added to waterways, they can become *eutrophic* (over-enriched in nutrients). In eutrophic systems, algae that use those nutrients grow

Nutrient Levels



Nutrient Loadings



in rampant blooms, and then deplete their resources and die. As they decay, oxygen is used by the bacteria that break them down and waters can become low in or even devoid of oxygen (see the section of this report on dissolved oxygen on page 65), affecting the other oxygen-breathing organisms that live there. Eutrophication can cause other problems as well, including diminished quality of seagrass bed habitat, changed food webs resulting in decreased fish production, noxious odors and increased nuisance algal blooms.

In the NY/NJ Harbor Estuary, anthropogenic inputs of nutrients, particularly nitrogen, are quite high because of the high volume of wastewater that enters the estuary from municipal sewage treatment plant discharges and inputs from tributary rivers. Approximately 2.5 billion gallons of (mostly treated) wastewater enters the estuary every day from municipal sewage treatment plants. When it rains more nutrients enter the system in the form of untreated sewage contributed by combined sewer overflows. Upstream sources such as fossil fuel combustion and agricultural fertilizer are also large. Nutrient loadings to the estuary are probably higher than in any other major estuary in North America.

Despite the high nutrient loadings to the Harbor Estuary, the degree to which eutrophication or hypoxia occurs in the harbor varies and is less severe than might be expected for a variety of reasons. One is that algal production is strongly regulated by the water *residence time,* the time that water remains in the estuary before being flushed out. Much of the time the estuary is well-flushed, so those nutrients get “washed out” into the ocean before the problematic algal blooms can occur. In addition, because it is so turbid, much of the estuary is often “light-limited,” meaning that not enough light penetrates the water column to provide for photosynthesis and blooms to occur. However, when the residence time increases, as during years with less rain and snow, or even during certain types of tidal cycles, the harbor estuary can become eutrophic. Climate change models predict that in the future, on average, there will likely be smaller freshwater inputs to the estuary in the summer, and the estuary will probably become more eutrophic.

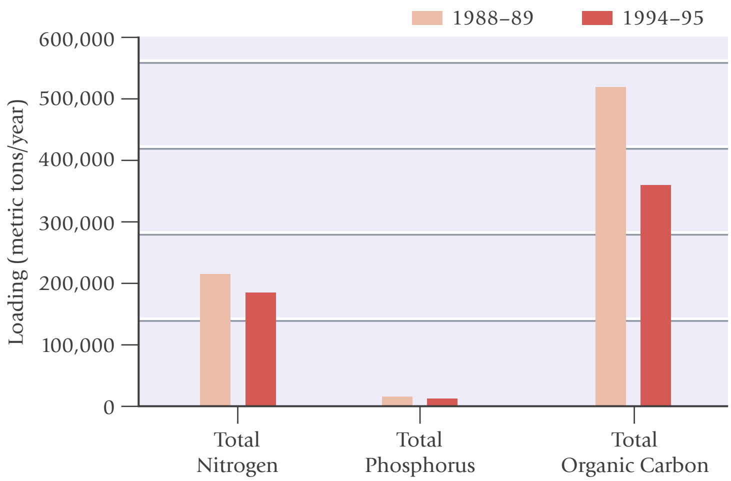
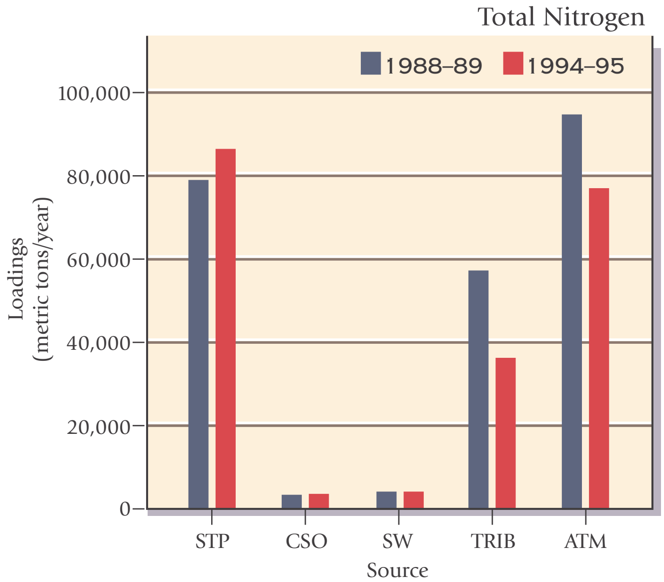
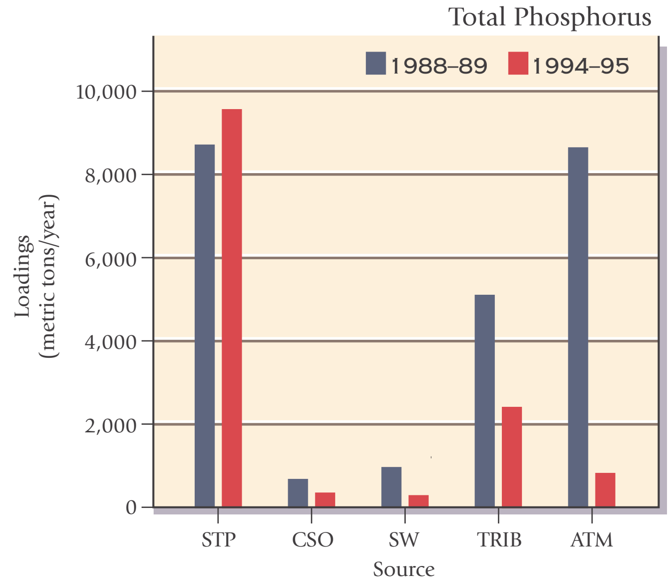


Figure 57 *Loadings of three nutrients to the Estuary in two years. Some of the smaller loads were estimated rather than measured (HydroQual 2001, Miller 2002).*

Figure 57 shows the total nutrient loadings (including total nitrogen, total phosphorus, and total organic carbon) to the Harbor Estuary in 1988–89 and 1994–95, as measured and estimated (for some of the smaller loads) during the development and calibration of New York City’s System-Wide Eutrophication Model (SWEM). Total nitrogen and organic carbon loadings were lower in 1994–95, while total phosphorus loadings stayed about the same. Although these differences could be due to interannual differences in other conditions such as freshwater flow, it is interesting to examine how the sources of nutrients are different between the two years, as is shown in Figure 58. In this figure the





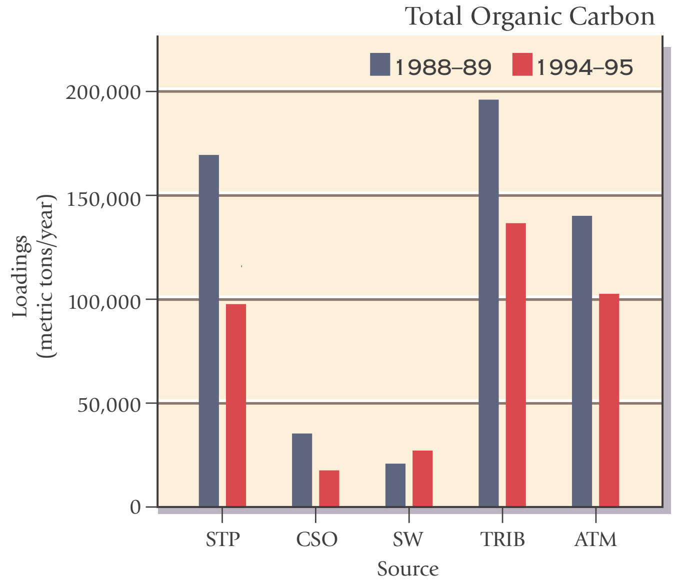


Figure 58 *Sources of loadings of three nutrients to the estuary in two years (HydroQual 2001, Miller 2002).*

loadings of nitrogen, phosphorus and organic carbon are shown for the same two years from specific sources: sewage treatment plants, combined sewer overflows, storm water, tributaries, and atmospheric deposition. For nitrogen and phosphorus, inputs from all sources have decreased except for sewage treatment plants, which exhibit increased loadings. For organic carbon, the only source that is larger in 1994–95 is storm water. Nutrient loads from sewage treatment plants were higher in 1994–95 as compared to 1988–89 because of the initiation of sludge de-watering (removing the water from sewage sludge) at the sewage treatment plants. Since the early 1990s, the solid material that is filtered out of sewage has been de-watered at some of the Harbor Estuary's sewage treatment plants, rather than dumped in the ocean as it had been previously. That de-watering process may now be contributing more nutrients to the harbor itself. It will be important to continue to monitor the plants to determine if an increasing trend in loadings from the plants is actually occurring, and, if so, what impact it is having.

