ENVIRONMENTAL HEALTH AND TRENDS OF THE NEW YORK–NEW JERSEY HARBOR ESTUARY

The State of the Estuary 2018

NY/NJ HARBOR & ESTUARY PROGRAM
HUDSON RIVER FOUNDATION

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Executive Summary

This State of Estuary Report compiles the best available data for 31 indicators selected by scientific and technical experts convened by the New York – New Jersey Harbor & Estuary Program (HEP). Where possible, this scientific information is used to illuminate long-term (roughly 30 years) and shorter-term trends, providing a broad assessment of progress toward HEP's goals of improving water quality, habitat, public access, maritime operations, and community engagement. The individual chapters detail the basis for this assessment and analysis. Where there is not sufficient data to draw conclusions, the information provided sets a baseline for future considerations of progress.

Water quality improvement is the Harbor Estuary's biggest success story. The short and long term trends for most water quality indicators show that conditions are improving over time. Dissolved oxygen levels in the water, critical for fish survival, are increasing. There is less garbage floating in the water and along the shoreline than there was 20 years ago. While pathogenic contamination has also decreased over the long-term, bacterial contamination emanating from combined sewage overflow and stormwater is sporadically high in many places and regularly high in a few parts of the Harbor Estuary, which restricts swimming and the desirability of other on-water recreation.

Toxic contaminants, such as heavy metals in sediments and PCBs in fish, are decreasing in concentration. The natural burial of contaminated sediments as well as the dredging of toxic sediments at Superfund sites and other contaminated areas have reduced large sources of contamination. Average PCB concentrations in key fish species have decreased markedly. However, many of these contaminants are persistent. Some of them, mercury in particular, remain at concentrations that are toxic to marine life and dangerous for human consumption in seafood. Sediments that are highly contaminated also affect the maritime economy, as they are costly for port operators to dredge.

Public access and stewardship in the Harbor Estuary is also improving. As water quality has improved, the number of public parks, human-powered boat launches, and people utilizing on-water programming has increased over the short-term. More access to the waters of the Harbor Estuary exists than it has for generations, with 37% of the shoreline being located in parks and other public spaces, allowing more people to enjoy the water and fostering a stewardship ethic in surrounding communities. Three of the Estuary's largest stewardship events (A Day in the Life of the Hudson & Harbor, City of Water Day, and Riverkeeper Sweep) are growing in popularity every year. The analyses of community engagement indicators form a baseline dataset, from which we can track the change in participation with stewardship groups, events, and citizen science programs.

Trends in **habitat and ecological health** are not as promising and only one of the indicators, stream health bioassessment, is showing an improving trend. Since the early 2000s, critical wetland, riparian, and coastal forest habitat has been lost to urban development, often despite state and federal regulations. Several indicators show habitat health is also declining, such as the abundance of estuarine and diadromous fish and horseshoe crabs. While efforts to improve the Estuary's ecology are likely helping, as indicated by established oyster beds and tributary connectivity, the pace is not in keeping with need.

The stress on wildlife species caused by **climate change** makes them even more vulnerable to this loss of habitat. The data in this report illuminates the fact that climate change is not a distant threat: it is affecting the Hudson-Raritan Estuary right now. The Estuary's waters are warming and species are responding by shifting their ranges and adjusting their life history patterns.

The report also makes clear that **large, intense storms** matter a great deal. Hurricanes Sandy, Irene, and Lee left their mark on the Estuary, as much of the data reported herein indicates. For some indicators, such as submerged aquatic vegetation and benthic health, improving trends were disrupted by these storms; more time is needed to determine if the improving environmental conditions or extent of these habitats can return. The intensity of storm surges and wave action during the storms may have also remobilized contaminated sediments.

Indicators at a Glance

WATER QUALITY

Indicators	Long Term Trend	Short Term Trend
Dissolved Oxygen	↗	↗
Enterococcus	↗	~
Nitrogen	↗	↗
Water Temperature	↘	~
Debris Collected by Skimmers and Booms	●	↗
Debris Collected on Beaches	↗	↗
Microplastics	●	●
Chemical Contaminants of Emerging Concern	●	●

HABITAT AND ECOLOGICAL HEALTH

Indicators	Long Term Trend	Short Term Trend
Benthic Index of Biotic Integrity	~	●
Estuarine and Diadromous Fish Abundance	↘	~
Established Oyster Beds	●	●
Whale and Dolphin Abundance	●	●
Tributary Habitat Connectivity	●	●
Riparian Area Integrity	●	↘
Stream Health Bioassessment	↗	●
Percent and Distribution of Natural Shorelines	●	●
Horseshoe Crab Abundance	●	↘
Submerged Aquatic Vegetation	●	↘
Area of Coastal Forest and Grassland	●	↘
Area of Wetlands	↘	↘
Nesting Pairs of Harbor Herons	~	↘

PORT AND MARITIME (Toxic Contaimination)

Indicators	Long Term Trend	Short Term Trend
Metals in Sediments	~	●
PAHs in Sediments	↗	●
Dioxin in Sediments	↗	~
PCBs	↗	↗

PUBLIC ACCESS AND STEWARDSHIP

Indicators	Long Term Trend	ShortTerm Trend
Publicly Accessible Waterfront	●	↗
On-Water Access	●	↗
On-Water Programs	●	↗

COMMUNITY ENGAGEMENT

Indicators	Long Term Trend	ShortTerm Trend
Capacity of Stewardship Organizations	●	●
Participation in Stewardship Events	●	↗
Participation in Citizen Science	●	●

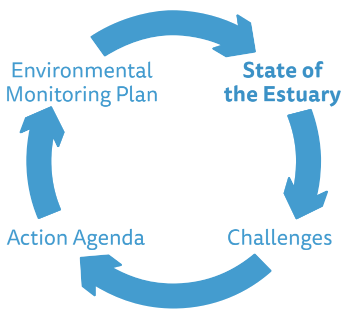
TREND IDENTIFIERS

- ↗ Indicates a trend that is improving in terms of environmental health
- ↘ Indicates a trend that is det eriorating in terms of environmental health
- ~ Indicates that the data are not trending, are stable or variable
- ● Indicates that there are insufficient data to determine a trend or that this type of analysis is not applicable

About the Estuary and the NY-NJ Harbor & Estuary Program

The New York – New Jersey Harbor Estuary is the biggest public resource in the nation's largest and most densely developed metropolitan area. The Estuary is defined by the mixing of fresh and salt water that creates its rich, productive, and diverse ecosystem. Every day, the incoming tides bring roughly 57 billion gallons of saltwater from the ocean, and an average of 80 billion gallons of water is returned to the ocean, including nearly two billion gallons of wastewater (Geyer and Chant, 2006). This tidal flux and the nutrients that it carries supports 12 square miles of tidal wetlands, more than 200 fish species, and over 300 bird species. The estuary also provides crucial resources for the more than 14 million people living along the Harbor Estuary's waterways, including recreational and economic benefits.

The New York – New Jersey Harbor & Estuary Program (HEP) helps bring together diverse stakeholders including scientists, citizens, and policymakers to work towards the goal of fishable and swimmable waterways for people and wildlife called for by the Clean Water Act. One of the Nation's 28 Estuaries of National Significance, HEP was created in 1988 by the U.S. Environmental Protection Agency (EPA) at the request of the governors of New York and New Jersey. The Hudson River Foundation manages the Program and provides the non-federal match to funds received from the EPA under the Clean Water Act.



Working with its many partners, HEP is addressing the challenges identified in this report. There are 40 specific actions in the 2017–2022 Action Agenda.[1] Some of those specific projects are highlighted in this report in the individual chapters under the HEP Role sections. Our Environmental Monitoring Plan[2] shows where data is being collected within the Estuary by public agencies, universities, and civic organizations.

1. www.hudsonriver.org/NYNJHEPActionAgenda.pdf
2. www.hudsonriver.org/NYNJHEPEnvMonitoring.pdf

Users Guide

ORGANIZATION

This report is organized by HEP's five goals: water quality, habitat and ecological health, port and maritime, public access and stewardship, and community engagement. The Water Quality section is comprised of the parameters used to evaluate if waters are in compliance with HEP's goal of establishing fishable and swimmable waters. The Habitat and Ecological Health section addresses how five key habitats in the Estuary (marine, riparian, shorelines, terrestrial and wetlands) are changing qualitatively (how is the condition of the habitat changing) and quantitatively (how much of the habitat is there). The Port and Maritime section focuses on the issue of legacy toxic contamination, its sources, and the threat it poses to people, wildlife, and commerce. The Public Access and Stewardship section indicates how easily people are able to access the shorelines and waters for recreational purposes. The Community Engagement section explores how the public is involved in decisions and stewardship of the Estuary.

SELECTION OF INDICATORS

The environmental indicators selected for this report are broadly representative of ecosystem health.

An initial list of indicators was developed and refined by HEP's Management Committee, technical workgroups, Citizens Advisory Committee (CAC), and especially the Science and Technology Advisory Committee (STAC), and reflects the priorities of these scientists, managers, educators, and advocates. Data sources for the indicators were suggested by HEP's workgroups and STAC. A Quality Assurance Project Plan (QAPP) was written and approved for the data collection and analysis effort, and all sources were recorded in a data log.[3]

Some of the indicators identified through this process, for example combined sewage overflow (CSO) discharge frequency and wetland quality are not included in HEP's State of the Estuary Report because available data are insufficient due to limited time scales, spatial extent, or data quality. These data gaps are informing recommendations in HEP's Environmental Monitoring Plan. Other indicators, such as microplastic abundance, lacked sufficient data to determine a trend, but were deemed important enough to include qualitatively in the report.

TREND DETERMINATION AND SCALING

The data were analyzed primarily by looking for statistically significant ($p<0.05$) trends in a linear regression; this often required a data reduction to an annual average. Trends reported herein are significant unless otherwise noted. Because many monitoring programs began at different times, where possible, data were compiled on two time scales: long term analysis roughly corresponds to the origination of the NY–NJ Harbor & Estuary Program (the late 1980's–early 1990's); short term analysis starts roughly in the early to mid 2000's. Spatially, the analysis was also broken down into two scopes: the Harbor Estuary, the more saline and urban waterways south of the Mario Cuomo (Tappan Zee) Bridge and the Dundee Dam on the Passaic River; and the entire Hudson-Raritan Estuary, which includes the fresh water reaches and watersheds of the Hudson south of the Troy Dam, Raritan, Passaic, and other rivers. The analysis of many indicators is further broken down by regions within the Harbor Estuary, such as the Upper Bay, Newark Bay, Raritan Bay, and Jamaica Bay. Instances of insufficient spatial or temporal representation are noted in the text.

3. See HEPs Environmental Monitoring Plan: www.hudsonriver.org/NYNJHEPEnvMonitoring.pdf

Acronyms and Glossary

AET	Apparent Effects Threshold
AMNET	Ambient Macroinvertebrate Network
CAC	Citizens Advisory Committee
CCAP	Coastal Change Analysis Program
CCEC	Chemical Contaminants of Emerging Concern
CPUE	Catch Per Unit of Effort
CSOs	Combined Sewer Overflows
EPA	U.S. Environmental Protection Agency
ERL	Effects Range Low
ERM	Effects Range Median
FDA	US Food and Drug Administration
GIS	Geographic Information System
HEP	NY-NJ Harbor & Estuary Program
HRECOS	Hudson River Environmental Conditions Observing System
HRF	Hudson River Foundation
IUCN	International Union for Conservation of Nature
MERI	Meadowlands Environmental Research Institute
NGO	Non-Governmental Organization
NJDEP	New Jersey Department of Environmental Protection
NJHDG	New Jersey Harbor Dischargers Group
NOAA	National Oceanic and Atmospheric Administration
NYCDEP	New York City Department of Environmental Protection
NYCDPR	New York City Department of Parks and Recreation
NYCEDC	New York City Economic Development Corporation
NYCWTA	New York City Water Trail Association
NYSDEC	New York State Department of Environmental Conservation
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PPM	Parts Per Million
PPT	Parts Per Trillion
PVSC	Passaic Valley Sewerage Commission
QAPP	Quality Assurance Project Plan
REMAP	Regional Environmental Monitoring and Assessment Program
RPA	Regional Plan Association
SAV	Submerged Aquatic Vegetation
STAC	Science and Technical Advisory Committee
STEW-MAP	Stewardship Mapping and Assessment Project
TNC	The Nature Conservancy
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Society
WCS	Wildlife Conservation Society
WWTP	Wastewater Treatment Plant

1. Water Quality

Goal Statement: Reduce the sources of pollution so that the waters of the Harbor Estuary will meet the fishable/swimmable goal of the Clean Water Act.

Dissolved Oxygen

Long Term Trend: Improving

Short Term Trend: Improving

Dissolved oxygen in the water is one of the most important ways that habitat quality is measured for fish and other aquatic organisms. Fish breathe the oxygen found in the water column and tend to swim away from areas of low dissolved oxygen. Acute hypoxia (very low dissolved oxygen), can cause fish kills and chronic low dissolved oxygen can affect predator-prey relationships in the estuary (Yozzo, 2018). Hypoxia is most problematic in slow-moving tributaries and deeper parts of the estuary where the water is not well mixed.

Background

Low dissolved oxygen occurs when algae in the water column bloom and sink, causing biochemical reactions that reduce oxygen and produce carbon dioxide. These algae blooms are a normal phenomenon, but become problematic when excess nutrients in the water allow algae to bloom too rapidly, a process called eutrophication. In the Harbor Estuary, excess nutrients mostly come from sewage effluent. Low dissolved oxygen is most common in the late summer when the algae is more active, warmer waters hold less oxygen and the water column in deeper areas, may be partially stratified, preventing mixing of surface and bottom waters. An additional source of oxygen deficits throughout the Harbor Estuary has historically been associated with the accumulation of organic carbon at the discharge points of CSO outfalls, especially those located within dead-end tributaries such as Gowanus Canal and Flushing Bay. High rates of sediment oxygen demand result from the decomposition of organic carbon in these "CSO mounds," which also impairs aquatic habitat.

Analysis

Dissolved oxygen was analyzed on three different time scales: long term (1950–2017), short term (2004–2016), and continuous measurements. The long term analysis uses June-October data from all available stations from 1950 to 2017, including New York City Department of Environmental Protection's (NYCDEP) Harbor Survey and data from the New Jersey Harbor Dischargers Group (NJHDG). The NJHDG data starts in 2004. EPA recommends two thresholds for hypoxia: acute hypoxia, the dissolved oxygen level at which most marine life dies, is 2.3 mg/L; chronic hypoxia, the continuous level at which dissolved oxygen hinders growth of marine life, is 4.8 mg/L.

The shorter term analysis (2004–2016) focused on August and September, the months when dissolved oxygen is at its lowest in the Harbor Estuary. Only the stations that consistently collect data were analyzed. Furthermore, because tributaries such as the Hackensack in New Jersey and Newtown Creek in New York, are less well-flushed and are often located in proximity to combined sewer outfalls, they were analysed separately from stations in relatively open waters.