Looking at nutrient loadings over a much longer time scale suggests that despite the sewage treatment plant upgrades in the 1970s that resulted in declines in nutrient loadings to the estuary, these loadings are extremely high today compared to pre-colonial times. Figure 59 shows estimates of nutrient loadings in pre-colonial times, the 1970s and 1990s, as well as a projection for approximate loadings some time in the future if certain nutrient control measures are

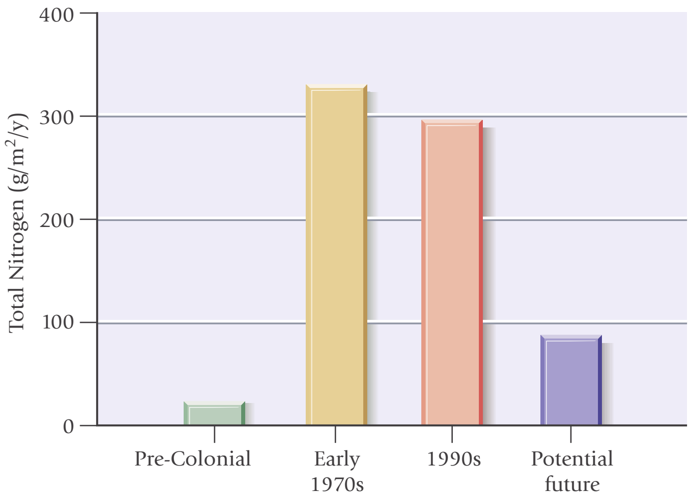


Figure 59 *Calculated nitrogen loading to the estuary during four time periods. Potential future loading based on modeling results assuming complete conversion to nutrient-reduction sewage treatment, elimination of CSO discharges, and a significant reduction in nitrogen loading from upriver tributaries (Howarth et al. 2002).*

For More Information about Nutrients:

The Hudson: An Illustrated Guide to the Living River, by Stephen P. Stanne et al (Rutgers University Press, 1996)

NYC DEP annual Harbor Survey report, available from DEP at 212-860-9339 or www.ci.nyc.ny.us/html/dep/home.html

www.epa.gov/maia/html/eutroph.html

www.chesapeakebay.net/nutr1.htm

taken. While the decline in loadings from the 1970s to the 1990s is clear, both of the 20th century loadings estimates are far higher than the pre-colonial estimate, an approximation of the "background" loadings without significant human influence. These scientists believe that the "potential future" loading on the graph can be achieved if a complete conversion to nutrient-reduction sewage treatment technologies is achieved, along with strict controls on CSOs and significant reductions in loadings from upriver tributaries. These controls are estimated to cost approximately $112 to $277 million per year.

Another way to look at the status of nutrients in the estuary is by examining ambient levels of nutrients in the water, rather than inputs (i.e., examining how much of a substance is already in the water, as opposed to how much is being added at a given time). Figure 60 shows the summer mean ambient concentration of ammonia and nitrate-nitrite, two types of nutrients, as measured by NYCDEP's Harbor Survey for four basins of the harbor for the years 1985–2000. Over this time period, these ambient nutrient concentrations have remained fairly stable, fluctuating somewhat from year to year, with a hint of a decline in ammonia in the Upper Bay. Concentrations of these nutrients is similar among basins, with slightly higher and more variable levels of ammonia found in Jamaica Bay. Changes in these particular nutrients, which are dissolved in the water, can be due to a variety of factors, including changes in uptake of them by microscopic plants (phytoplankton).

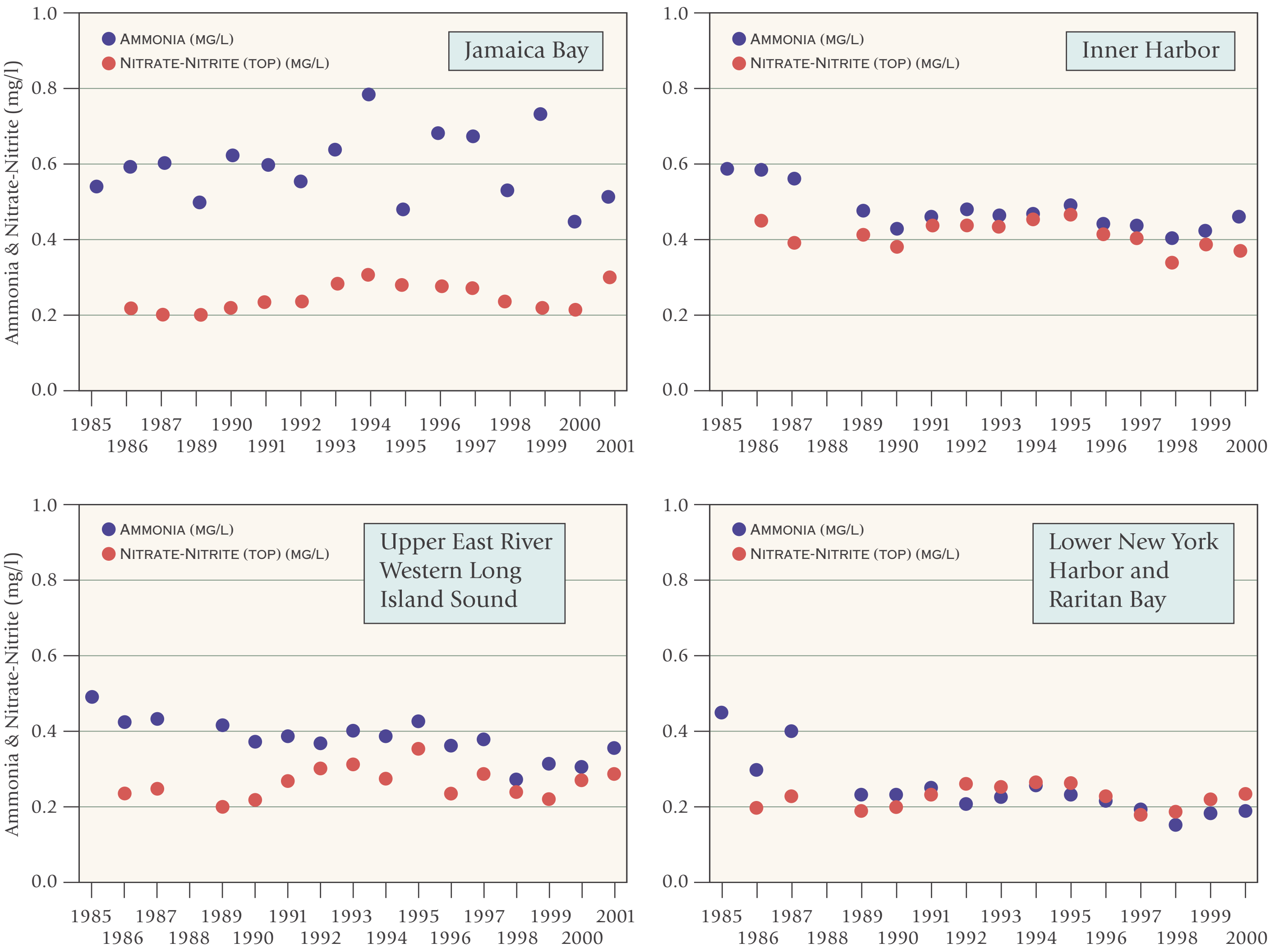
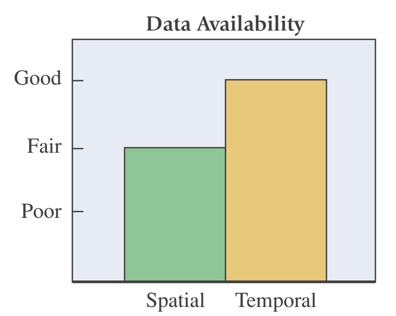


Figure 60 *Ammonia and Nitrate-Nitrite concentrations in four estuary basins, 1985–2000 (Ranheim 2002).*

DISSOLVED OXYGEN

For most marine animals, presence of oxygen in their environment is as critical as it is for humans because they respire by using dissolved oxygen in the water around them. When waters become hypoxic (low in oxygen) or anoxic (lacking oxygen), organisms unable to move away from the affected area experience a spectrum of problems ranging from low growth to mass mortality. Hypoxia occurs when decomposition of excess organic matter in the water uses up oxygen; that organic matter can be raw sewage or dead algae that have bloomed in response to an overabundance of nutrients and then died off quickly (living algae also consume oxygen when they are not in the presence of light). Higher temperatures in the summer



months can exacerbate the problem, which is also usually worse in the bottom layers of water, because they are not as well-mixed and oxygenated as surface waters.