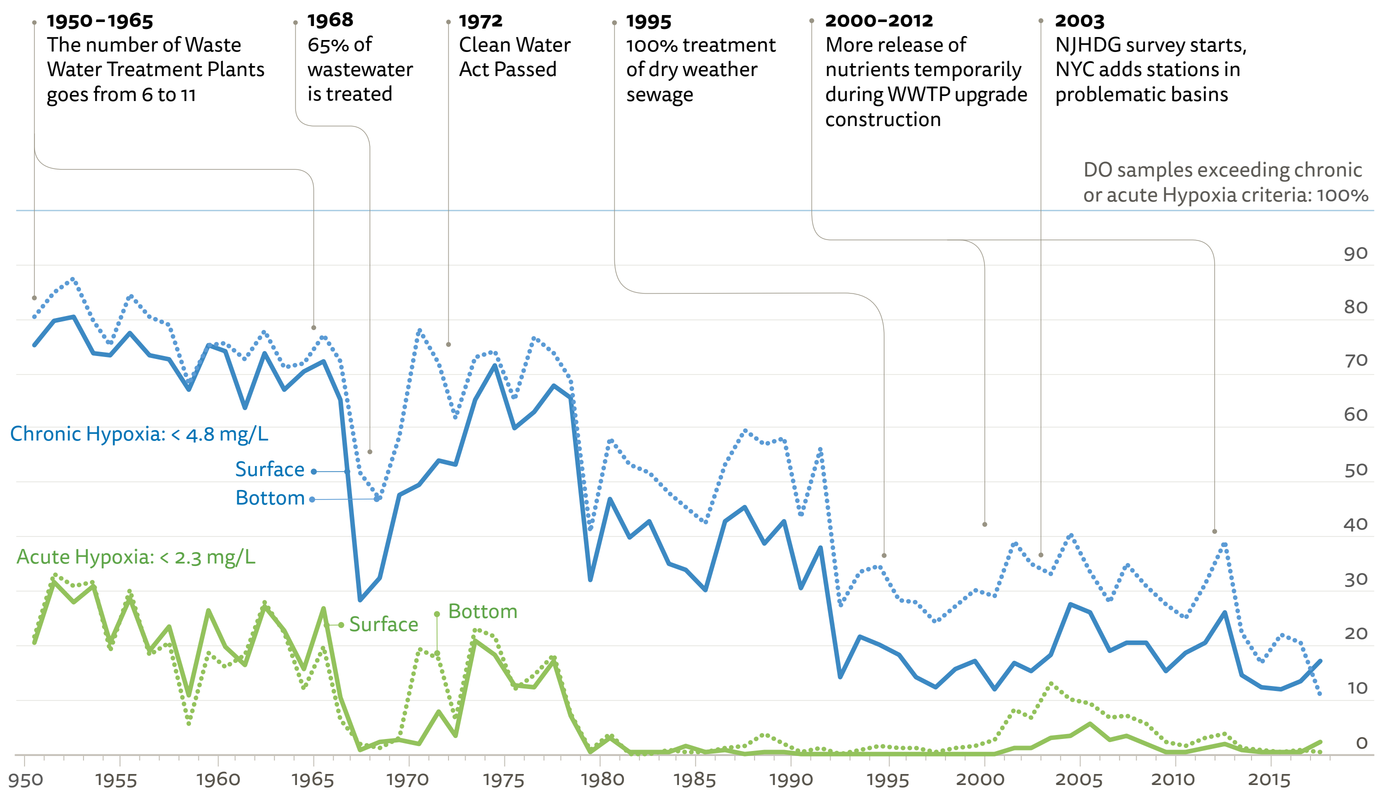
Continuous monitoring of dissolved oxygen enables HEP and its partners to better understand the daily fluctuations that can stress fish and other organisms, especially during low flow periods in the warmer months. Continuous monitoring is done by permanently installed probes that take readings as often as every 15 minutes. These continuous readings allow for monitoring of potentially significant fluctuations in day and night dissolved oxygen concentrations. Progress has been made in installing continuous monitoring probes throughout the Harbor Estuary, including the HRECOS (Hudson River Environmental Conditions Observing System) series of stations that have been installed along the Hudson and Harbor. Continuous monitoring data was assessed from several HRECOS stations and compared with nearby standard water quality sampling sites.

Dissolved Oxygen

Findings

Incidents of low dissolved oxygen have decreased significantly throughout the Harbor Estuary with time. Low dissolved oxygen levels were once common throughout the Harbor Estuary, but upgrades to wastewater treatment plants in New York City and in New Jersey have dramatically improved hypoxic conditions.

Dissolved Oxygen Percent of Hypoxic Samples per Year



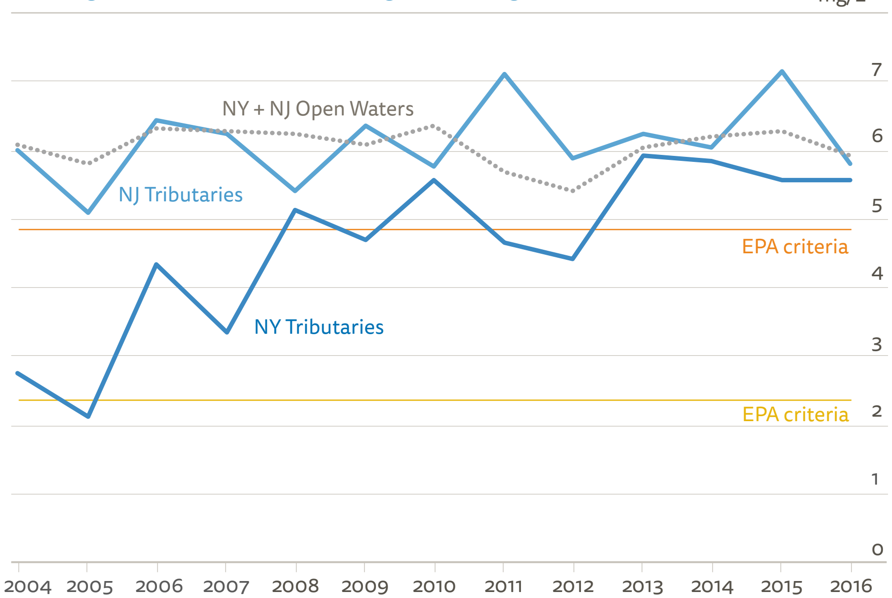
Data sources: NYCDEP, Harbor Survey Program, NJHDG, Ambient Water Quality Monitoring (Data incorporated for 2004-2016).

Dissolved Oxygen

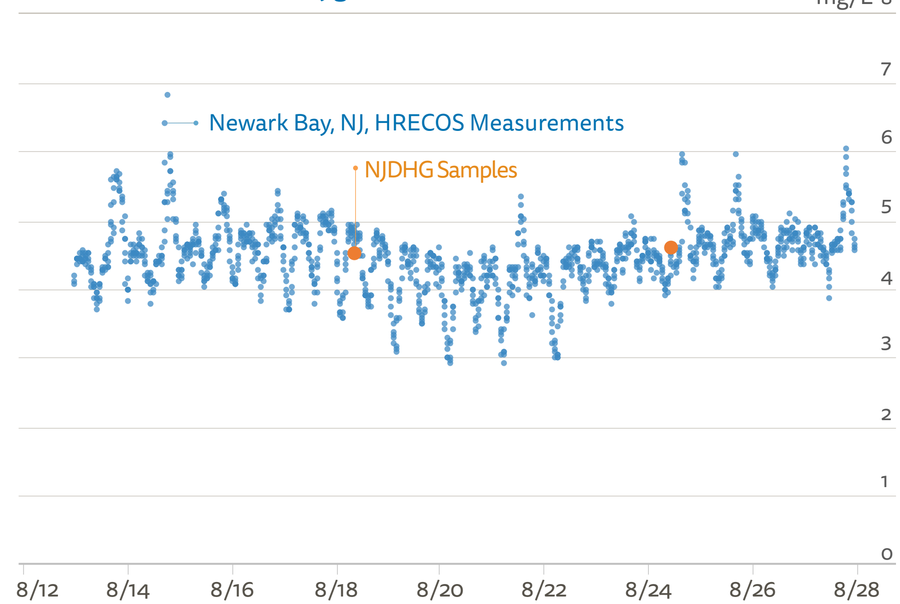
Hypoxic conditions tend to be most common in August and September. However, 2004–2016 data shows that average dissolved oxygen concentrations for these months is above 4.8 mg/L, a concentration that is supportive of growth and reproduction in marine life (EPA, 2000). The results show that while stations in the New York tributaries had problematic averages of dissolved oxygen in the mid 2000's, they have since shown a statistically significant improvement, approaching the average concentrations of open-water stations.

HEP's preliminary analysis of continuous dissolved oxygen data highlights the importance of using continuous data for habitat protection. Dissolved oxygen is lowest in the early morning, which is not when most sampling occurs. Samples from the New York and New Jersey harbor survey stations co-located with continuous probes were often within the range of values reported by the probes or slightly higher. However, it is clear that non-early morning instantaneous sampling does not always capture instances when low dissolved oxygen can be harmful to marine life.

Average Annual Dissolved Oxygen for August and September



Continuous Dissolved Oxygen, 2016



Data sources: NJHDG, Ambient Water Quality Monitoring (left and right), NYCDEP, Harbor Survey Program (left), HRECOS, Hudson River Environmental Conditions Observing System (right)

Pathogens

Long Term Trend: Improving

Short Term Trend: None

When people swim or kayak in polluted waters, they may come in contact with pathogens (harmful bacteria or viruses) that can cause disease and sickness. These pathogens enter our waterways via sewage and stormwater outfalls flowing into the estuary. New York City has a combined sewer system, which means that sanitary sewers in homes and businesses are connected to storm drain sewers. The benefit of a combined system is that during dry weather, street runoff can be treated before being released into local waterways, while in separated systems storm drainage would enter surrounding waterways untreated. However, during large storm events, runoff combined with sanitary sewage can exceed the capacity of treatment plants and is diverted and released through sewer outfalls directly into the waterways to avoid backups of drains and plumbing systems. This is called a combined sewer overflow (CSO). These events represent a substantial source of pathogens, chemical contaminants, nutrients, and debris to the Harbor Estuary (NYCDEP, 2017).

ENTEROCOCCUS

Background

Enterococcus is a bacterial pathogen found in human and animal waste that scientists use to indicate the presence of untreated sewage in the waterways. The more *Enterococcus* cells in a water sample, the more we can expect that water to contain pathogens that can be harmful to humans. In 1986, the EPA chose *Enterococcus* as its preferred indicator to measure pathogens in marine waters and has set the unacceptable level for human health as greater than 35 cells/mL (over a 30-day geometric mean of five samples or more). Prior to the use of the more reliable *Enterococcus* standard, another type of bacteria called fecal coliform was used as the primary indicator for pathogens. Pathogen levels as measured by fecal coliform are decreasing significantly from historic levels due to increases and upgrades in wastewater treatment.

Photos: Left: Combined Sewer Overflow (CSO) discharge, Raritan Riverkeeper. Right: Water testing, Rob Buchanan; Citizens Water Quality Testing program (CWQT).

Pathogens / *ENTEROCOCCUS*

Analysis

The NYCDEP Harbor Survey data and the NJHDG water quality monitoring data were used to calculate an annual regional geometric mean of *Enterococcus* concentrations for 2007–2016. 2007 was chosen as a starting year because that is when the NJHDG began collecting *Enterococcus* samples, and when the number of stations became more consistent in New York waters. The geometric mean was calculated per monitoring station per year, using only the stations that consistently collected data throughout the time period. The geometric means were then averaged by region. This analysis only includes data from April–October, the time of year when people have the most contact with the water.

The majority of the water quality monitoring in our estuary occurs by boat near the center of the channel; however, people come into contact with the water mostly at the shoreline. This dichotomy, together with the shoreline release of untreated sewage and stormwater through CSOs and other wet weather discharge, has led many to wonder if the existing monitoring protocol does not adequately capture the extent of pathogenic risk to humans. Shoreline *Enterococcus* monitoring has been initiated largely by citizen scientists and NGOs in order to broaden public understanding of pathogenic contamination and to inform decisions by public officials as well as recreational users of the water. The Citizens Water Quality Testing Program led by the New York City Water Trail Association (NYCWTA), as well as shoreline data regularly collected by the NYC Department of Health, was used to create a map highlighting the extent of shoreline *Enterococcus* contamination in 2017 (May–September). Both organizations sampled weekly with roughly 15-20 samples collected during each sampling season.

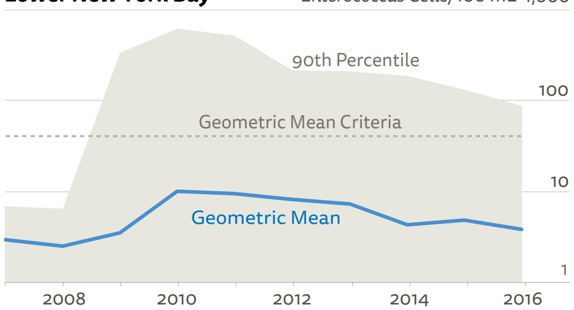
Findings

Enterococcus averages varied widely throughout the Harbor Estuary. The region containing Newark Bay and the New Jersey tributaries, such as the Hackensack and Passaic Rivers, has never experienced a year where average concentration is under the acceptable 35 cells/mL criteria, whereas Jamaica Bay and the Lower New York Bay regions do not have any years where the average exceeds the acceptable limit. None of the regional averages showed a significant trend in average *Enterococcus* concentrations with time. Annual geometric means seem to be lowering over time, but the data from 2007 to the present is much too variable to know if a trend exists.

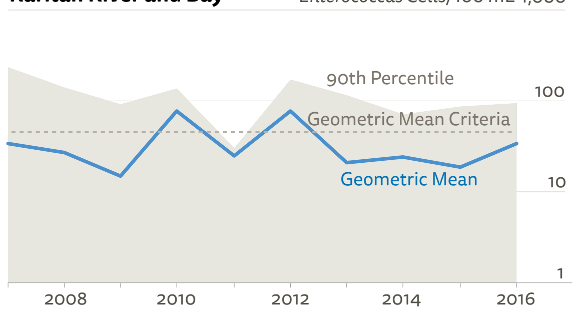
The analysis of shoreline *Enterococcus* contamination has shown that it is very common for waters to exceed the acceptable criteria of 35 cells/mL. Only two locations did not exceed 35 cells/mL in 2017. The high concentrations of pathogens detected close to shore necessitates more attention and consistent monitoring. Currently there are only a few years of shoreline data available.