Because dissolved oxygen is so critical to sustain marine life and is a direct measurement of water quality, it has been used to gauge the health of the harbor for almost a century. Figure 61 shows dissolved oxygen data collected by NYCDEP between 1946 and 2001. NYCDEP takes water samples at a series of stations throughout the harbor about every two weeks; for this analysis the data from all stations were averaged to show trends over the whole harbor for the summer months. During the 55 years shown, there has been an upward trend in the levels of dissolved oxygen in surface and bottom waters of the harbor. Conditions improved swiftly and dramatically starting in the early 1970s because of construction and upgrading of sewage treatment plants as required by the Clean Water Act. Previously, dissolved oxygen levels in bottom waters of the harbor were routinely below 1.5 mg/L in the summer months (although the averages were always higher, as reflected in the figure), and therefore lethal to most organisms. These conditions would often persist for many weeks at a time. For this entire duration, average oxygen concentrations have been above the EPA's guideline of 2.3 mg/L, the minimum concentration to which marine organisms can be exposed for more than 24 hours without experiencing increased mortality of juveniles and adults (see the discussion of this benchmark below). These data probably overestimate dissolved oxygen levels to some extent, because algae consume oxygen in the dark, generally leading to lower oxygen levels just before dawn.

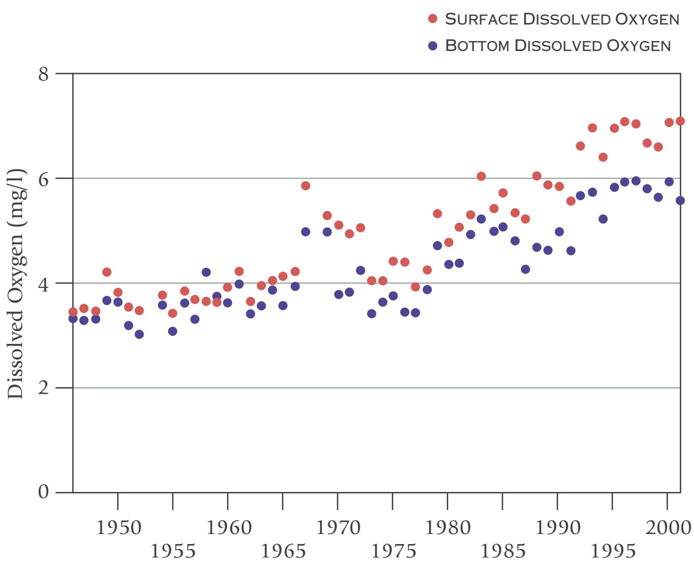


Figure 61 *Mean harbor-wide dissolved oxygen concentrations (surface and bottom), 1946–2001 (Ranheim 2002, Yao 2002).*

For More Information about Dissolved Oxygen:

NYC DEP annual Harbor Survey report, available from DEP at 212-860-9339 or www.ci.nyc.ny.us/html/dep/home.html

www.epa.gov/ost/standards/dissolved/

www.nyc.gov/html/dep/html/hypoxia.html

Some scientists believe that some of the fluctuations seen here can be attributed to variations in phytoplankton productivity resulting from changes in the amount of fresh water entering the estuary. When fresh water discharges are decreased (drought years), the residence time increases, leading to more algal production, and, ultimately, lower dissolved oxygen.

Figure 62 shows more detailed trends in dissolved oxygen levels over both time and space between 1946 and 2001 for bottom waters (where more severe hypoxia is more likely to occur). The color of the dots indicates the lowest level of dissolved oxygen observed in the bottom water of that station in that year, relative to some recently-developed EPA guidelines which provide guidance on appropriately protective levels of dissolved oxygen in marine waters of the mid-Atlantic region. The guidelines state that 2.3 mg/L is the minimum concentration of dissolved oxy-

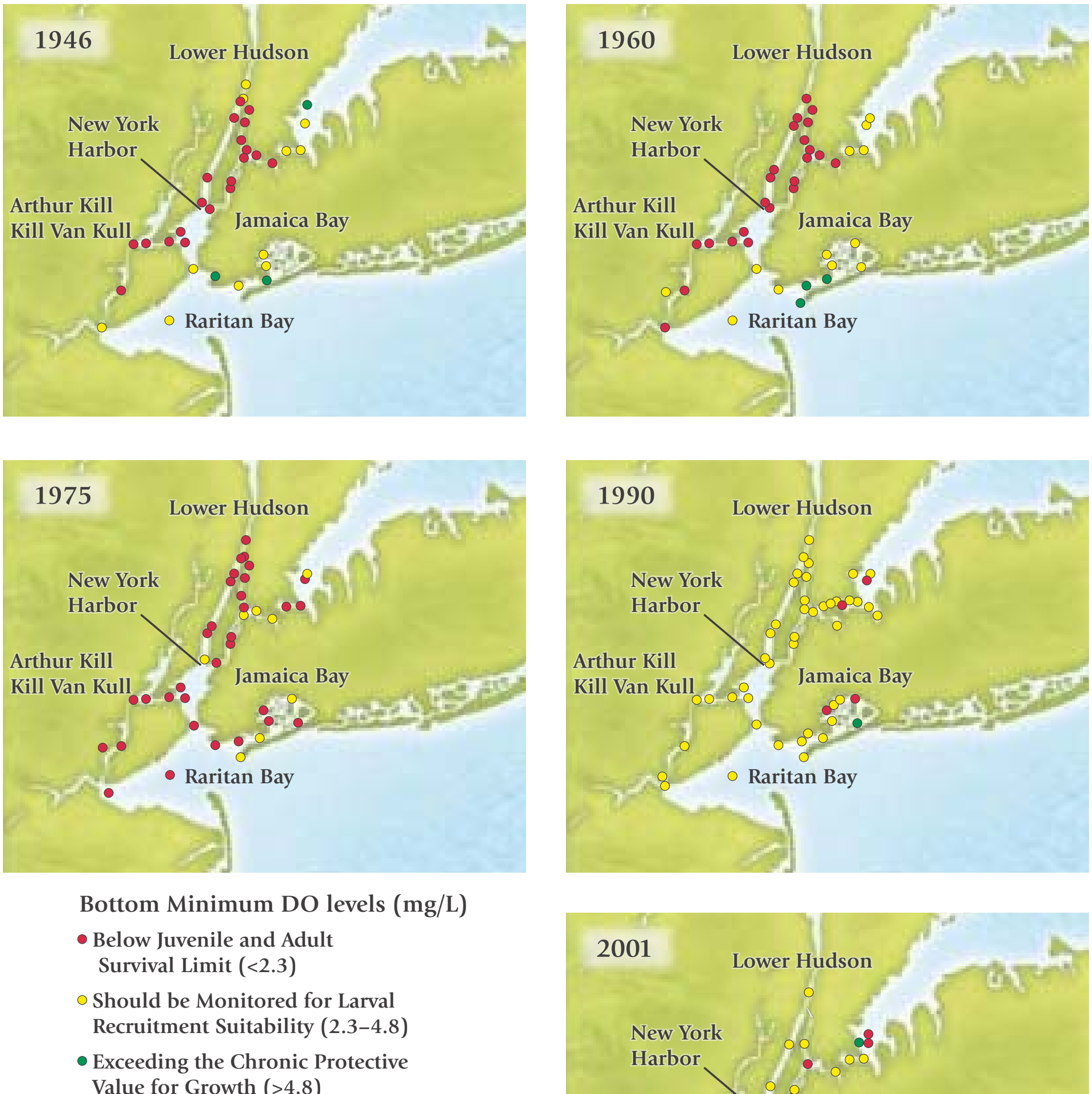


Figure 62 *Minimum measured bottom DO levels in the Harbor in five selected years (Ranheim 2002, Yao 2002).*

gen to which marine organisms can be exposed for more than 24 hours without experiencing increased mortality of juveniles and adults. If the DO is below 2.3 mg/L, the site does not meet EPA's objectives for protection. DO above 4.8 mg/L is considered necessary for growth of marine organisms. If DO is above 4.8 mg/L at a site, the site is considered to meet objectives for protection of marine life. If a site falls between those two guidelines, it should be monitored more closely to determine if the duration and extent of hypoxia is significant.

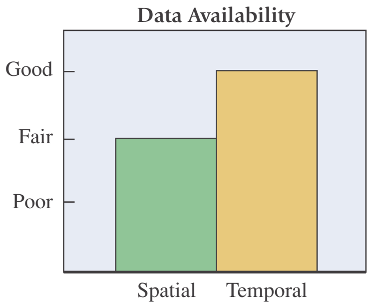
The number of stations that exhibit a minimum DO below the juvenile and adult survival limit of 2.3 mg/L has decreased over time. In 1946, 1960 and 1975 DO below the 2.3 mg/L guideline was observed in many parts of the estuary, most notably in the East River and the Kills. After sewage treatment improvements, increases in bottom DO were observed throughout the estuary. In 1990 and 2001, minimum DO at most stations was observed to be in the 2.3–4.8 mg/L range.