Pathogens / *ENTEROCOCCUS*

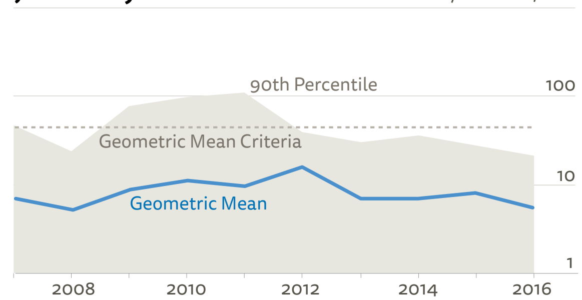
Lower New York Bay
Enterococcus Cells/100 mL 1,000



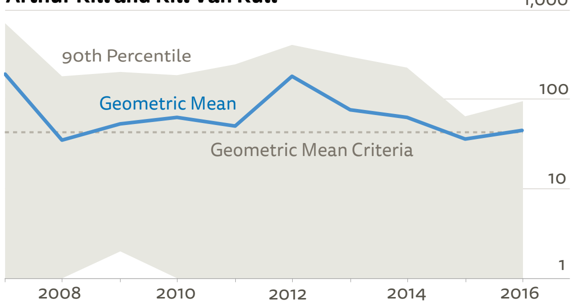
Raritan River and Bay
Enterococcus Cells/100 mL 1,000



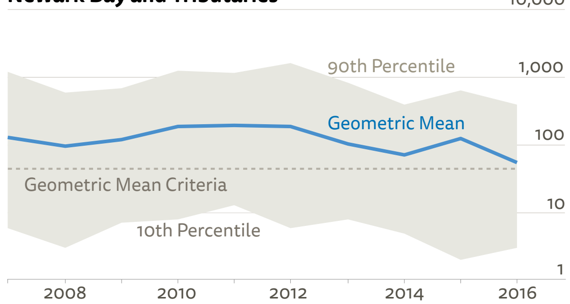
Jamaica Bay
Enterococcus Cells/100 mL 1, 000



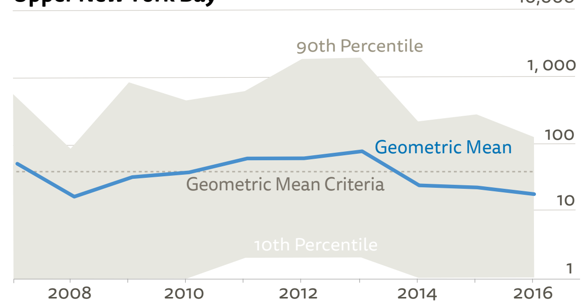
Arthur Kill and Kill Van Kull
1,000



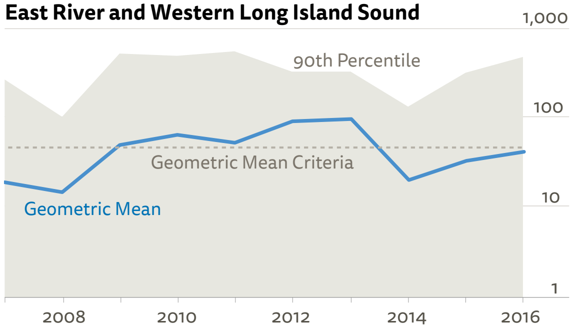
Newark Bay and Tributaries
10,000



Upper New York Bay
10,000



East River and Western Long Island Sound
1,000



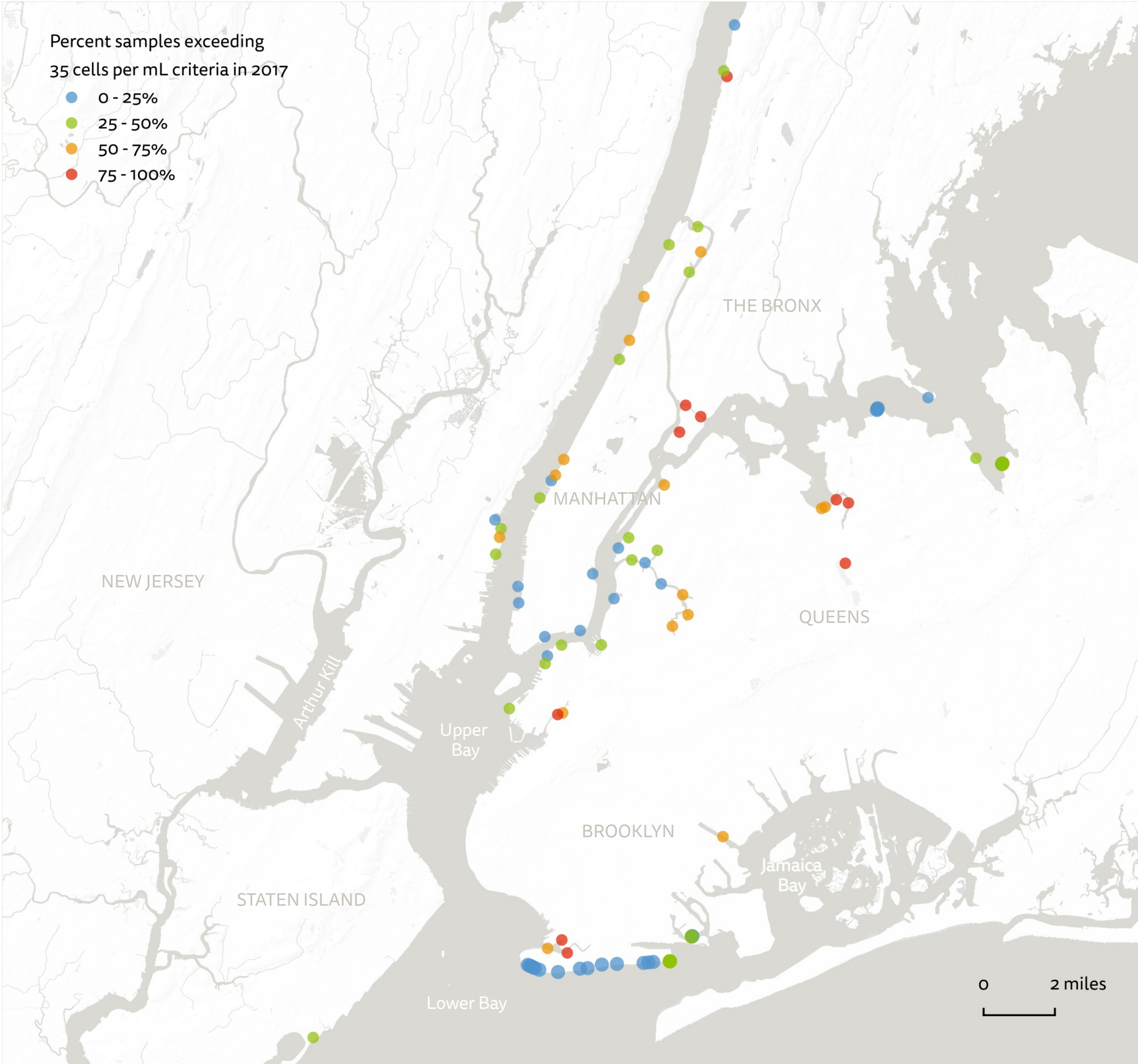
The geometric mean is similar to an average but it better represents the typical number in a set of values such as these. The gray area in between the 10th and 90th percentiles represents the range in which most of the measurements fall.

Data sources: NJHDG, Ambient Water Quality Monitoring. NYCDEP, Harbor Survey Program.

Pathogens / ENTEROCOCCUS

HEP Role

HEP and its partners are working together to advance pathogen research and new science to improve water quality in the shared waterways. HEP supports the states and EPA in developing water quality standards that are both scientifically defensible and protective of appropriate highest attainable uses in the shared waters. In 2016, HEP partnered with the Interstate Environmental Commission and local organizations to enable citizen scientists to monitor for pathogens (Enterococcus), pH, dissolved oxygen, and other parameters at public access locations. Partners monitored for pathogen levels in nearshore areas along the Kill Van Kull, Upper Bay, and Raritan Bay in both New York and New Jersey. By integrating the data with similar data collected by the NYCWTA and other groups, HEP and its partners will begin to develop a systematic approach to monitor pathogen levels for near-shore areas in reference to primary recreational contact and other uses by the public.



Data sources: Citizens Water Quality Testing Program, NYC Department of Health.

Nutrients

Long Term Trend: Improving

Short Term Trend: Improving

Nutrients are essential for the growth and survivorship of all living things. However, excess nutrients, called eutrophication, can cause marine plant populations, normally controlled by periodic nutrient limitation and grazing by zooplankton, to bloom rapidly. This causes algal blooms that can be dense and pervasive; can cause low dissolved oxygen, block light into the water column and sometimes be toxic. Eutrophication is not a major concern in many parts of the Harbor Estuary because the large tidal flows to and from the Atlantic along with the fast-moving currents provided by the Hudson and Raritan rivers dilute nitrogen concentrations and limit the time it is in the system. However, smaller tributaries, embayments and other areas of slow tidal flushing remain areas of concern for eutrophication.

NITROGEN

Background

Among the major nutrients, nitrogen is the one that is limiting in the marine environment. That is, in the marine environment, carbon and phosphorus are plentiful and it is inputs of nitrogen that cause the most growth and reproduction in plants (Nixon, 1995). Nitrogen enters our waterways through CSOs but it is also prevalent in most treated wastewater. Atmospheric deposition and fertilizer are also sources of nitrogen to the Estuary. Historically, high nitrogen concentrations have been a problem in our neighboring waterbody, Long Island Sound, and in 2001, the EPA, along with the States of New York and Connecticut agreed to decrease the nitrogen load (how much nitrogen is entering the waterbody) to the Sound by 58 percent.

Generally, nitrogen concentrations are most problematic during the spring and summer when the algae are more active. Although nitrogen concentrations of less than 0.45 mg/L are generally supportive of marine health, there are no EPA or state guidelines regulating nitrogen concentrations in the estuary.

Analysis

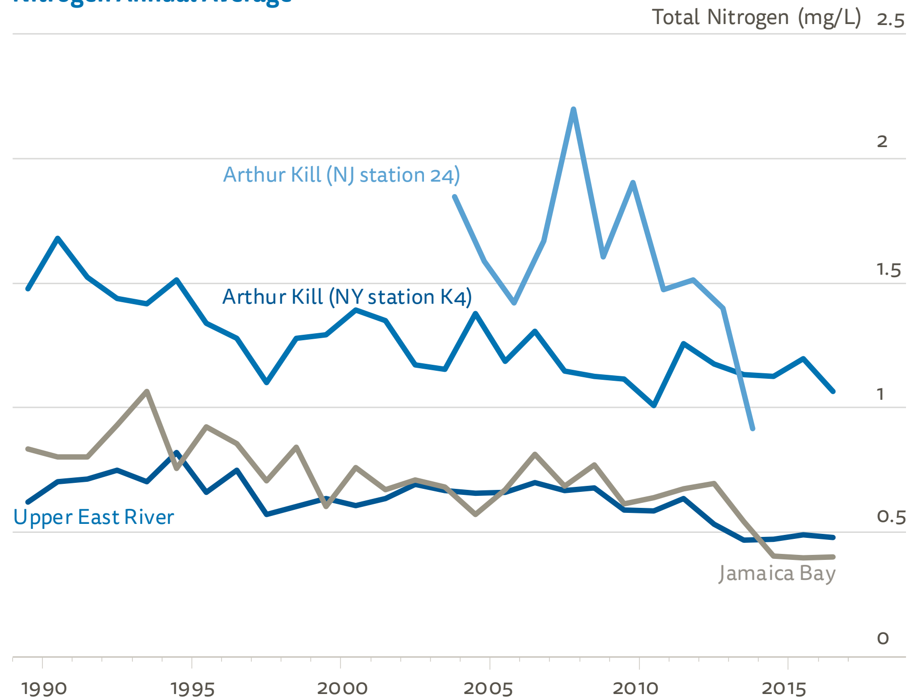
Analysis of nitrogen concentrations in the Harbor Estuary utilized data from the NYCDEP's Harbor Survey, focusing on areas in the estuary with poor tidal flushing. Stations were selected that consistently collected data between 1990 and 2016: one on the Arthur Kill, seven in the upper East River, and nine from Jamaica Bay. Annual average nitrogen concentration was calculated for each of these waterways. The short term analysis consisted of looking at the same data from 2004–2017 with the inclusion of a NJHDG site on the Arthur Kill. Only two sites were used for the Arthur Kill region because they were the most spatially representative. Data from stations outside these areas and time-frame was also reviewed to identify particularly problematic stations.

Nutrients / NITROGEN

Findings

Average annual nitrogen concentrations in all the specific waterways are trending down significantly in both the long and short term analysis. Interestingly the New Jersey data has consistently higher yearly averages and is more variable than the New York data for similar locations on the Arthur Kill, despite both data sets including a similar number of samples per year. A few Jamaica Bay stations that were added in 2008 did have high nitrogen concentrations as they were in proximity to CSO outfalls, but those sites are also trending down significantly with time. The overall decrease in nitrogen concentration throughout the Harbor Estuary is likely linked to upgrades in wastewater treatment though previous research from EPA shows that nitrogen reductions are needed to reach dissolved oxygen standards in the Harbor Estuary (EPA, 2010). The Upper East River region has benefited from the efforts towards the Long Island Sound load reduction. As of the end of 2016, the Long Island Sound reduction goal for wastewater was accomplished, though the targets remain outstanding for atmospheric deposition and agricultural nitrogen loads.

Nitrogen Annual Average



Data sources: NJHDG, Ambient Water Quality Monitoring. NYCDEP, Harbor Survey Program.

Climate Change

Long Term Trend: Deteriorating

Short Term Trend: Not Trending

Climate change is caused by the emission of excess carbon dioxide and other greenhouse gases into our atmosphere from human activity including the burning of fossil fuels for transportation and energy generation. This excess carbon warms the air and water, and causes a myriad of other dramatic changes including sea level rise, ocean acidification, and increased severity in storms. Climate change is affecting the Hudson-Raritan Estuary on a local level as sea levels and air temperatures are rising and wildlife distribution and migratory patterns are changing (HEP, 2012).

WATER TEMPERATURE

Background

Worldwide, the upper ocean has warmed by 0.2°F every decade since the 1970's (IPCC, 2014). Warming water affects our ecosystem in a number of ways. Even very small increases in water temperatures can affect the growth, behavior, and species distribution of aquatic animals; for example, we are losing species that are at the southern edge of their ranges and species from the mid-Atlantic are migrating northward to the Estuary in response to warming temperatures (Daniels et al., 2005). Warmer temperatures also decrease dissolved oxygen in the water column, and increase biological oxygen demand (Najjar et al., 2000). Warmer temperatures are especially problematic for smaller tributaries and embayments that are less well flushed or more sensitive to summer heat waves.

In the Harbor Estuary, however, the relationship between water temperature and climate change is not so straightforward. Historically, many electric and other utilities released hot water used for once-through cooling systems into waterways. This practice continues today but with greater regulation. Treated wastewater is also a higher temperature than receiving waters due to the bacterial activity that degrades sewage into less harmful components. However, thanks to water conservation measures, new sources of power (solar, wind), federal and state regulation, and and electric transmission from out of the region, these injections of warmer water have decreased in volume with time.

Analysis

The effects of climate change are seasonally disproportionate: the relative warming is happening much faster during winter than the summer. Therefore, even though it is warmer summer waters that are the most harmful, the winter water temperatures from December – February were used for this analysis because they are more indicative of climate change. Samples taken from both the surface and bottom (just above sediments) of the water column by the NYCDEP and NJHDG Harbor Surveys were averaged and 10th and 90th percentiles were calculated to get a sense of the range of values per winter. Three years (1988, 1990, 1998) were removed from the analysis for quality reasons because there were less than three sampling days per winter. Air temperatures for the same time were also averaged to explore the relationship between air and water temperatures in the Harbor Estuary.