Oxygen levels can exhibit a high degree of variability which affects this type of trend analysis. For example, meteorological differences among years can cause considerable interannual variability in observed DO. In addition, the maps shown here can be affected greatly by single short-term events that may not have any ecological consequences: a very brief hypoxic episode that happens to coincide with a sampling date may cause a station to appear troublesome. It is likely that these types of variability make 2001 appear to be worse with respect to bottom DO than 1990. There are more stations with DO less than 2.3 mg/L in 2001 than 1990, but the data for 2000, not shown here, actually show fewer <2.3 mg/L stations than 2001. Overall, dissolved oxygen levels have improved dramatically in the harbor during the course of this survey.

However, it is important to note that episodic hypoxia and anoxia still occur in some parts of the harbor in the summertime. NYCDEP reports that hypoxic conditions persist, and in some places have become more severe in recent years — in parts of western Long Island Sound and, to a lesser extent, Jamaica Bay. The Comprehensive Conservation and Management Plans of both the NY/NJ HEP and the Long Island Sound Study outline steps to improve dissolved oxygen conditions by addressing nutrient loadings to these estuaries (see the discussion of nutrient levels and loadings on page 61).

CHLOROPHYLL *a*

Chlorophyll, the "green" part of green plants, is the substance inside plant cells that performs photosynthesis, turning sunlight, carbon dioxide and water into energy. The concentration of one kind of chlorophyll, chlorophyll *a*, can be surveyed in the waters of the estuary as a more easily-measured surrogate for the mass of phytoplankton – microscopic algae – in the water. While concentrations of phytoplankton vary dramatically over time and space in response to environmental conditions, large amounts of phytoplankton can be an indicator of eutrophication, or an overabundance of nutrients. When phytoplankton bloom quickly and prolifically in response to a high load of nutrients (or some other necessary factor for growth) to a system, they often use up those nutrients and other resources quickly and then die off. Their subsequent decomposition uses up oxygen, particularly in bottom waters, leading to hypoxic (low-oxygen) or anoxic (no oxygen) conditions which can adversely affect other organisms in the estuary (see the discussion of dissolved oxygen on page 65).



Phytoplankton do bloom naturally in the spring and fall in the waters of the estuary, and form the basis for many estuarine food webs. Eutrophication can result from large inputs of nutrients from sewage treatment plant discharges, combined sewer overflows, non-point source runoff from the land, and other sources (see the discussion of nutrient loads and levels on page 61).

NYCDEP has been measuring concentrations of chlorophyll *a* at stations in the harbor since 1985. Average chlorophyll *a* concentrations in the summer months (when eutrophication is most likely to occur) in four different basins of the harbor are shown over time in Figure 63. There is a gap in the data between 1991 and 1999 because the data for those years are not reliable because of problems encountered in the laboratory. The remaining years of data shown here are accurate.

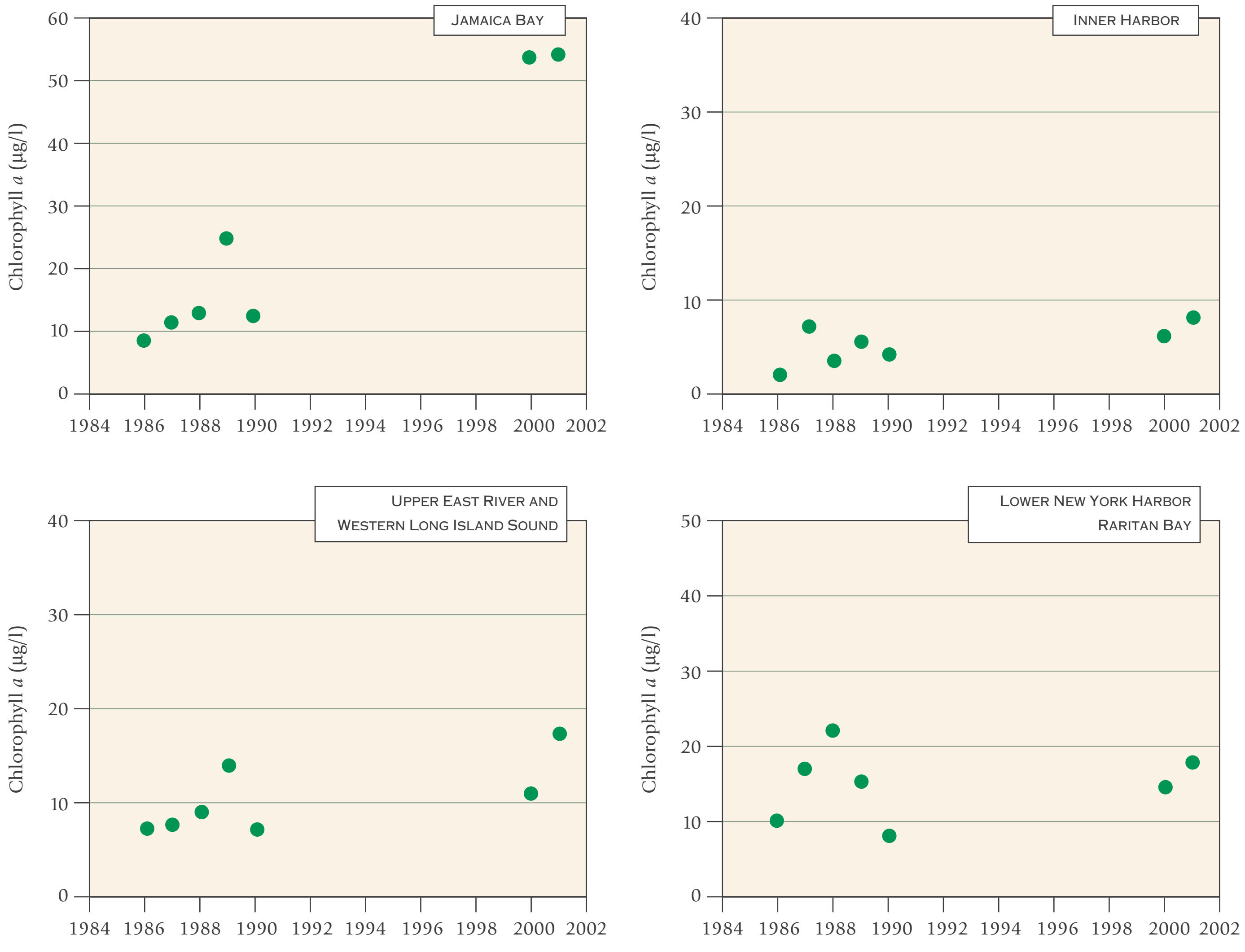
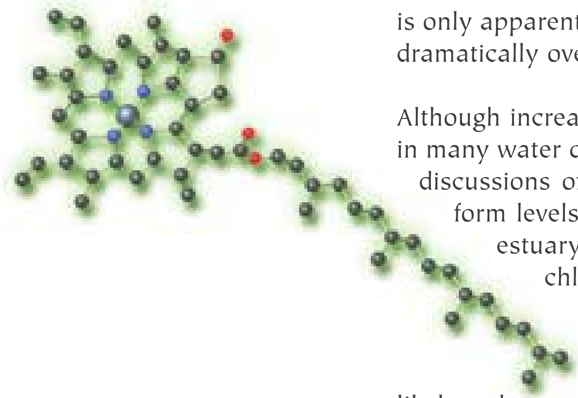


Figure 63 *Average summer chlorophyll a concentrations in four Harbor basins, 1986–2001. See text for explanation of missing years (Ranheim 2002).*



In most of the harbor for the years shown, chlorophyll *a* concentrations are fairly stable, fluctuating somewhat from year to year. There is a hint of an increase in the Upper East River/Long Island Sound. A true directional trend is only apparent in Jamaica Bay, where chlorophyll *a* concentrations increased dramatically over this time period.