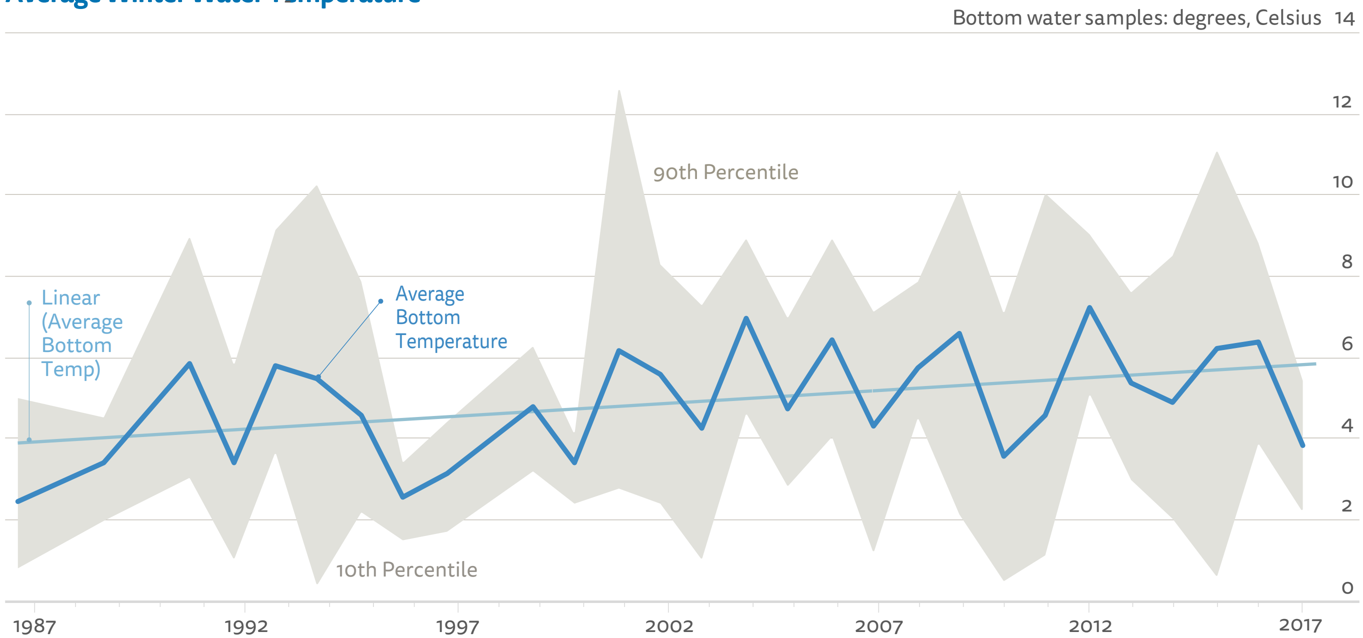
Climate Change / **WATER TEMPERATURE**

Findings

Average bottom winter water temperatures are increasing significantly with time, which indicates a declining trend in environmental health. The surface water temperatures are too variable to determine a trend. While they are not changing significantly, the number of unusually warm samples (the 90th percentile) are increasing with time while the number of cooler samples (the 10th percentile) are staying about the same (although decreasing slightly in the short term). This result, as well as a decline in a statistical measure called the R^2 value (in the averages for both the surface and bottom samples), suggests increasing water temperature variability with time. Average winter air temperatures for the same time period were significantly correlated with the survace average water temperatures.

It is difficult to determine what effect, if any, the reduction in warm water inputs from wastewater and other thermal discharges or the effect that air temperatures may be having on these data. It is possible that the polarizing influence of the two drivers (climate change and decreasing thermal pollution) could cause increased variability.

Average Winter Water Temperature



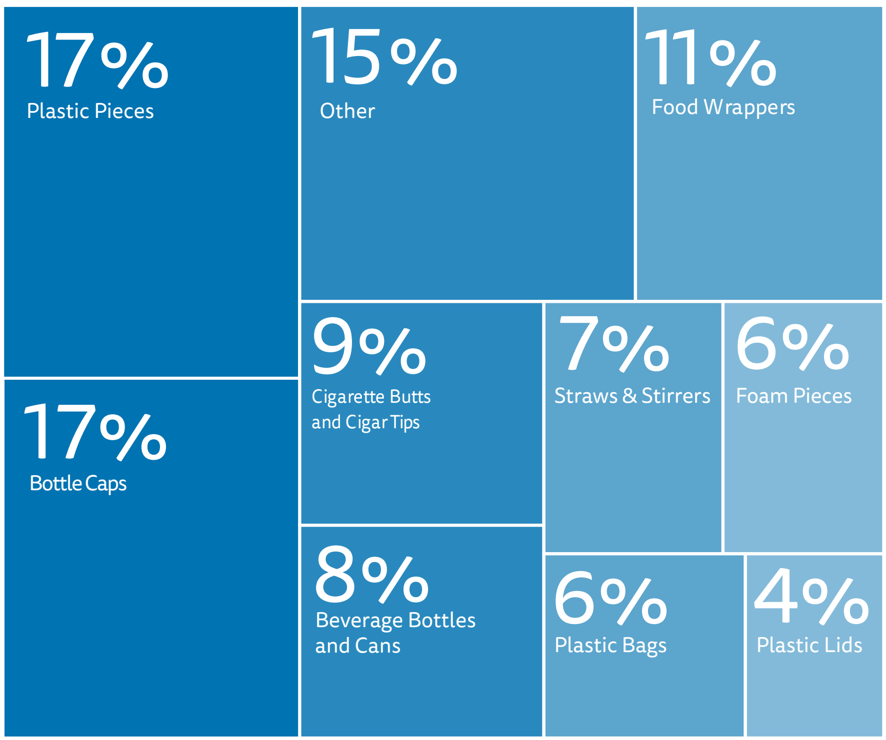
Data sources: NJHDG, Ambient Water Quality Monitoring. NYCDEP, Harbor Survey Program.

Floatable Debris

Long Term Trend: Improving
Short Term Trend: Improving

Floatable Debris or garbage in our estuary waters and shorelines affects the ability to swim and fish, and with larger debris, can interfere with navigation. Floating trash, that can enter the waterways by flowing out of sewer and stormwater drains, being dumped on shorelines, or being blown to the water by the wind, is an easily distinguishable indicator of water pollution.

Ocean Conservancy (NJ) 2016 Beach Cleanups
Dominant debris types by volume



DEBRIS COLLECTED ON BEACHES

Background

Shoreline cleanups have been an increasingly popular method of stewardship, bringing together community and business partners for an activity with tangible benefits. Many of the environmental groups that organize beach cleanups keep track of the amount of garbage they remove and some even inventory what kind of garbage they find.

Analysis

This analysis used only shoreline cleanup programs that have long-term datasets and additionally keep track of the mileage of shoreline they cover while collecting. Some of the data sets also track the number of volunteers per day; this metric was used where available. Keeping a consistent measure of effort allows us to make assumptions about how much trash is on the beach per year and thus, whether the problem of debris is getting better or worse. The annual amounts of debris collected in pounds per mile of shoreline or pounds per mile of shoreline per person were calculated and reviewed from Ocean Conservancy, the American Littoral Society, and the NJ Clean Shores Program.

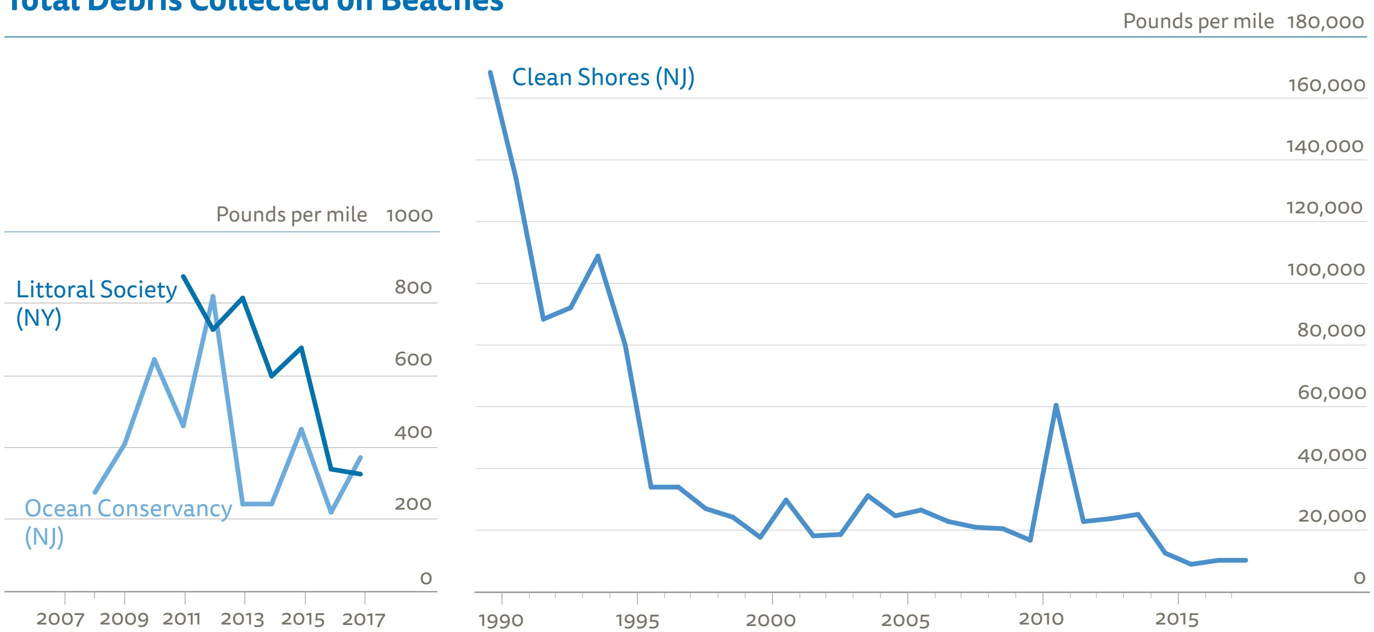
Data source: Ocean Conservancy, NJ Coastal Cleanup Programs. Photo: Rob Pirani, NY-NJ HEP.

Floatable Debris / **DEBRIS COLLECTED ON BEACHES**

Findings

The most robust collection effort, New Jersey's Clean Shores Program, is showing a statistically significant decline in debris on beaches, as is The American Littoral Society's New York State beach cleanup program. When the metric of volunteers is included, the Littoral Society's data shows the same downward trend. These strong trends indicate that there has been less garbage on the shorelines over time. The Ocean Conservancy data was too variable to show a trend, but indicates that single-use plastics and food containers are the most prolific floatable debris found on New Jersey beaches.

Total Debris Collected on Beaches



Data sources: Ocean Conservancy, NJ Coastal Cleanup Programs (left). American Littoral Society, NY State Beach Cleanup (left). NJDEP, Clean Shores Program (right).

Floatable Debris

Long Term Trend: Insufficient Data

Short Term Trend: Improving

DEBRIS COLLECTED BY SKIMMERS AND BOOMS

Background

Three different agencies operate skimming and boom programs in the Harbor Estuary. Skimmer vessels are boats fitted with a front-mounted conveyer belt that skims the surface water down to a two to three feet depth and collects floating debris. Booms are floating nets that are usually placed across tributaries entering the harbor to collect trash flowing downstream.

Photo: PVSC

Floatable Debris / DEBRIS COLLECTED BY SKIMMERS AND BOOMS

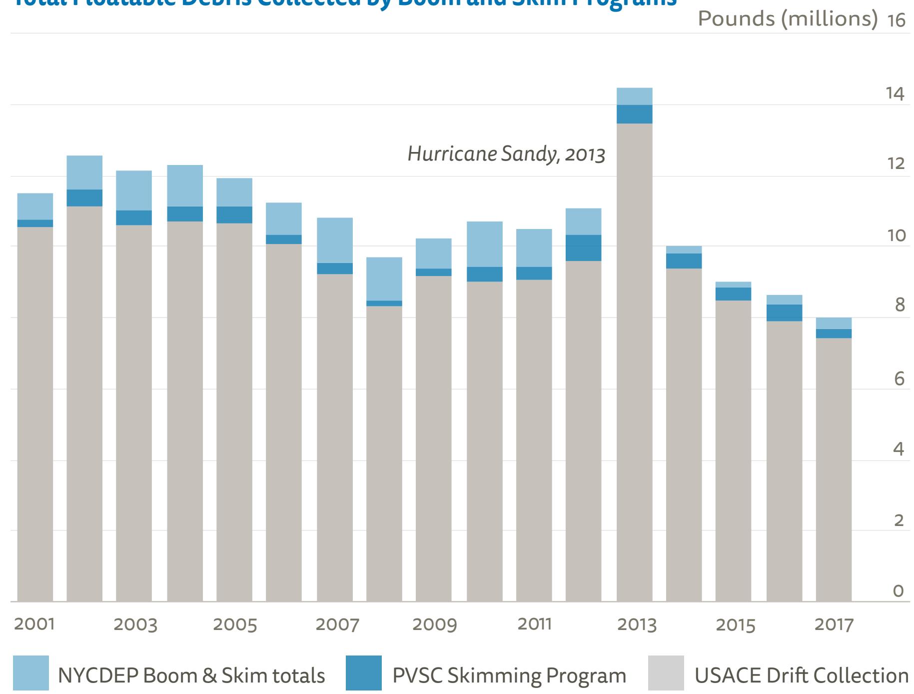
Analysis

The US Army Corps of Engineers (USACE), the NYC Department of Environmental Protection (NYCDEP) and the Passaic Valley Sewerage Commission (PVSC) all have skim or boom and skim programs where they track the amount of floatable debris collected. It was assumed that less garbage collected means less garbage floating around to collect as the agencies report that their efforts has not changed much throughout the analysis period.

Findings

The largest skimming program, operated by USACE, as well as the program run by the NYCDEP are showing a downward trend in floatable debris collected. Some of the decrease in floatable debris may be due to stricter permit requirements and efforts by municipalities and utilities to install catch basin inserts or netting systems on stormwater outfalls. There are a few complicating factors in determining this trend. Some of this reduction may be attributable to the removal of heavier than normal debris, such as derelict piers, in the earlier part of the monitoring period. There has also recently been an increase in stewardship efforts including beach cleanups, which may affect the amount of debris collected by these agencies. For example, the Bronx River Alliance operates a boom upstream of the NYCDEP boom on the Bronx River.

Total Floatable Debris Collected by Boom and Skim Programs



HEP's Role

Stopping Trash Where It Starts: HEP and The Montclair State University's Passaic River Institute developed a protocol for street litter surveys to track trash to specific points of sale, to identify types of trash, and to record visual observations of conditions that could influence the transport of trash to storm drains. Similar to national surveys, this survey found that the most abundant floatable debris in number was cigarette or tobacco related items while the highest volume of materials found in the Passaic River Watershed was drink or food related single-use, plastics. The final report includes recommendations for how to best eliminate or reduce local and/or regional sources of floatable debris and a trash reduction toolkit includes lessons learned, how to replicate the litter surveys, and recommended courses of action for community groups. HEP is now conducting similar surveys in the Bronx, Harlem and Hackensack River watersheds.

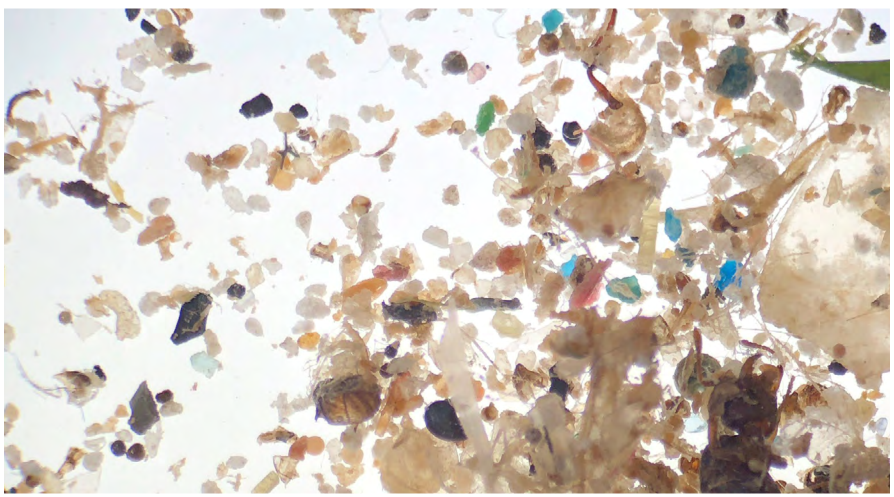
Data sources: USACE, Drift Collection. NYCDEP, Boom and Skim Program. PVSC, River Restoration Skimming Program.