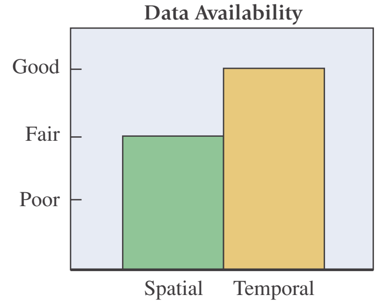
Although increased and improved sewage treatment has led to improvements in many water quality indicators in the estuary over the past 30 years (see the discussions of dissolved oxygen, nutrient loads and levels, and fecal coliform levels in this report), chlorophyll *a* levels are stable in much of the estuary. (Researchers from Cornell University have compared other chlorophyll *a* data sets and believe that chlorophyll *a* concentrations were actually higher in the lower estuary in the 1990s than in the 1970s; see Howarth et al. 2000). There are a number of possible explanations for this trend. It is most likely that while nutrient inputs to the estuary have fluctuated, overall nutrient concentration is quite high, meaning that nutrients are not "limiting" in this estuary. (Other factors, light availability for example, place a cap on phytoplankton productivity, regardless of the amount of nutrients added to the system.) Therefore, no matter how much extra nutrient load is added to the estuary, no additional phytoplankton blooms can take place. In addition, physical factors in the estuary prevent algal blooms. For example, the "retention rate" of the estuary is generally fairly low: nutrients get washed out of the system before they can cause algal blooms. Also, the vertical mixing in the estuary is fairly high: the water is moved rapidly between the surface and the bottom. Therefore, phytoplankton "spend more time" deeper in the estuary where light fails to penetrate, preventing them from growing very fast.

In Jamaica Bay, however, there has been an increasing trend in chlorophyll *a* over the years examined. While the reasons for this increase are not entirely clear, it can be speculated that Jamaica Bay "works" differently than other parts of the estuary. For example, because it is semi-enclosed, perhaps the retention rate in the Bay is higher than in other parts of the estuary. Jamaica Bay is also quite shallow, a greater proportion of the phytoplankton there are growing under good light conditions, leading to more growth. A recent NYCDEP annual report noted that "Jamaica Bay waters consistently exhibit the greatest average chlorophyll *a* concentrations and highest levels of variability (which reflects the degree of planktonic activity at a site)." (NYCDEP 1998).

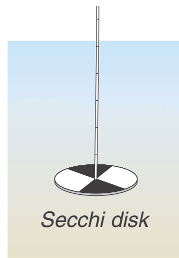
For More Information about Chlorophyll:

NYC DEP annual Harbor Survey report, available from DEP at 212-860-9339 or www.ci.nyc.ny.us/html/dep/home.html

TRANSPARENCY



As discussed in the section of this report on suspended sediment loads (page 26), the waters of the Harbor Estuary are not (and should not be) clear like those of the Caribbean because the Harbor Estuary naturally contains a large amount of suspended materials – sediment, plankton, organic materials, and more. However, changes in water clarity can be indicative of human impact on a water body. For example, a sudden increase in water clarity -- *transparency* -- is often associated with acidification of lakes due to acid rain. While this process does not take place in the harbor itself, other external factors can influence transparency in the estuary. For example, human activities can decrease transparency by adding an overabundance of nutrients to the system that can result in phytoplankton blooms, and development can cause increasing runoff and subsequent erosion of soil from the land into the estuary.



Not all changes in transparency are due to human impacts; transparency naturally fluctuates in the estuary over the course of a year. During the spring freshet, the increase in freshwater input to the estuary from snowmelt upstream carries with it much higher concentrations of sediment, resulting in decreased transparency. Even a heavy rainstorm can influence transparency over short periods of time.

One of the simplest, most “low-tech” ways to measure transparency is by using a Secchi disk, a disk divided into 4 quadrants that are colored black and white and suspended from a rope along which are marked depth intervals (see illustration). The investigator drops the disk into the water and lowers it through the water column, recording the depth at which the disk can no longer be seen. This depth is referred to as the Secchi depth of the water.

Secchi depth has been monitored at stations throughout the harbor by the NYCDEP since 1986. Average summer Secchi depth for 4 basins of the harbor from 1986 to 2001 is shown in Figure 64. For all basins, Secchi depth does not appear to have changed markedly over the period of time shown. There is a hint of a declining trend in Jamaica Bay, seemingly related to the increasing chlorophyll *a* concentrations observed there (see the section on Chlorophyll *a*, page 68). A statistical comparison of secchi depth and chlorophyll *a* concentrations in Jamaica Bay reveals that the two parameters are closely related.

For More Information about Transparency:

NYC DEP annual Harbor Survey report, available from DEP at 212-860-9339 or www.ci.nyc.ny.us/html/dep/home.html

dipin.kent.edu

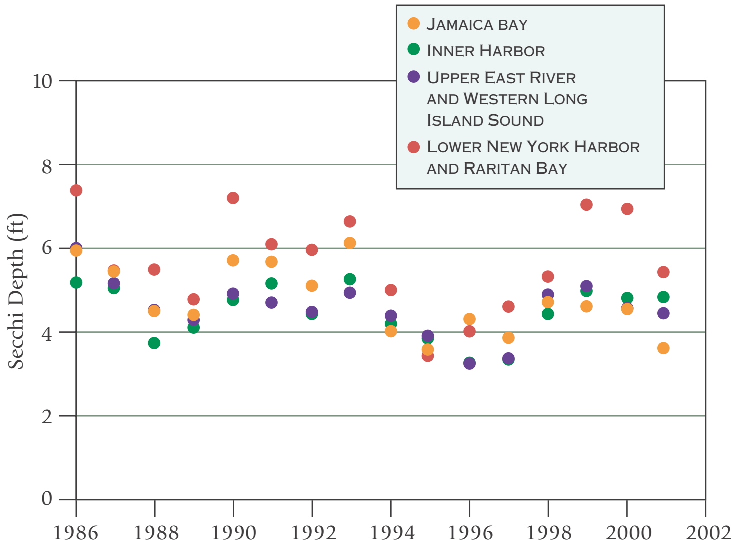
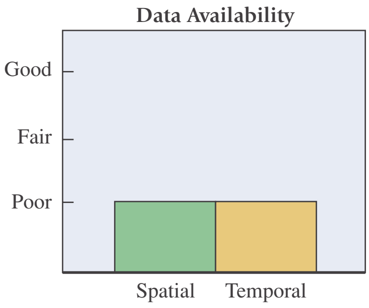


Figure 64 *Average summer Secchi disk measurements in four harbor basins, 1986–2001 (Ranheim 2002).*



HARMFUL ALGAL BLOOMS

Microscopic algae, or phytoplankton, are at the bottom of most marine food chains and are therefore critical to sustaining life on the entire planet. Typically, in early spring as mid-Atlantic waters begin to warm and nutrients become available, local waters experience a phytoplankton bloom. There is also a smaller bloom in the fall. Under a variety of special circumstances which are not well understood, a small number of algal species can undergo blooms of very high density at other times of the year, with a variety of undesirable results. These blooms of a single species with some harmful attribute, lasting from days to months, are referred to as Harmful Algal Blooms (HABs). Depending on the species and severity of the bloom, HABs can cause fish and shellfish kills, and can concentrate in the flesh of edible species, causing illness and even death if fish or shellfish from bloom areas are consumed. Some species are skin irritants, causing discomfort to bathers. Although most of these incidents occur in coastal waters, in 1990 six fishermen on Georges Bank 100 miles east of Cape Cod, Massachusetts almost died from consuming mussels caught in their nets that had been exposed to a toxic bloom. These more severe and dangerous impacts of blooms have not been observed in this region to date; the worst impact of HABs observed in New York and New Jersey (other than impacts on shellfish of brown tide, referred to below) has been rashes experienced by bathers in the vicinity of some blooms.

The causes of HABs are not known with much certainty, although there does seem to be a correlation between poor water quality (decreased dissolved oxygen and an overabundance of nutrients, for example) and the occurrence of blooms.

Figure 65 *Total number of harmful algal blooms, 1975–1995. Blooms defined as chlorophyll a levels twice the mean level (Cosper and Cerami 1996).*

In our estuary, several agencies record the occurrence and extent of these blooms, including NYCDEP, NJDEP, the Interstate Environmental Commission, and the National Park Service. Figure 65 shows the total number of blooms (defined in this case as a chlorophyll *a* concentration twice the long-term mean for that area) recorded by all monitoring programs between 1975 and 1995. The map indicates that the Lower Bay and lower Jamaica Bay are the areas most prone to blooms, but this information does not tell us anything about the impact of those blooms on the ecosystem or human health.

Table 4 summarizes the severity of documented blooms between 1957 and 1995 in coastal waters and inner bays of the Harbor Estuary and New York Bight. The numbers in each column represent the number of blooms of a particular severity in a particular time period. These numbers are not based on measurements of chlorophyll *a* as in Figure 65, but instead are based on documented observations of blooms in which qualified personnel determined the species of the bloom as well as its other characteristics. None of the blooms were severe enough to cause food poisoning in humans, and most of the blooms only discolored the water and reduced water clarity. After a relatively severe extensive dinoflagellate bloom in New Jersey coastal waters in 1976, bloom monitoring increased, probably accounting for the higher numbers of blooms recorded in later years.

Bloom Severity →

Year	Discolors water and reduces clarity		Causes hypoxia		Harmful to shellfish/fish		Itching/ respiratory ills in humans		Food poisoning in humans	
1957–1960		4								
1961–1965	1	5						4		
1966–1970							1	5		
1971–1975								5		
1976–1980	8	7	1		1			1		
1981–1985	9	9		1		1	3			
1986–1990	8	10		2	1					
1991–1995	5	10		1	1					

TABLE 4

Number of documented blooms of corresponding severity levels. Left-hand (white) columns = blooms observed in coastal waters; yellow = blooms observed in inner bays. Numbers indicate numbers of blooms of that severity in that time period. Observations most likely increased in all areas following the 1976 bloom of the dinoflagellate Ceratium tripos *in New Jersey coastal waters (Cosper and Cerami 1996).*

One type of bloom that is not included in these data sets is "brown tide," which has had a devastating effect on the scallop fisheries in Long Island and has started to appear in New Jersey coastal waters as well. This species has not been observed to bloom in the harbor, but it has appeared in Great South Bay, Long Island. We also have not experienced blooms of *Pfiesteria piscicida* in this area. This mysterious dinoflagellate has caused fish kills and even neurological damage in people from North Carolina to Delaware. There is some evidence that a non-toxic form of *Pfiesteria* exists in some New York waters, but it has yet to bloom, and very little is known about what causes it to bloom.

For More Information
about Harmful Algal Blooms:

www.whoi.edu/redtide/

www.nwfsc.noaa.gov/hab/blooms.htm

www.bigelow.org/hab/

Conclusions

Taken as a whole, what do the trends in the indicators discussed in this report mean? Is the estuary getting cleaner? Healthier? More productive? *Better?* Have management programs been successful in protecting and restoring the estuary? What challenges remain?

These questions are, of course, very difficult to answer; the reasons for observed trends are often unclear. However, some general observations can be made about the data presented. Table 5 summarizes the trends in the indicators presented in this report, characterizing the trends as “improving,” “deteriorating,” mixed trend,” and “no trend.” There is a fairly even distribution of trends among these categories, with slightly more indicators showing improvement than staying the same or deteriorating. While some measures of estuarine health have exhibited improvement over the time scales displayed here, such as dissolved oxygen concentrations and loadings of contaminants, other trends are not as positive. For example, population sizes of some species of fish are declining.

It appears that the story of the health of the estuary is as complicated as the ecosystem. Although major improvements have been made on the time scale of a century, improvements have not continued at the same rate on more recent and smaller time scales. The Clean Water Act and other legislation have had a tremendous positive impact on cleaning up our waterways and protecting habitat, an impact reflected in the improvements in dissolved oxygen, large time-scale contaminant loading, and the decrease in loss of wetlands compared to earlier decades. But potential ongoing sources of chemical contaminants, and the legacy of pollution in the estuary, have meant that sediment toxicity is still a concern, with implications for bioaccumulation of contaminants as well. The decline in indices of population size of some fish species is also worrisome, and could reflect changes in habitat quality in the estuary. Diversity of the fish community in Haverstraw Bay has also been declining over the past 20 years, perhaps another troubling reminder that we have much work left to do in this region.

Finally, inadequate availability of data is a significant barrier to properly interpreting the estuary’s health. Many of the indicators originally selected for monitoring changes in the Harbor Estuary (see Introduction, page 1) are not currently monitored, and additional data gaps are due to geographic or spatial inconsistencies of some existing monitoring programs. Table 6 summarizes the data availability graphs presented in each chapter: It is clear from this table that although many indicators are being measured, existing monitoring programs are inadequate to fully describe temporal and spatial trends for many HEP indicators. In some cases, data availability might be inconsistent between New York and New Jersey; for example, New Jersey's beach monitoring program is coordinated at the state level while New York's is not, and while NYCDEP's Harbor Survey has monitored the waters of New York Harbor on the New York side for almost 100 years, there is no such comprehensive program in New Jersey's waters. In addition, the data that are being collected can be difficult to find or use. In order for a greater understanding of the estuary's health to be developed, new or better monitoring programs for the following indicators need to be implemented:

- Incidence of harmful algal blooms
- Sediment toxicity
- Disease caused by consuming contaminated shellfish
- Levels of contaminants in fish and shellfish tissue, other than PCBs in striped bass
- Coliform bacteria outside of New York City waters
- Beach closures in New York
- Habitat acreages (some is done for wetlands but a more complete regular inventory of the estuary's habitats needs to be implemented, including shallow habitats such as mud flats, deep habitats, and acreages of submerged aquatic vegetation)
- Habitat function
- Fish population indices focusing on the lower estuary in both states
- Bird reproductive success
- Suspended sediment loadings and an overall sediment budget for the harbor (by repeating a version of the CARP program periodically)
- Contaminant loadings and levels (by repeating a version of the CARP program periodically)
- Fish tissue contamination focused on the lower estuary in both states
- Sediment fluxes of nutrients
- Levels of coliphages
- Incidence of illness related to bathing at local beaches

Environmental monitoring of a shared resource such as the NY/NJ Harbor Estuary should also be coordinated more closely between the states of New York and New Jersey. Lessons learned about bi-state cooperative monitoring by the HEP's Contaminant Assessment and Reduction Project (CARP) should be applied to other types of monitoring so that better spatial coverage is achieved. For some monitoring programs, resources could be shared between the two states to reduce the burden on the individual states. For other indicators, perhaps greater federal

TABLE 5

Summary of trend direction for each indicator included in this report. Arrows indicate improvement, deterioration, no trend, or mixed trend.

Habitat and Key Species	Trend
Changes in Habitat Acreage (overall)	↑
Wetland Acreage	↑
Changes in Newark Bay	↑
Wetlands in Jamaica Bay	↓
Habitat in the Hackesack Meadowlands	↑
Abundance of Wading Birds	↓
Abundance of Fish and Crustaceans (overall)	↕
Striped bass	↔
American shad	↓
Winter flounder	↔
Summer flounder	↔
White perch	↓
American eel	↓
Forage fish	↔
Blue crab	↔
Benthic Community Health	↑
Sediment loading	↑
Toxic Contamination	
Contaminant Levels	↑
Contaminant Loadings	↑
Sediment Toxicity	↔
Contaminants in Fish Tissue	↑
Pathogens	
Acres of Shellfish Beds Open	↑
Disease Linked to Contaminated Shellfish	↑
Levels of Coliform Bacteria	↑
Beach Closures	↔
Floatable Debris	
Floatable Debris	↔
Nutrients and Organic Enrichment	
Nutrient Levels and Loadings	↕
Dissolved Oxygen	↑
Chlorophyll a	↔
Transparency	↔
Harmful Algal Blooms	↑

↑ improving trend ↓ deteriorating trend
↔ no trend ↕ mixed trend

participation in monitoring would be helpful. A follow-up to the 1995 workshop should be held to review the monitoring plan, update it if necessary, and further discuss how to improve existing monitoring and implement new monitoring programs as necessary.

TABLE 6
Summary of data availability for each indicator included in this report.

Indicator	Data availability	
	Spatial	Temporal
Habitat area	fair	poor
Bird abundance	good	good
Fish/crustacean abundance	poor	good
Benthic community health	good	poor
Sediment loading	fair	poor
Contaminant levels/loadings	good	poor
Sediment toxicity	good	poor
PCBs in striped bass	good	good
Contaminants in fish tissue	poor	poor
Acres of open shellfish beds	good	good
Disease/contaminated shellfish	poor	poor
Coliform concentrations	fair	good
Beach closures	fair	fair
Floatable debris	fair	good
Nutrients levels	poor	poor
Nutrient loadings	fair	good
Dissolved oxygen concentrations	fair	good
Chlorophyll *a* concentrations	fair	good
Transparency	poor	poor
Harmful algal blooms	fair	good

○ poor ◖ fair ● good

Future HEP Indicator Work

It will be important for the HEP to continue to examine trends in environmental indicators on a regular basis in order to evaluate the health of the estuary and the effectiveness of management actions. This process will soon become more important than ever, because the HEP is now establishing some firm targets and goals: statements of how much improvement the program will seek to achieve by specific dates. It will be critical to monitor the program's progress -- as well as the estuary's -- by evaluating trends annually in a suite of indicators similar to the ones assessed in this report.

References

Able, K. W. and M. P. Fahay. 1998. *The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight.* New Brunswick, NJ: Rutgers University Press.

Able, K.W., R. E. Matheson, W. W. Morse, M. P. Fahay, and G. Shepherd. 1989. Patterns of summer flounder *Paralichthys dentatus* early life history in the Mid-Atlantic Bight and New Jersey estuaries. Fish. Bull. 88:1-12.

Abood, Karim. 2002. LMS Engineers. Personal communication 10/02.

Adams, Darvene. 2003. US Environmental Protection Agency. Personal Communication 3/03.

Adams, Darvene. 2002. US Environmental Protection Agency. Personal Communication 4/02.