Contaminants of Emerging Concern

Long Term Trend: Insufficient Data

Short Term Trend: Insufficient Data

The ubiquitous presence of microplastics and Chemical Contaminants of Emerging Concern (CCECs) in the Estuary have become of increasing concern to scientists and public health officials. CCECs are synthetic organic chemicals that have a wide variety of classes and uses, and include industrial chemicals such as pesticides (DEET) and plastic additives (BPA), pharmaceutical compounds, and personal care products (such as sunscreen and synthetic fragrances). Schnoor et al. (2014) estimate that 84,000 different kinds of commercial CCECs are used daily in the United States. Microplastics are small plastic fragments that are typically less than 0.5 millimeters in diameter that pose significant threats to wildlife when they are ingested. The presence of both of these types of contaminants is not new, but they are only recently starting to be monitored and regulated and data are insufficient to determine long and short term trends. The threat they pose to marine life merits a qualitative look at their presence in the waters of the Harbor Estuary.



MICROPLASTICS

Background

Following the mass production of plastic products during World War II, disposable plastics began to flood a market of consumers eager for convenience. Single use plastics, such as straws, water bottles, takeout containers, and utensils, are especially concerning. The typical single-use plastic bag, for example, is only used for around 12 minutes on average (NYS Plastic Bag Task Force, 2018), but these non-biodegradable plastics never disappear. Exposed to the sun and other forces, they only break up into smaller and smaller pieces (Horton et al., 2017).

Small marine animals such as plankton and larval fish, frequently mistake the resulting tiny pieces and other microplastics for food. When microplastics enter an animal's digestive system, they can cause harm in a number of ways: the object itself can fill up an animal's stomach, satiating it despite having consumed no nutrition whatsoever. Furthermore, recent research shows that the plastic can absorb toxic chemicals in the water, causing significant tissue damage (Bakir et al., 2014). Microfibers, the smallest microplastics, are shed from washing clothing made from synthetic fabrics.

Microplastics research in the Harbor Estuary is relatively recent, although more research and monitoring is being undertaken each year. At least five organizations have conducted microplastics research in the Harbor Estuary: NY/NJ Baykeeper, Rutgers University, Clearwater Inc., Hudson River Park Trust and Lamont-Doherty Earth Observatory/Hudson Riverkeeper. Their work from 2014–2018 covers a large part of New York Harbor, particularly the lower Hudson, Upper Bay, and Raritan Bay. Though there is no standardized monitoring protocol for collecting microplastics, four of the five studies use a similar net size and break the plastics down into similar groups by size and type. The Lamont-Doherty/Riverkeeper study is unique in that it used a plankton net, which is able to capture much smaller particles such as microfibers, and focused their sampling near areas of heavy wastewater flow.

Most local microplastics research examined six different categories of microplastics: nurdles, fragments, foam, line, pellet, and film. Nurdles are pre-production plastic fragments that are an indicator of industrial microplastic pollution; fragments are

Photo: Mircoplastics, Hudson River Park Trust

Contaminants of Emerging Concern / **MICROPLASTICS**

small, hard pieces of unidentified plastic; foam, or Styrofoam, is a material frequently used to make coffee cups; line microplastics include microfibers from clothing and fishing line; pellets are plastic spheres, also known as microbeads, that are common in personal care products; and film is a thin microplastic likely originating from plastic bags.

The studies were conducted in different parts of the estuary and had different methodologies, sample sizes, and goals. While the studies all found a large amount of microplastics in the water column, the specific results differed. Baykeeper's 2015 study of marine waters revealed a significant amount of nurdles, or pre-production plastic pellets, which indicates a continued input into waterways from industry. Foam and blue spherical microbeads typically derived from personal care products, were aslo abundant. The Clearwater's 2015 study of the Hudson River found microbeads constituted only 2% of the plastics they collected; larger fragments were more prevalent (40%). For both the 2015 Rutgers University and the Hudson River Park Studies (2016–2017), plastic fragments were the most abundant type found.

The Lamont/Riverkeeper study found 15,000 – 80,000 plastic particles per liter (Lim et al., 2017). While this result was much higher than the averages from the other studies, they used a smaller mesh that allowed the to capture the more prevalent microfibers; they also sampled areas near wastewater effluent releases.

The concentrations of microplastics found in the estuary suggests that more monitoring and research is required. In addition to characterizing the scope of microplastic pollution, scientists are also studying the effects these plastics are having on our ecosystem, particularly at vulnerable life stages for animals, and the combined impact effects that could result from these plastics absorbing and transporting toxicants.

Microplastics Research in the Harbor Estuary

Organization	Dates of study	Average Estimated Abundance of particles/km^2
Baykeeper (Marine)	March – Aug 2015	256,000
Rutgers University/Baykeeper (Freshwater)	May – August 2016-2017	28,000 – 3,000,000
Clearwater, Inc.	Aug 2014 – Aug 2015	3,000,000
Hudson River Park Trust	June – October 2016, 2017	100,000 – 189,000

Contaminants of Emerging Concern

Long Term Trend: Insufficient Data

Short Term Trend: Insufficient Data

CHEMICAL CONTAMINANTS OF EMERGING CONCERN (CCECS)

Background

CCEC's find their way to the estuary in a number of ways including wastewater treatment discharges, combined sewer outfalls (CSOs), improper disposal, and runoff from both urban and agricultural lands (Pochodylo and Helbling, 2015). Given the large variety of the Harbor Estuary's land use types, sewer systems, and hydrology, it is likely that a vast array of CCEC's are released in the watershed each day.

There have been only a few recent studies on CCEC's in the area. In 2015, researchers from Cornell University analyzed 24 water samples from eight sites along the tidal portion of the Hudson River. This project focused on 117 target CCECs that included a diverse range of uses, including pharmaceuticals, pesticides, and industrial chemicals. Eighty-three of the 117 were found in at least one sample. Eight CCEC's were found in every sample collected: atenol (a beta-blocker), atenolol acid, venlafaxine (an anti-depressant), caffeine, parazanthine (a metabolite of caffeine), sucralose (an artificial sweetener), methyl benzotriazole (an industrial chemical), and DEET (an insect repellent). Every sample contained between 8 and 10 different pesticides, which may suggest that the influx sources of pesticides into the estuary are diverse. Pharmaceutical contamination was highest near sewage treatment plant outfall sites. Also common were various herbicides, nicotine, and lidocaine (an anesthetic). When compared to CCEC concentrations in other western countries, these findings suggest that the Hudson Estuary is no more contaminated than most other waterways.

A concurrent study analyzing CCEC concentrations in the Hudson River Valley found a prevalence of amphetamine compounds in the river; given that a majority of sampling was done after rain events, these results indicate amphetamine concentrations in the estuary may be controlled by CSOs (Paspalof et al., 2015). Two other compounds that were consistently detected were DPH (Benadryl) and Carbamazepine (an anti-convulsant used to treat seizures). Both compounds are known to cause stress and behavioral changes in fish species (Paspalof et al., 2015). An earlier study of Jamaica Bay in 2002 found a consistent presence of caffeine, cotinine (a metabolite of nicotine), and paraxanthine (a metabolite of caffeine) in all samples (Benott and Brownawell, 2002).

Cantwell et al. (2018) conducted the most recent study documenting pharmaceutical contamination in the Hudson-Raritan Estuary in the summer of 2016. Sixteen pharmaceutical compounds were studied based on their frequent prescription and potential to cause harmful biological effects. Single-grab samples were collected during a dry weather period from the Federal dam in Troy to the Battery in Manhattan. Sites in New York Harbor that are CSO-impacted were also sampled during wet weather. This study found that these pharmaceuticals were present at most of the sites during both sampling events.

Because these samples were collected under similar precipitation and river flow conditions, these results suggest a ubiquity of the selected compounds. The detection frequency for the seven Harbor sites was generally higher than the average for the entire study. Mean frequency of detection of the 16 pharmaceutical compounds studied was higher in the Hudson-Raritan Estuary than a national study surveying 182 rivers and streams. Several compounds were found at levels high enough to cause chronic effects for marine life.

Part of the challenge with monitoring CCEC's is determining what to monitor. Scientists do not know what levels of exposure are harmful for many of the compounds or how those compounds may concentrate as they move up the food web, similar to the bioaccumulation of more familiar toxic chemicals. Based on existing research of the toxicity of a small subset of chemicals, it is possible that when many CCEC's collect in waterways, their subsequent complex mixtures can lead to developmentally or genetically harmful effects on both aquatic and human health (Pochodylo and Helbling, 2015). More work is needed to quantify the extent of CCEC contamination, understand the effects of low-level chronic exposure, and determine best wastewater treatment practices to lessen their prevalence in waterways.

Cantwell et al. (2018) Study of Pharmaceutical Contamination in the Estuary

Month	% of sites where the compounds were found	Detection frequency of 16 compounds across all sites
May 2016	98%	55%
July 2016	92%	52%

2. Habitat and Ecological Health

Goal Statement: Protect and restore the vital habitat, ecological function, and biodiversity that provide society with renewed and increased benefits.

Marine

Long Term Trend: Not Trending
Short Term Trend: Insufficient Data

The marine habitat is the area of deeper waters, less affected by tides, currents and waves and generally with higher salinities, that comprises the habitat for some of the Estuary's most charismatic wildlife species including large fish and marine mammals.

BENTHIC INDEX OF BIOTIC INTEGRITY

Background

One way to determine the health of the marine ecosystem is to survey the animals that live in the superficial sediments of the Estuary. These animals, mostly benthic worms and small mullosks and crustaceans, can be tolerant or intolerant of the historic and ongoing pollution in our waterways. The presence of specific species and their relative abundance is used as an indicator of marine ecosystem health. The health of these animals also has broader implications for the health of large marine animals.

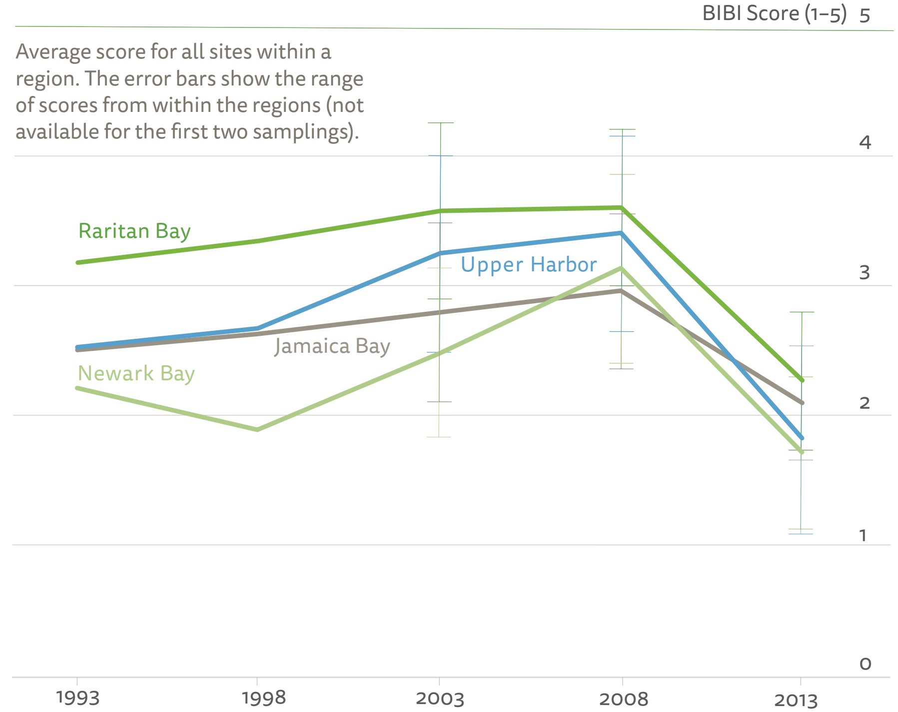
Analysis

The EPA Regional Environmental Monitoring and Assessment Program (REMAP) sampled the sediments throughout the Harbor five times from 1993 – 2013. The Benthic Index of Biotic Integrity used scores from five different metrics: overall species abundance, biodiversity, biomass, percent of pollution-sensitive species, and percent of pollution-tolerant species. The scores for these metrics were averaged per site and the sites were then averaged by region. The scoring is 1–5, with "5" being the representative score for an unpolluted reference site and "1"representing low ecological health. An additional in-depth analysis called rarification was performed by a benthic ecologist to validate the results.

Findings

The Benthic Index of Biotic Integrity scores were improving until 2013, with a positive trend in each region except for Newark Bay prior to 2013. Interestingly, however, the scores for each region plummeted in the 2013 sampling, largely driven by a lower overall abundance of animals and less biodiversity. In 2003 and 2008, over 200 different species were found throughout the Harbor while in 2013, there were only 58 found with the same sampling methods. Rarification suggests that the results from 2013 truly represent the existing species composition rather than lab error. The 2013 results may have been caused by Hurricane Sandy in 2012, which washed-out or buried the benthic animals and redistributed sediments that define habitat for the "missing" species. Further sampling is needed to determine whether benthic abundance has recovered and if overall benthic health is continuing to get better with time.

Benthic Index of Biotic Integrity



Marine

Long Term Trend: Declining

Short Term Trend: Not Trending

ESTUARINE AND DIADROMOUS FISH ABUNDANCE

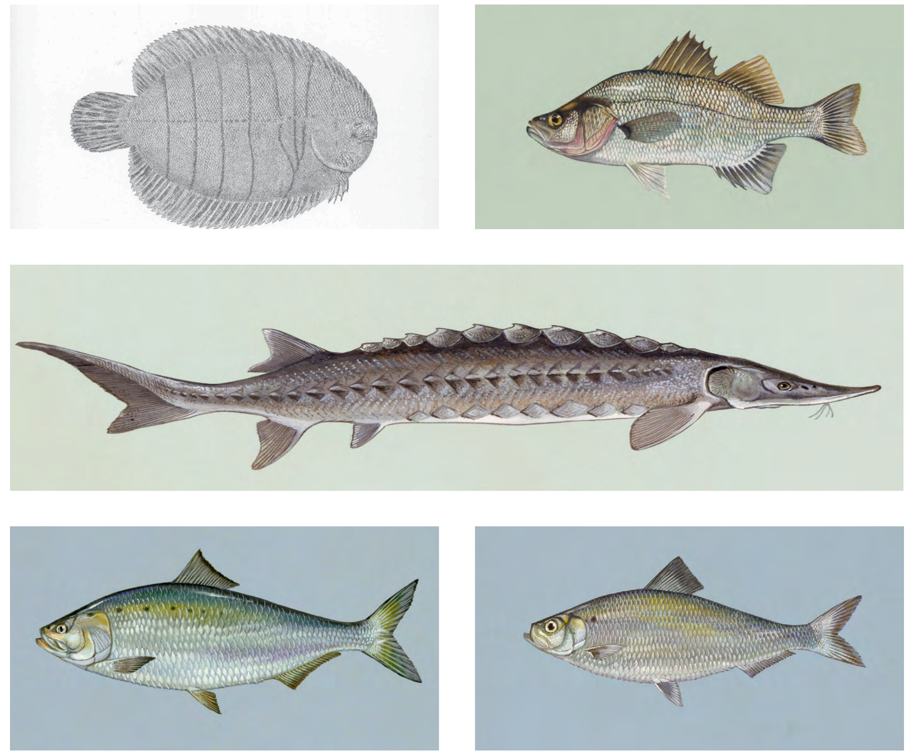
Background

Historical accounts of the estuary describe our waters as teeming with fish. Dramatically altered shorelines and benthic environments, a booming commercial fishing industry and water pollution took their toll and now fish populations are a fraction of what they once were. For example, even as recently as the 1940's, Hudson River landings of American shad were up to 50 times greater than what they were by the time the Hudson River shad fishery closed in 2010.