Adams, D. A., J. S. O'Connor and S. B. Weisberg. US Environmental Protection Agency. 1998. Sediment Quality of the NY/NJ Harbor System: An Investigation Under the Regional Environmental Monitoring and Assessment Program (R-EMAP). New York, NY: US EPA.

American Littoral Society. 1999. New York State Beach Cleanup Annual Report.

Auermuller, Robert. 2000. Division of Watershed Management, New Jersey Department of Environmental Protection. Personal Communication 3/00.

Ayres, R. and S. R. Rod. 1986. Patterns of Pollution in the Hudson-Raritan Basin. Environment 28(4): 14–43.

Barnes, Deborah. 2000. New York State Department of Environmental Conservation, Division of Fish, Wildlife and Natural Resources. Personal Communication 6/00.

Bopp, Richard. 2000. Rensselaer Polytechnic Institute. Personal Communication 3/00.

Boyle, R. H. 1979. *The Hudson River: A Natural and Unnatural History.* New York, NY: W. W. Norton & Company.

Brosnan, T. M. and M. O'Shea. 1996. Long-term improvements in water quality due to sewage abatement in the lower Hudson River. Estuaries 19(4): 890–900.

Buckel, J. A., D. O. Conover., N. D. Steinberg, and K. A. McKown 1999. Impact of age-0 bluefish (*Pomatomus saltatrix*) predation on age-0 fishes in the Hudson River estuary: evidence for density-dependent loss of juvenile striped bass (*Morone saxatilis*). Can. J. Fish. Aquat. Sci. 56: 275–287.

Burger, Joanna, ed. 1994. *Before & After an Oil Spill: The Arthur Kill.* New Brunswick, NJ: Rutgers University Press.

Burger, J., K. Viscido and M. Gochfeld. 1995. Eggshell thickness in marine birds in the New York Bight – 1970s to 1990s. Arch. Environ. Contam. Toxicol. 29: 187–191.

Burger, J., M. Horoszewski Lavery and M. Gochfeld. 1994. Temporal changes in lead levels in common tern feathers in New York and relationship of field levels to adverse effects in the laboratory. Environ. Toxicol. Chem. 13(4): 581–586.

Chambers, J.R. 1992. Coastal degradation and fish population losses. Pp. 45–51. In R.H. Stroud, ed. Stemming the Tide of Coastal Fish Habitat Loss. Proceedings of a symposium on conservation of coastal fish habitat, Baltimore, MD, March 7–9, 1991. National Coalition for Marine Conservation, Savannah, GA.

Chytalo, Karen. 2001. New York State Department of Environmental Conservation. Personal Communication 8/01.

Cosper, E.M. and J.C. Cerami. 1996. Assessment of historical phytoplankton characteristics and bloom phenomena in the New York Harbor estuarine and New York Bight ecosystems. Final Report to the Hudson River Foundation.

de Cerreño, A. L. C., M. Panero and S. Boehme. 2002. Pollution Prevention and Management Strategies for Mercury in the New York/New Jersey Harbor. New York Academy of Sciences, New York, New York.

Eisele, Bill. 2000. New Jersey Department of Environmental Protection, Bureau of Marine Water Monitoring, New Jersey State Shellfish Classifications. Personal Communication 6/00–8/00.

Grebe, Helen. 2000. US EPA. Personal Communication 2/00.

Hartman, Jean Marie. 2002. Rutgers University. Personal Communication.

Hasse, J. and R. Lathrop. 2001. Measuring Urban Growth in New Jersey: A Report on Recent Land Development Patterns Utilizing the 1986–1995 NJ DEP Land Use/Land Cover Data Set. Center for Remote Sensing and Spatial Analysis, Rutgers University. http://crssa.rutgers.edu/projects/lc/urbangrowth/index.html.

Holcomb, Mara. 2000. New York State Department of Health Bureau of Community Sanitation and Food Protection. Personal Communication 12/00.

Horn, E. G. 1990. Seafood Safety: A Regulatory Perspective. In: NY/NJ Harbor Estuary Program 1990. Cleaning Up Our Coastal Waters: An Unfinished Agenda. Proceedings of a Regional Conference, March 12–14 1990. New York, NY: US EPA.

Howarth, R. W., R. Marino, D. P. Swaney and E. W. Boyer. In press 2002. Wastewater and Watershed Influences on Primary Productivity and Oxygen Dynamics in the Lower Hudson River Estuary. In J. Levinton (ed.) book on the Hudson River.

Howarth, R. W., D. Swaney, T. J. Butler, and R. Marino. 2000. Climatic control on eutrophication of the Hudson River estuary. Ecosystems 3: 210–215.

Hudson River Foundation. 1997. Summary Report: New York Harbor/Estuary Sediment Budget Workshop (proceedings of a workshop held at the Hudson River Foundation on December 5, 1996).

Hurst, Thomas P. 2002. National Marine Fisheries Service. Personal Communication 03/02.

Hurst, T. P. and D. O. Conover. 2001. Nearshore Fish Communities of the mid-Hudson River Estuary, 1985–2000. Stony Brook, NY: Marine Sciences Research Center, SUNY Stony Brook.

Hurst, T. P. and D. O. Conover. 1998. Winter mortality of young-of-the-year Hudson River striped bass (*Morone saxatilis*): size-dependent patterns and effects on recruitment. Can. J. Fish. Aquat. Sci. 55:1122–1130.

Hurst, T. P., K. McKown and D. O. Conover. In review. Interannual and Long-term Variation in the Nearshore Fish Community of the Mesohaline Hudson River Estuary.

Jamaica Bay Blue Ribbon Panel on Marsh Loss and Coastal Sea Level Rise. 2001. A Future Agenda for Mitigation and Pilot Investigations. Final Report. Brooklyn, NY: US Department of the Interior, National Park Service.

Kane, R. and P. Kerlinger. 1993. Raritan Bay Habitat and Wildlife Inventory, 1992–1993. Franklin Lakes, NJ: New Jersey Audubon Society.

Kerlinger, P. 2001 New York City Audubon Society's Harbor Herons Project: Nesting Survey – 2001. New York, NY: New York City Audubon Society.

Klauda, R.J., J.B. McLaren, R.E. Schmidt and W.P. Dey. 1988. Life history of white perch in the Hudson River estuary. American Fisheries Society Monograph 4 (*Science, Law, and Hudson River Power Plants: A Case Study in Environmental Impact Assessment*): pp. 69–88.

Lewis, Daniel. 2000. New York State Department of Environmental Conservation, Division of Fish, Wildlife and Natural Resources, Bureau of Marine Resources, Shellfisheries. Personal Communication 3/00.

LoBue, Carl. 2002. New York State Department of Environmental Conservation. Personal Communication. 07/02.

Loftin, Virginia. 2000. Division of Watershed Management, New Jersey Department of Environmental Protection. Personal Communication 03/00.

Long Island Sound Study. 1993. Comprehensive Conservation and Management Plan.

Maccarone, A. D. and J. N. Brzorad. 2000. Wading bird foraging: Response and recovery from an oil spill. Waterbirds 23(2): 246-247.

Maccarone, A. D. and J. N. Brzorad. 1998. The use of foraging habitats by wading birds seven years after the occurrence of major oil spills. Colonial Waterbirds 21(3): 367-374

MacKenzie, C. L. Jr. 1992. *The Fisheries of Raritan Bay.* New Brunswick, NJ: Rutgers University Press

Mattes, K. C. 1989. The Ecology of the American Eel *Anguilla rostrata* in the Hudson River. Final Report to the Hudson River Foundation.

McHugh, J.L. 1977. Limiting Factors Affecting Commercial Fisheries in the Middle Atlantic Estuarine Area. In *Estuarine Pollution and Control Assessment: Proceedings of a Conference,* 1: 149–169. Washington, D.C.: US Environmental Protection Agency.

McHugh, J.L. and Jay J.C. Ginter. 1978. Fisheries: MESA New York Bight Atlas Monograph 16. Albany, NY: New York Sea Grant Institute.

McKown, Kim. 2002. New York State Department of Environmental Conservation 2002. Personal communication 04/02.

National Oceanic and Atmospheric Administration, National Ocean Service. 1995. National Status and Trends Program for Marine Environmental Quality: Magnitude and Extent of Sediment Toxicity in the Hudson-Raritan Estuary. NOAA Technical Memorandum NOS ORCA 88.

National Oceanic and Atmospheric Administration. 2001. Navigational Chart of Newark Bay.

National Oceanic and Atmospheric Administration. 1985. Navigational Chart of Newark Bay.

National Oceanic and Atmospheric Administration National Climatic Data Center. 2000. www.ncdc.noaa.gov.

Natural Resources Defense Council. 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000. Testing the Waters.