Fish abundance is a complicated indicator of habitat value because population changes can occur for reasons other than habitat quality. Overfishing, climate change, and shifts in predator-prey distribution can all be factors. The analysis for this indicator focuses on two groups of fish species. The first group represents estuarine species, which spend the majority of their lives in the Estuary, thus, their abundance is more likely to be related with habitat condition. The relationship is less certain with anadromous species, such as American shad and sturgeon, that use fresh and salt water in different parts of their life cycles. While these two groups are good indicators of habitat value, it is important to note that this analysis does not reflect the trend for all fish found in the Estuary; the bulk of the fish are neither resident nor diadromous.

Analysis

Four different long-term abundance surveys were analyzed for trends in the abundance of either estuarine or diadromous fish. All of the surveys are from the Hudson River from the dam at Troy to lower Manhattan. Most of the surveys start in the late 1980's or early 1990's with the exception of the NYSDEC Atlantic sturgeon survey that did not start until 2004. The surveys vary in their methods (trawls, shoreline seining, traps), corresponding to a greater or lesser ability to catch different species at different life stages. An effort was made to chose surveys that were likely to be representative of abundance but it is important to note that no survey is perfect for all fish species. A study from the New Jersey Meadowlands Environmental Research Institute was also reviewed to increase spatial representation, thought it lacks the same frequency as the annual surveys.



Estuarine: hogchoker (top left), white perch (right).
Diadromous: Atlantic sturgeon (middle), American shad, (left), alewife (right).
Illustrations: Duane Raver/U.S. Fish and Wildlife Service.

Marine / ESTUARINE AND DIADROMOUS FISH ABUNDANCE

Findings

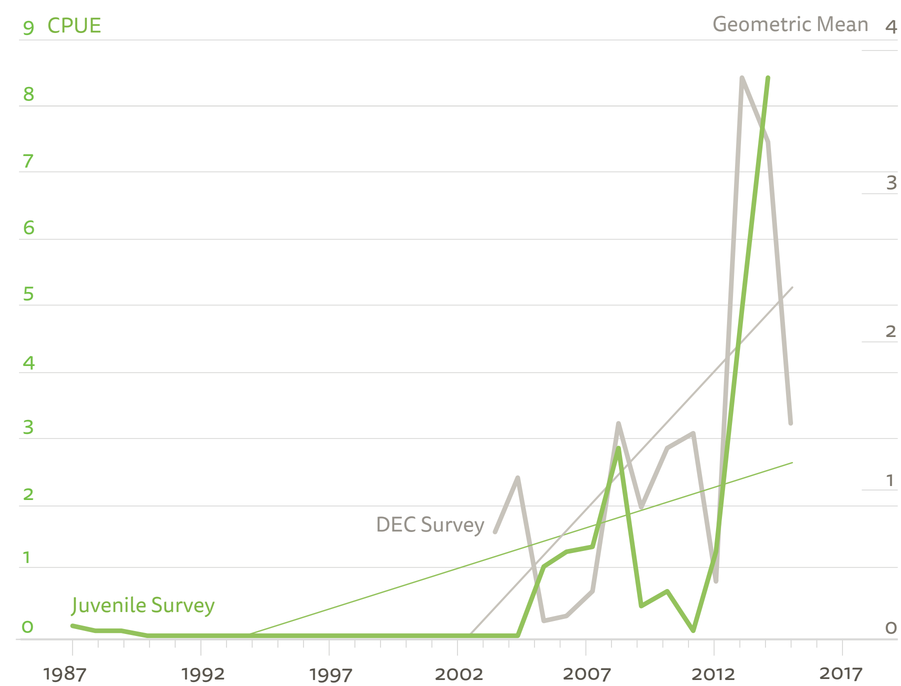
Both estuarine and diadromous fish populations are trending down over the long term. Five estuarine species and seven diadromous species were found to be trending significantly in at least one of the surveys used. The species increasing are Atlantic sturgeon and alewife; Atlantic silversides are showing a mixed trend with one survey increasing and another decreasing. In the short term, the same group of species were not trending overall. Interestingly, hogchoker is showing a improving short term trend despite a deteriorating long term trend, possibly indicating a recovery.

Monitoring data from the New Jersey side of the Harbor Estuary is lacking. However, a study by MERI compared the abundance of fish species from two time periods: 1987–1988 and 2001–2003. This study found an increase in alewife and Atlantic silverside, similar to the annual surveys used in this analysis, but also found an increase in striped bass and white perch that was not seen in the Hudson River data. The MERI study also found that tomcod and blueback herring decreased in abundance similar to the trends found in New York (Bragin et al., 2005).

One of the species showing a positive trend is Atlantic sturgeon. A moratorium was placed on sturgeon fishing in the Hudson River in 1995 along with the fishing of sub-adults in New York and New Jersey's coastal waters. In 2006, Atlantic sturgeon were federally protected as a "near threatened" species (the listing was upgraded to endangered in 2012). As it takes 12 – 18 years for a female Atlantic sturgeon to spawn for the first time, fisheries experts believe that the increase owes to these protection efforts. The other species showing a positive trend is alewife. Though the numbers of this herring species are low, preliminary results of recent spawning stock surveys are showing signs of a healthy stock. These signs include a wide ranging age structure, an increasing or stable length at a given age and increasing prevalence of repeat spawn marks on scales indicating females have spawned multiple times through the time series (Adams, 2017).

It is unclear how much of the decline of fish populations can be attributed to habitat loss. Fishing pressure is likely less of a control on these populations than it once was. Other pressures including climate change are likely to be the cause of some of the negative trends. One such example is tomcod, which is at the southerly tip of its range in the Hudson. Other species are likely affected by competition for food with non-native Zebra Mussels that have invaded the Hudson (Casselberry and Schultz, 2013).

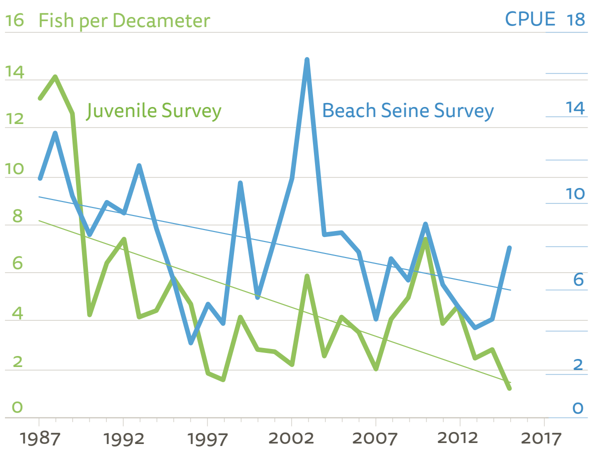
Atlantic Sturgeon



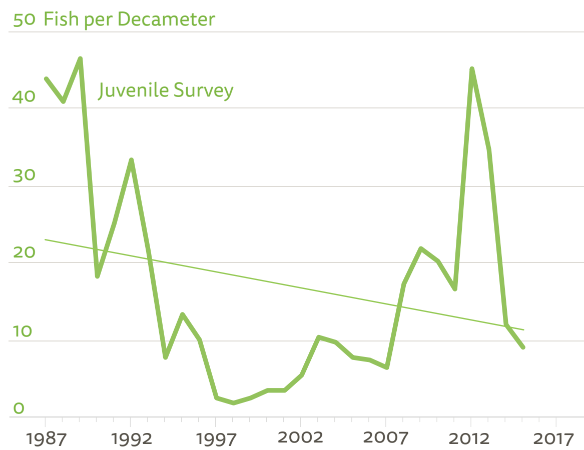
Marine / ESTUARINE FISH ABUNDANCE

Estuarine Fish

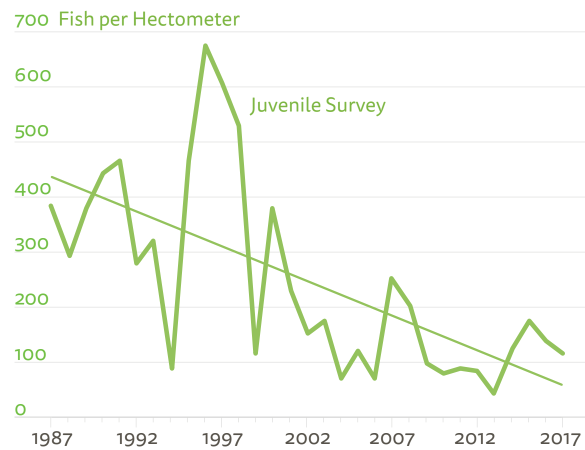
White Perch



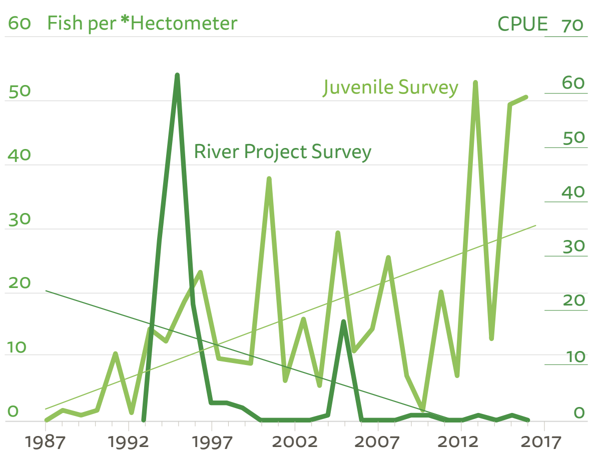
Hogchoker



White Catfish



Atlantic Silverside

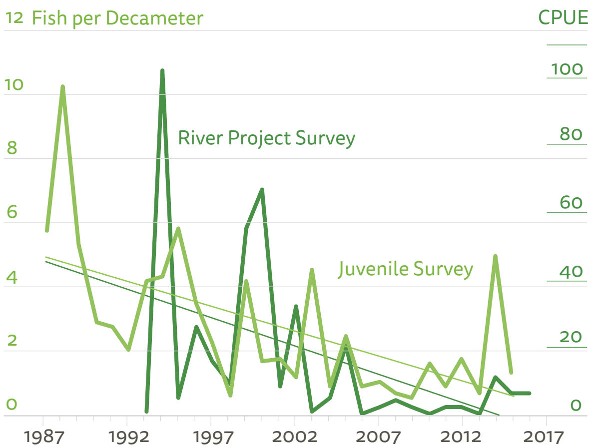


Data sources: Hudson River Utilities Fall Shoals Juvenile Survey: 1987–2015, units: catch per hectometer of water sampled for Atlantic silverside and white catfish, catch per decameters of water sampled for all others. Utilities Beach Seine Survey: 1987–2015, units: catch per number of seine hauls per year. The River Project Fish Trapping Survey: 1993–2016, units: catch per total number of traps.

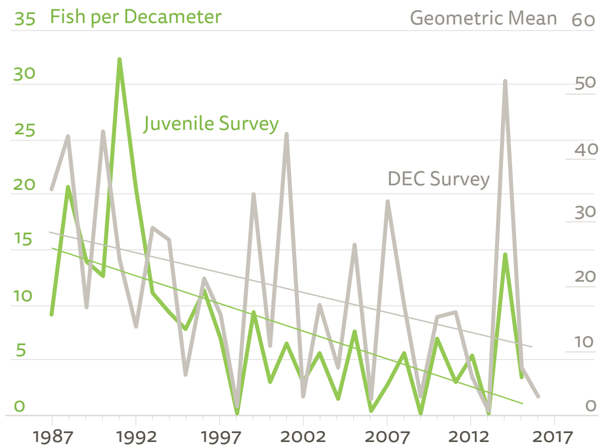
Marine / ESTUARINE AND DIADROMOUS FISH ABUNDANCE

Diadromous Fish

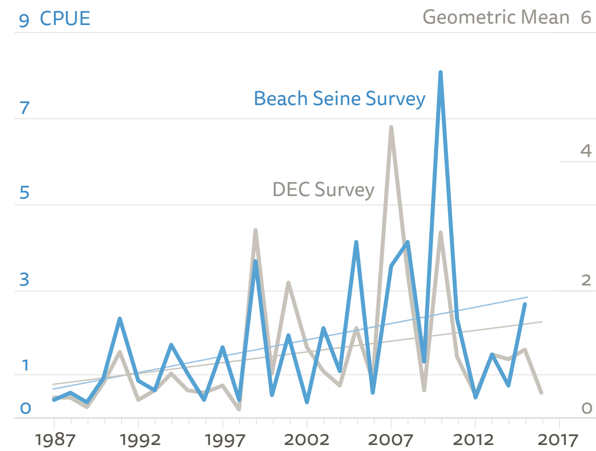
Striped Bass



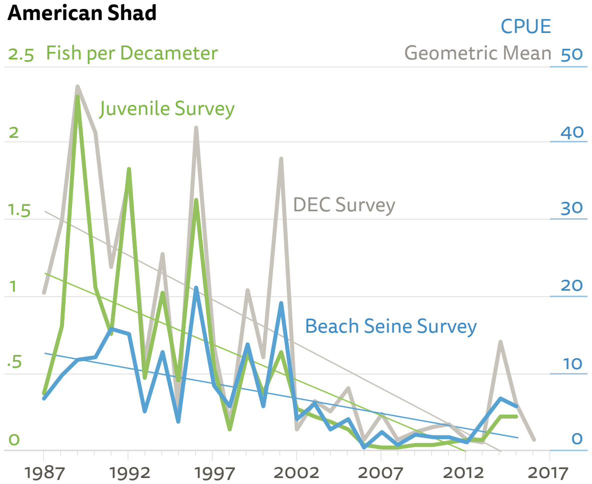
Blueback herring



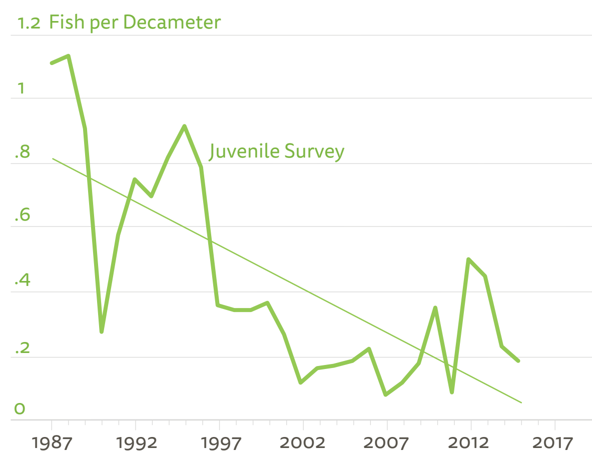
Alewife



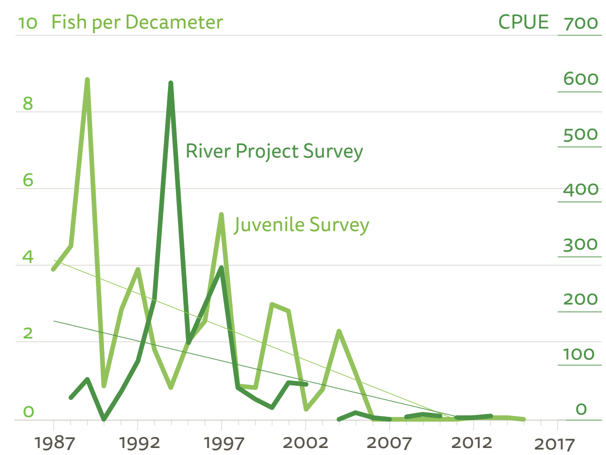
American Shad



American Eel



Atlantic Tomcod



Data sources: Hudson River Utilities Fall Shoals Juvenile Survey: 1987–2015, units: catch per decameters of water sampled. Utilities Beach Seine Survey: 1987–2015, units: catch per number of seine hauls per year. The River Project Fish Trapping Survey: 1993–2016, units: catch per total number of traps. New York State Department of Environmental Conservation (NYSDEC) Juvenile Anadromous Surveys for alewife, American shad, blueback herring and striped bass (1987–2016) units: annual geometric mean of all hauls; Atlantic sturgeon (2004-2016), units: mean CPUE.

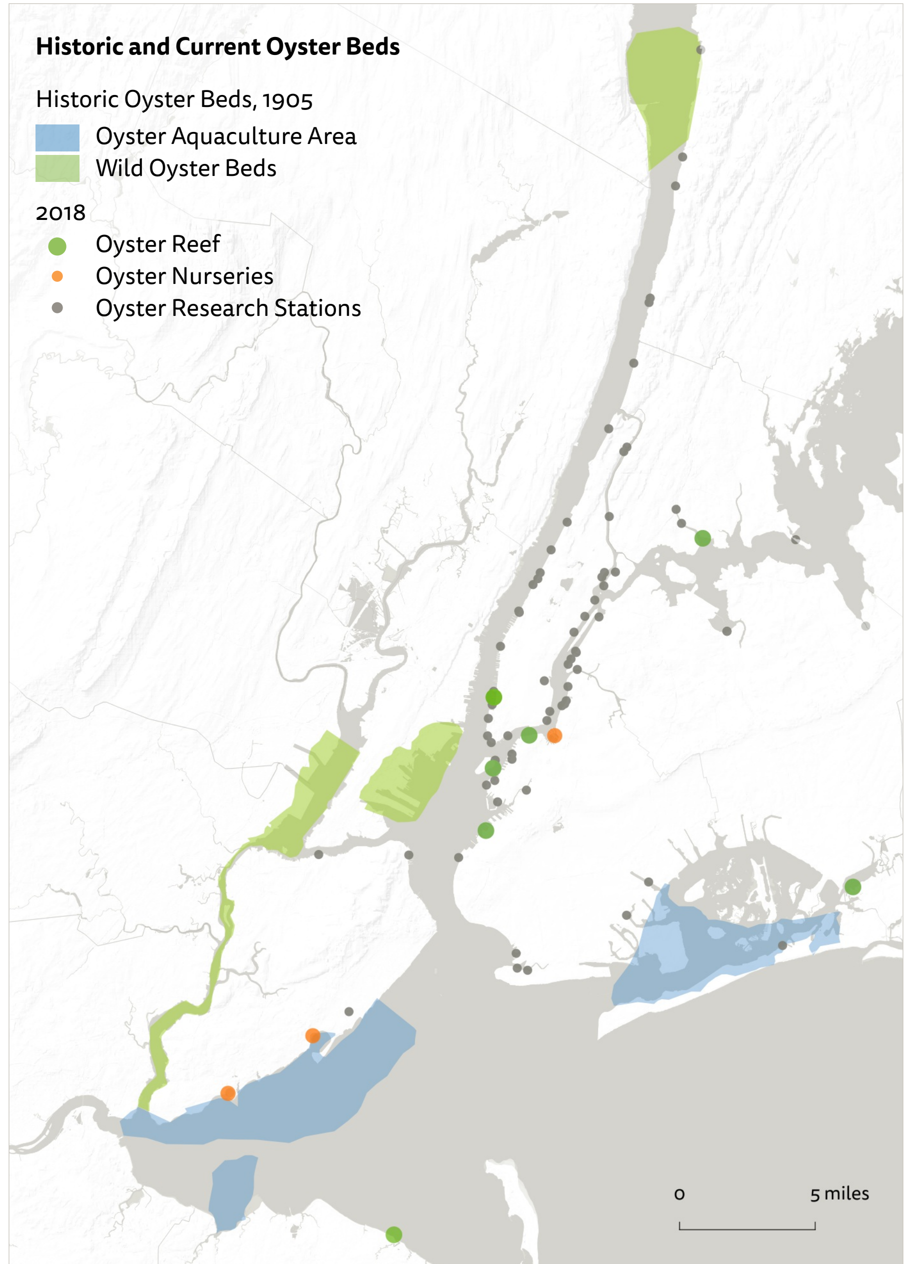
Marine

ESTABLISHED OYSTER BEDS

Background

When Henry Hudson first sailed into the New York–New Jersey Harbor in 1609, massive reefs of the eastern oyster spanned more than 35,000 acres of the harbor. Before the arrival of Dutch and English colonizers, the native Lenape people relied on oysters as a staple food for thousands of years (Birney and McNamara, 2017). In addition to supporting human populations, the oysters provided critical three dimensional habitats, similar to coral reefs, which supported hundreds of other species, such as fish, crabs, shrimp, and anemones, helping to make the Harbor Estuary uniquely productive and biodiverse (Billion Oyster Project, 2018). The remarkable capacity of oysters to clean water—one oyster can filter 50 gallons of water a day—provided additional ecosystem services to the estuary and its residents. By 1906, the combination of overharvesting, toxic pollutants, shellfish diseases, and sediment dredging in the Estuary destroyed the reefs. The population of oysters has not yet recovered.

In recent years, there has been a renewed interest in recovering the Harbor Estuary's oyster populations—not for food, but for the ecosystem services they supply. Following in the wake of Hurricane Sandy, oyster reefs are now being recognized not only for their ability to provide three dimensional habitat and filter water, but also to attenuate wave action and stabilize shorelines from erosion (Coen et al., 1999). Since HEP's last State of the Estuary Report in 2012, the number and scale of oyster restoration projects in the Estuary has grown from small pilot scale research studies to several acre restoration efforts. Oyster restoration in New York is experiencing increased governmental and private investment. The local academic community has embraced oyster research resulting in more advanced information regarding disease, genetics and habitat suitability. Public interest has also been piqued resulting in greater oyster stewardship and education programing.



Data sources: Billion Oyster Project, NY/NJ Baykeeper, Hudson River Park Trust. Historic areas interpreted by the Hudson River Foundation from the Report of the New York Bay Pollution Commission, 1905.

Marine / ESTABLISHED OYSTER BEDS

- Long Term Trend: Insufficient Data
- Short Term Trend: Insufficient Data

Oyster populations are rebounding in the Estuary, but these mollusks still face a host of challenges. Due to the history of dredging and sediment removal in the Harbor Estuary, bottom substrate is likely different than in the past, making the growth of large oyster reefs challenging. Ironically, the same adaptations that allow oysters to filter water also make them highly susceptible to toxic contamination and disease. Furthermore, combined sewer overflow (CSO) events continue to contaminate the harbor. Sewage, excess nitrogen, heavy metals, and Polychlorinated Biphenyls (PCBs) all make their way to the Hudson-Raritan Estuary from CSOs, contaminating the water and making oysters more stressed and susceptible to disease (Medley, 2010). The lack of a viable natural population to build from continues to challenge restoration practitioners in much of the Estuary and leaves the goal of restoring self-sustaining populations still unfulfilled.

Water quality in the harbor has improved immensely since the passage of the Clean Water Act in 1972, creating waters capable of supporting larger oyster populations. Wild oysters are still found in lower densities throughout the harbor and notably, a giant oyster was found underneath Pier 40 in the lower Hudson in July 2018; at 8.9 inches, this is the largest wild oyster seen in the Estuary in over a century and is likely more than 14 years old (The River Project, 2018). One promising area is near the Mario Cuomo (Tappan Zee) Bridge in the Hudson. Here a natural and possibly self-sustaining population, spanning tens of acres has recently been identified and a study to optimize a restoration project showed annual natural recruitment. In 2018, the largest restoration project to date, a five-acre project consisting of large reef balls and oyster shell gabions, was completed. Many other restoration and research projects exist throughout the Harbor Estuary, most of which are collaborative partnerships that bring together public agencies, non-profits and academia.

Photo: Melissa Rex, The River Project

Marine

Long Term Trend: Insufficient Data

Short Term Trend: Insufficient Data

WHALES AND DOLPHIN ABUNDANCE

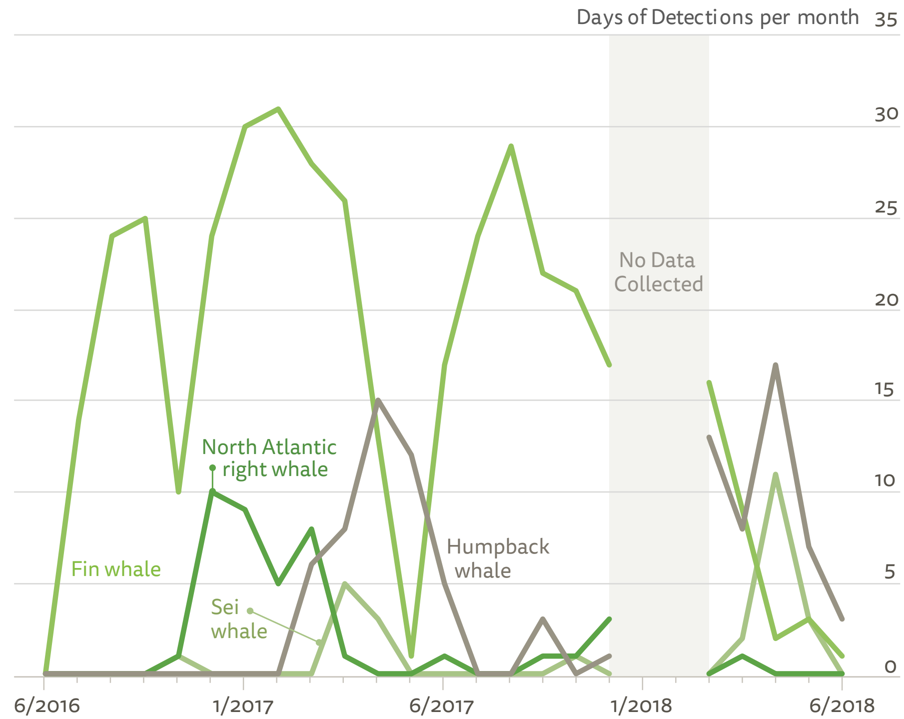
Background

Whale and dolphin sightings appear to be increasing in offshore waters and potentially in the Harbor Estuary. Recent sightings of whales in the harbor captured media attention and New York City's whale watching operations are logging more sightings every year (Gotham Whale, 2017). However, there is very little baseline scientific data on whale and dolphin presence or relative abundance in our estuary, and several years of data are needed before we can analyze trends.

For some species, such as humpback whale, there may be a relationship between their presumed increase in presence and an increase in the abundance of their prey species, a fish called Atlantic menhaden. Recent sightings by scientists, fishermen and others on the water, do often coincide with whales that are feeding or seem to be chasing a school of Atlantic menhaden.

There are more whales in the area than previously thought. Researchers from the Wildlife Conservation Society (WCS) and Woods Hole Oceanographic Institute have placed an acoustic buoy in the New York Bight (approximately 16 miles from Sandy Hook NJ) that records underwater ocean sound and can automatically detect the vocalizations of four different species of whale. With support from the Hudson River Foundation, researchers from WCS and Cornell University have just started a new research project in the summer of 2018, placing a series of acoustic recording units, this time much closer to shore and up into the lower Harbor, to listen for whales and dolphins as well as track the noise pollution that may interfere with their health and navigation.

Whale Detections



Data source: WCS and Woods Hole Oceanographic Institute. See https://blueyork.org/.

Marine / WHALES AND DOLPHIN ABUNDANCE

A second monitoring effort was conducted between March of 2017 and February of 2018 by the NYSDEC. They conducted monthly aerial surveys of the area from the south shore of Long Island to the continental shelf, to estimate the density and abundance of North Atlantic right whales, fin whales, humpback whales, sei whales, sperm whales, and blue whales in the 43,449 square km that make up the New York Bight. They found a total of 73 sightings of North Atlantic right, fin, humpback, sperm, and blue whales; 321 sightings were of other marine mammals such as dolphins and beaked whales, and a further 562 sightings were of sea turtles, sharks, rays or fish. These monthly surveys will continue through 2020, and will help to characterize our understanding of whale abundance, distribution, and behavior in the New York seascape.

Despite federal protections for whales and seasonal vessel speed restrictions (in particular for the endangered North Atlantic right whale), the full scope of how these large creatures interact with our busy estuary is not well understood. Boat strikes, noise pollution, and offshore wind, oil and gas exploration could have effects on the health of marine mammal populations. With increased monitoring and knowledge about marine mammal presence and movements throughout the various seasons, managers and scientists should have a better understanding of how to mitigate against impacts from the competing uses of Harbor Estuary waters.

Photo: Artie Raslich, Gotham Whale

Riparian Habitat

Long Term Trend: Insufficient Data

Short Term Trend: Insufficient Data

The tributaries in the Hudson-Raritan watershed are critically important habitat for migratory fish such as herring that use them to spawn. Many other wildlife species also use these streams and surrounding forests, fields, and wetlands for laying eggs, drinking, bathing and feeding. Riparian areas, which include streambanks and floodplains, contain unique vegetation, readily available nutrients, and a variety of habitat types, making them extremely biodiverse ecosystems. Dam construction, erosion, pollution, and development threaten the biodiversity and health of riparian areas, making them an important focus for conservation action.

TRIBUTARY HABITAT CONNECTIVITY

Background

In an effort to control water for milling, industrialization, road creation and other development, more than 2,000 dams and 10,000 roadway culverts have been installed on tributaries in the Hudson-Raritan watershed. Most dams and many culverts are too tall or poorly designed to allow fish to navigate over or through them, dramatically reducing available habitat crucial for spawning, foraging, and nurseries. Of particular concern is the impact on native migratory fish: Anadromous species, including the American shad, blueback herring, alewife, and striped bass, are born in the estuary, live most of their lives at sea, and return to the tributaries to spawn. The Estuary's only catadromous species, the American eel, is born at sea and spends most of its life in tributaries. The blueback herring, alewife, and American eel have been candidate species for protection under the United States Endangered Species Act, making their protection and safe passage through tributaries of the watershed even more vital. Studies have shown that the longer the stretch of connected stream habitat, the more resilient those ecosystems will be to climate change (NYSDEC, 2018).