New Jersey Department of Environmental Protection. 2003. www.state.nj.us/dep/dsr/njmainfish.htm

New Jersey Department of Environmental Protection. 2001. www.nj.state.us/dep

New Jersey Department of Environmental Protection Division of Watershed Management. 2000. New Jersey Clean Shores Program 2000 Report. www.state.nj.us/dep/dsr/watershed/area12-appendix3-c.htm.

New York City Department of Environmental Protection. 2001. New York City 2000 Regional Harbor Survey.

New York City Department of Environmental Protection. 1998. 1997 New York Harbor Water Quality Survey. New York, New York: New York City Department of Environmental Protection.

New York City Department of Environmental Protection. 1994. The State of the City's Waters 1994. Ithaca, NY: Cornell University, New York State Water Resources Institute.

New York/New Jersey Harbor Estuary Program. 2002a. Harbor Health/Human Health: An Analysis of Environmental Indicators for the NY/NJ Harbor Estuary. Hudson River Foundation/US EPA.

New York/New Jersey Harbor Estuary Program. 2002b. The Status of Shellfish Beds in the NY-NJ Harbor Estuary. US EPA/NYNJHEP.

New York/New Jersey Harbor Estuary Program. 2002c. New York/New Jersey Beach Closures and Monitoring Information. US EPA/NYNJHEP.

New York - New Jersey Harbor Estuary Program. 1996a. Analysis of Pathogen Sources. Prepared by HydroQual, Inc.

New York - New Jersey Harbor Estuary Program. 1996b. Comprehensive Conservation and Management Plan. US EPA

New York State Department of Environmental Conservation. 2002. www.dec.state.ny.us/website/dfwmr/marine/twloss.html.

New York State Department of Health. 2003. www.health.state.ny.us/nysdoh/environ/fish.htm.

Rippey, S.R. 1989. Shellfish-borne Disease Outbreaks. Shellfish Sanitation Program Technical Report. Food and Drug Administration, Northeast Technical Services Laboratory, Davisville, RI. In: New Jersey Department of Environmental Protection and NY/NJ Harbor Estuary Program Pathogens Work Group 1990 report: Characterization of Pathogen Contamination in the NY/NJ Harbor Estuary.

Sañudo-Wilhelmy, S. A. and G. A. Gill. 1999. Impact of the Clean Water Act on the levels of toxic metals in urban estuaries: The Hudson River Estuary revisited. Environ. Sci. & Technol. 33(20): 3477–3481.

Secor, D. H. and W. E. Morrison. 1999. Progress Report, Year 2: Ecology and Contamination of the Hudson River American Eel. Report to the Hudson River Foundation.

Sindermann, C. J. 1994. Quantitative Effects of Pollution on Marine and Anadromous Fish Populations. NOAA Technical Memorandum NMFS-F/NEC-104. National Oceanic and Atmospheric Administration, Northeast Fisheries Science Center, Woods Hole, MA.

Skinner, L. C. 2001. New York State Department of Environmental Conservation. Organic Chemicals and Mercury in Selected Fish Species Taken from New York Harbor.

Skinner, L. C., A. J. Newell, J. Waldman and J. Shastay, Jr. 1997a. New York State Department of Environmental Conservation. Chemical Residues in Fish, Shellfish and Crustaceans from the New York - New Jersey Harbor Estuary: PAHs in Winter Flounder and Softshell Clam.

Skinner, L. C., R. Prince, J. Waldman, A.J. Newell and J. Shastay, Jr. 1997b. New York State Department of Environmental Conservation. Chemical Residues in Fish, Bivalves, Crustaceans and a Cephalopod from the New York - New Jersey Harbor Estuary: Dioxins and Furans.

Skinner, L. C., S. J. Jackling, G. Kimber, J. Waldman, J. Shastay, Jr. and A. J. Newell. 1996. New York State Department of Environmental Conservation. Chemical Residues in Fish, Shellfish and Crustaceans from the New York - New Jersey Harbor Estuary: PCB, Organochlorine Pesticides and Mercury.

Sloan, R. 1999. Briefing on 1997 Striped Bass PCB Results, February 11, 1999. Briefing memo to James Colquhoun. NYSDEC.

Sloan, R., B. Young and K. Hattala. 1995. NYS DEC Technical Report 95-1: PCB Paradigms for Striped Bass in New York State.

Sloan, R. and K. A. Hattala. 1991. NYS DEC Technical Report 91-2: Temporal and Spatial Aspects of PCB Contamination in Hudson River Striped Bass.

Sobsey, M. D. 1997. Evaluation and Verification of Pathogenic Indicator Populations in the NY/NJ Harbor System. Final Report to the Hudson River Foundation, Grant Number 004/93R.

Squires, D. F. 1992. Quantifying anthropogenic shoreline modification of the Hudson River and Estuary from European contact to modern time. Coastal Management 20: 343–354.

Squires, D. F. 1990. A Historical Review of Changes in Near-Shore Habitats in the Sound-Harbor-Bight System. In Cleaning Up Our Coastal Waters: An Unfinished Agenda - Proceedings of a regional conference, March 12–14 1990. New York, NY: US EPA.

Stanne, S. P., R. G. Panetta and B. E. Forist. 1996. *The Hudson: An Illustrated Guide to the Living River.* New Brunswick, NJ: Rutgers University Press.

St. John, John. 2002 HydroQual, Inc.. Personal communication. 09/02.

Sullivan, R. 1998. *The Meadowlands: Wilderness Adventures at the Edge of a City.* New York, NY: Scribner.

Suszkowski, D. J. 1978. Sedimentology of Newark Bay, New Jersey: An Urban Estuarine Bay. Ph.D. Dissertation. University of Delaware, Newark, Delaware.

Suszkowski, D. J. 1990. Conditions in the NY/NJ Harbor Estuary. In Cleaning Up Our Coastal Waters: An Unfinished Agenda - Conference Proceedings of regional conference, March 12–14 1990. New York, NY: US EPA.

Swaney, D.P., D. Sherman and R. W. Howarth. 1996. Modeling water, sediment and organic carbon discharges in the Hudson-Mohawk basin: Coupling to terrestrial sources. Estuaries 19(4): 833–847.

Swanson, R. L. and R. L. Zimmer. 1990. Meteorological conditions leading to the 1987 and 1988 washups of floatable wastes on New York and New Jersey beaches and comparisons of these conditions with the historical record. Estuarine, Coastal and Shelf Science 30: 59–78.

Thatcher, M. L. and C. Mendoza. 1990. Final Report, New York/New Jersey Harbor Estuary Program Module 6: Hydrologic Modifications. New York, NY: NY/NJ Harbor Estuary Program.

US Congress. 2000. Public Law 106–284, 106th Congress. Beaches Environmental Assessment and Coastal Health Act of 2000.

US EPA. 2000. Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras.

US EPA. 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Volume 1: Fish Sampling and Analysis, Third Edition.

US EPA. 1999. Helicopter Monitoring Report: A Report of the New York Bight Water Quality. Summers of 1997 and 1998.

US EPA Region 2. 1998. Floatables Action Plan Assessment Report.

US Fish and Wildlife Service. 1997. Significant Habitats and Habitat Complexes of the New York Bight.

Vaughn, D. S. 1988. Section 3: Entrainment and Impingement Impacts: Introduction. AFS Monograph 4, Science, Law and Hudson River Power Plants:121–123.

Waldman, J. 1999. *Heartbeats in the Muck: The History, Sea Life, and Environment of New York Harbor.* New York, NY: Lyons Press.

Wells, A. W., J. A. Matousek, and J. B. Hutchison. 1992. Abundance Trends in Hudson River White Perch. In Smith, C. Lavett, ed. *Estuarine Research in the 1980s.* Albany, NY: State University of New York Press.

Wolf, Gary. 2001. New Jersey Department of Health and Senior Services, Consumer and Environmental Health Services, Food/Drug and Milk Program, Shellfish Control. Personal Communication 1/01.

Wolfe, D. A., E. R. Long and G. B. Thursby. 1996. Sediment toxicity in the Hudson-Raritan Estuary: distribution and correlations with chemical contamination. Estuaries 19(4): 901–912.

Woods Hole Oceanographic Institute. 2000. www.redtide.whoi.edu/hab

Yan, E. 2001. "Marshland Mystery." New York Newsday, Sunday, April 8, 2001. pp. A7.

Yuhas, C. 2003. NJ Clams Meet Highest Standards from Harvest to Market. The Jersey Shoreline 21(4): 4–8.

Ziskowski, J. J., L. Despres-Patanjo, R. A. Murchelano, A. B. Howe, D. Ralph and S. Atran. 1987. Disease in commercially valuable fish stocks in the Northwest Atlantic. Marine Pollution Bulletin (18)9: 496–504.

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