Photo: Esopus Creek, Ulster County, NYSDEC

Riparian / TRIBUTARY HABITAT CONNECTIVITY

Increasing habitat connectivity of Hudson and Raritan River tributaries can occur through dam removal, installing fish ladders or other devices that allow fish passage over dams, and resizing or reshaping culverts. Many of these dams have outlived their usefulness and are expensive to maintain. Many culverts are undersized given changing watershed and climate conditions. In an effort to increase tributary habitat connectivity for fish passage, USACE, National Oceanic and Atmospheric Administration (NOAA), The Nature Conservancy (TNC), NYSDEC, NYC Department of Parks and Recreation (NYCDPR), and other agencies and non-profit organizations are working to prioritize dams and culverts for removal or resizing for fish passage. Landowner permission, environmental review, and evaluation of how the community uses the barrier are essential next steps.

Dam and Culvert Removal / Right-Sizing

1. 2011
Calco Dam Removal
Opened 10 miles of habitat

2. 2012
Roberts Street Dam Removal
Opened 2 miles of habitat

3. 2013
Nevios Dam Removal
Opened 6 miles of habitat

4. 2014
182nd Street Dam Fish Ladder Installation
Opened 0.8 miles of habitat

5. 2016
Ancram Culverts Replacement
Opened 3.6 miles of habitat

6. 2016
Shapp Pond Dam Removal
Opened up 5 miles of habitat

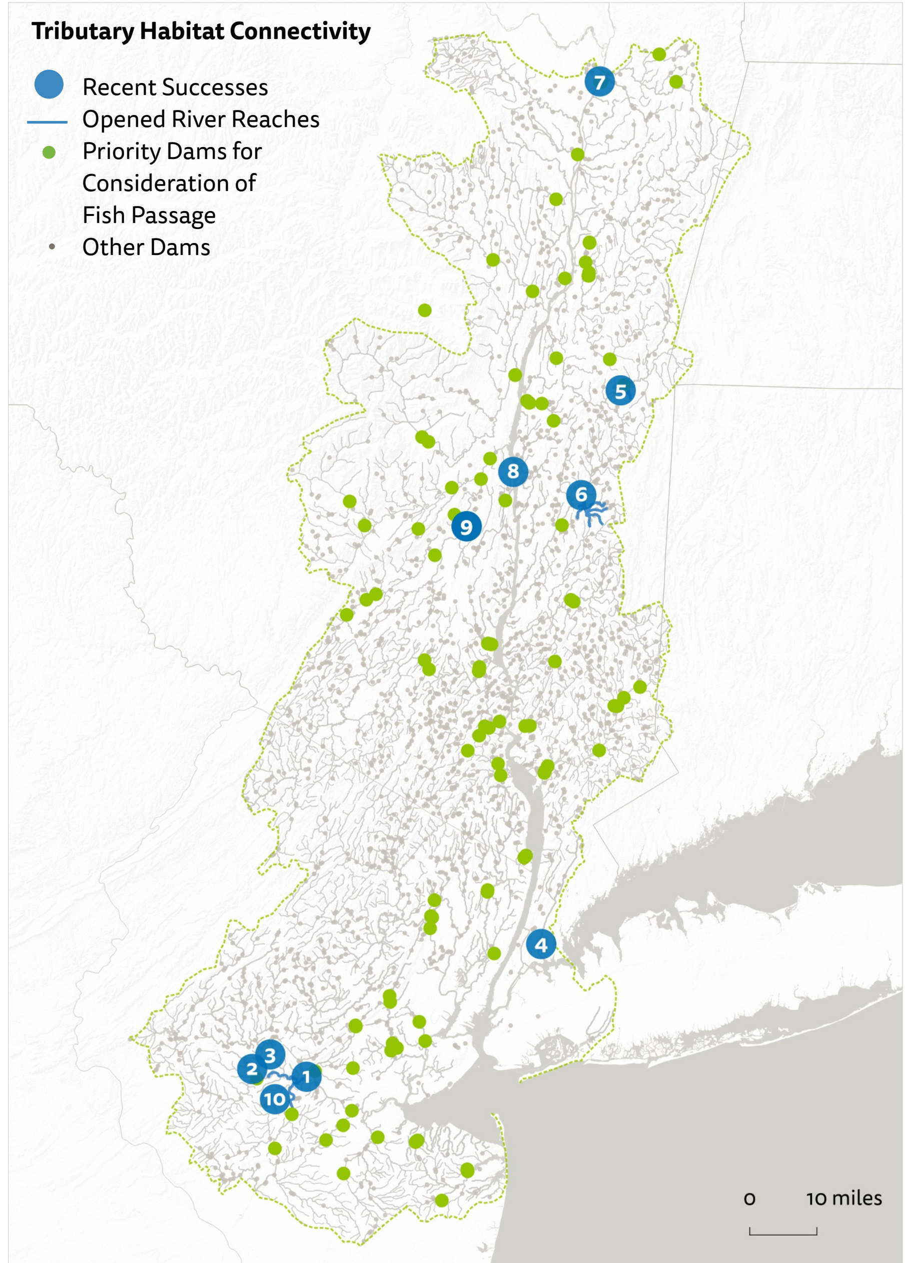
7. 2016
Wyants Kill Tidegate Removal
Opened 0.25 miles of habitat

8. 2017
Klyne Esopus Kill Culvert Replacement
Opened 0.8 miles of habitat

9. 2017
New Paltz Culverts Replacement
Opened 0.1 miles of habitat

10. 2017
Weston Mills Dam Removal
Opened 4.7 miles of habitat

This map highlights some recent successes in tributary habitat connectivity by HEP's partners. Potential dams for fish passage in New York were identified by NOAA, Partners Restoring the Hudson, the NYSDEC and Cornell University; New Jersey dams were identified by the USACE as part of their analysis for the Hudson-Raritan Estuary Comprehensive Restoration Plan.



Data sources: NYSDEC and Cornell University, Aquatic Connectivity and Barrier Removal Project. Raritan River Fish Passage Initiative. USACE, Comprehensive Restoration Plan. NJDEP.

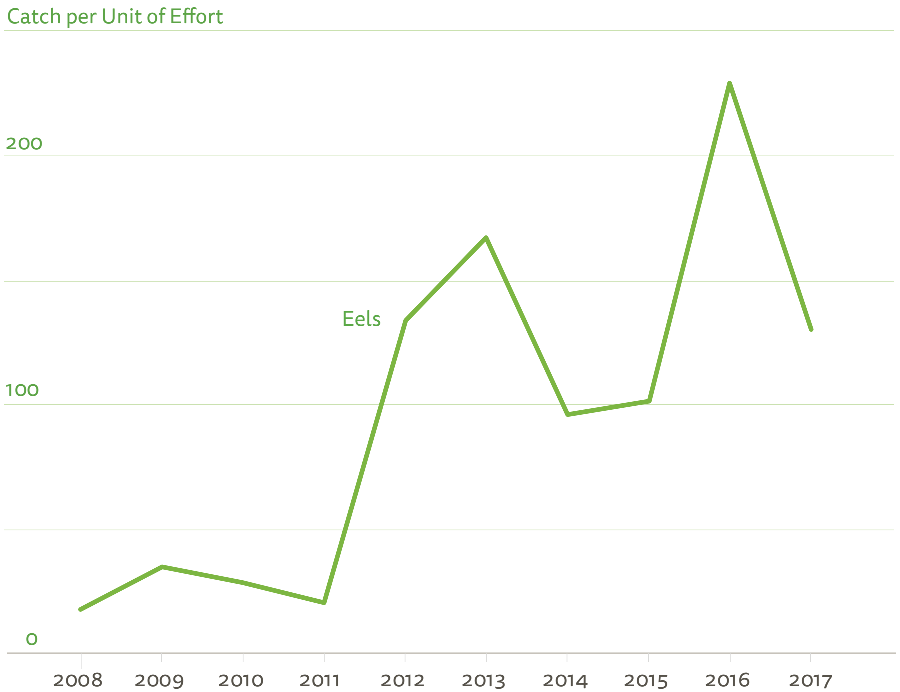
Riparian / TRIBUTARY HABITAT CONNECTIVITY

American Eels

The American eel is an Atlantic Ocean-born catadromous fish that migrates to North American estuaries, including the Hudson-Raritan Estuary, as small, transparent "glass eels" each spring. American eel are an important prey species for many fish in the Estuary. Once an important commercial fishery, the stock of American eels is historically low due to overfishing, habitat loss, changes in food web dynamics, environmental changes, poor water quality, and disease (ASMFC, 2018). The American eel is listed as endangered on the IUCN Red List.

Because American eel have complex and changing habitat requirements throughout their various life stages, they are a good indicator of estuary health. Recent data from an ongoing monitoring program by the NYSDEC found American eels are caught in their tributary monitoring stations in increasing numbers. Awareness of the benefits of stream connectivity, coupled with dam and culvert mitigation across multiple East Coast states, may be of great benefit to this depleted species. Other factors that may affect abundance could include habitat restoration efforts, such as streambank plantings, improved water quality, commercial fishing restrictions, and more abundant prey species (USFWS, 2001).

American Eel Catches & Stations



American eel total annual CPUE (the number of eels caught per day, averaged across all collection sites), 2008–2017 (NYSDEC American Eel Research Project).

Data source: NYSDEC American Eel Research Project. Photos: Chris Bowser, NYSDEC.

Riparian

Long Term Trend: Insufficient Data

Short Term Trend: Deteriorating

RIPARIAN AREA INTEGRITY

Background

The forests and grasslands along rivers and streams, including streambanks and floodplains, improve water quality by filtering out toxins and excess nutrients, keep waters cool, and provide food for aquatic organisms (USDA, 2018). The health and integrity of these riparian areas is directly correlated with aspects of stream health including flow regime and water quality (Snyder et al., 2003).

Analysis

Changes in land cover over time (2001–2011) were used to characterize 150 feet of riparian area around all major streams in the Hudson-Raritan Estuary watershed. Negative changes included the conversion of natural habitats (forests, grasslands or wetlands) to developed land, barren land, open water, pasture, or cropland. Positive changes included the conversion of these more urban and agricultural uses to forests, wetlands or grasslands.

HEP's Partners Role

In 2018, the New York Natural Heritage Program launched the Statewide Riparian Opportunity Assessment in support of NYSDEC's Trees for Tribs program. The goal of the assessment is to help identify and prioritize riparian sites for restoration and protection by packaging geographic data into an online mapping system that will allow conservationists to view comprehensive information about riparian areas. The data in the assessment includes indicators of ecological health and stress, including land use, water quality, and erosion potential and habitat potential. With the assessment's database, scientists will be able to conserve important species and habitats, improve water quality, and enhance ecosystem resiliency, thereby increasing the overall health of riparian areas throughout New York State and the Harbor Estuary.

Change in acres of natural riparian habitats (forested, grassland, wetland) from 2001–2011:

Developed land	Barren Land	Pasture	Cultivated Crops	Open Water
1,212	25	4	7	81

Change in acres of developed (high, medium or low intensity) or barren land, pasture, cropland from 2001–2011:

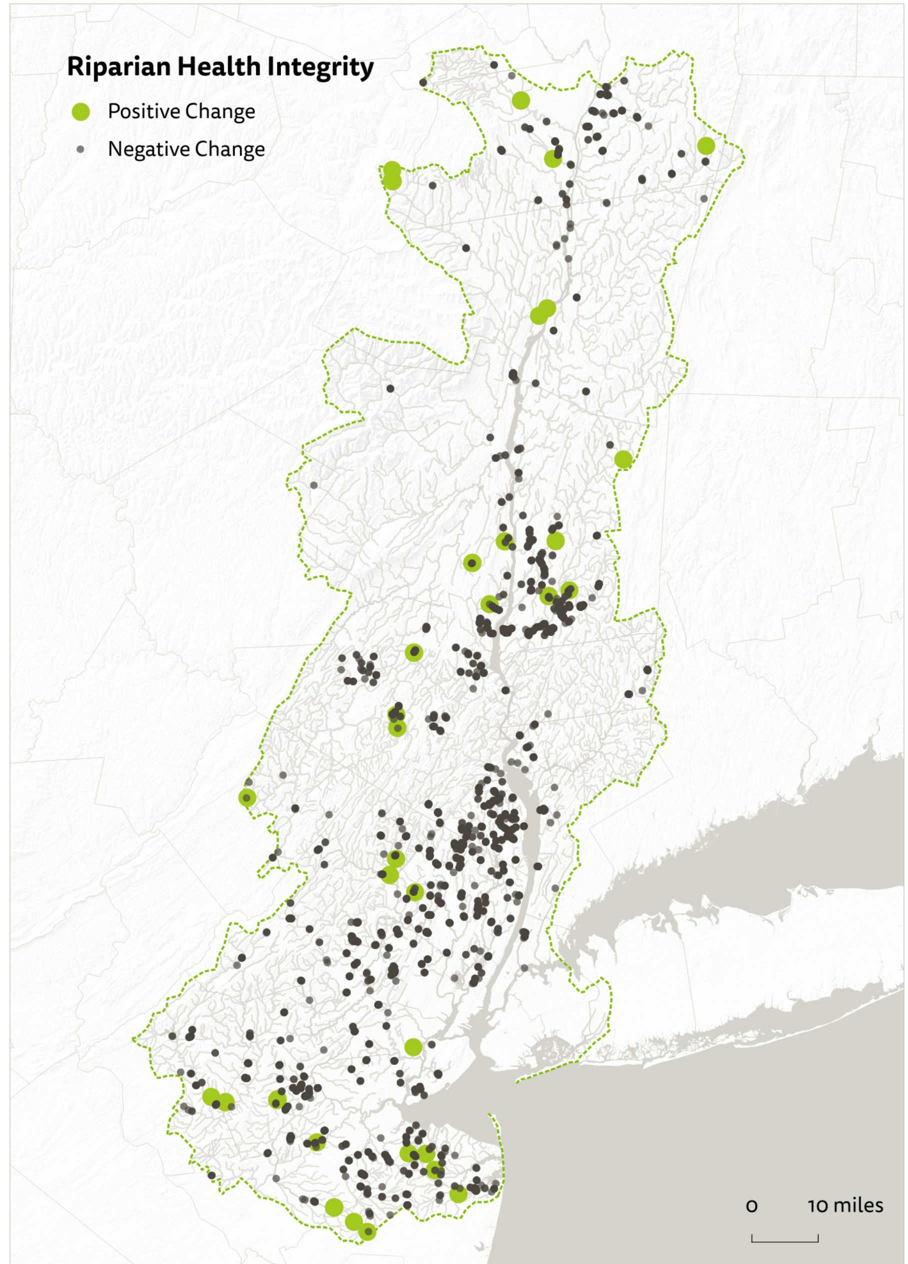
Forest	Wooded wetlands	Herbaceous wetlands	Grassland	Scrub/shrub
10	5	7	3	1

Data Sources: USGS National Land Use Land Cover Dataset

Riparian / RIPARIAN AREA INTEGRITY

Findings

Development is continuing to occur up to the water's edge: forests, wetlands and other vegetated lands in these critical riparian areas are being converted to urban uses throughout the Estuary at an average rate of 122 acres per year. Less than three acres per year of riparian areas are revegetating. The areas exhibiting the most negative change in riparian area are in Monmouth and Bergen counties in New Jersey and Rockland, Dutchess, and Rensselaer counties in New York. These findings are likely an underrepresentation of this problem given that only the largest streams were used in this analysis. Development around smaller and intermittent streams is even more likely to occur as they are less regulated. Moreover, smaller streams are more vulnerable to the stressors associated with not having a riparian buffer.



Data source: USGS National Land Use Land Cover Dataset

Riparian

Long Term Trend: Improving

Short Term Trend: Insufficient Data

STREAM HEALTH BIOASSESSMENT

Background

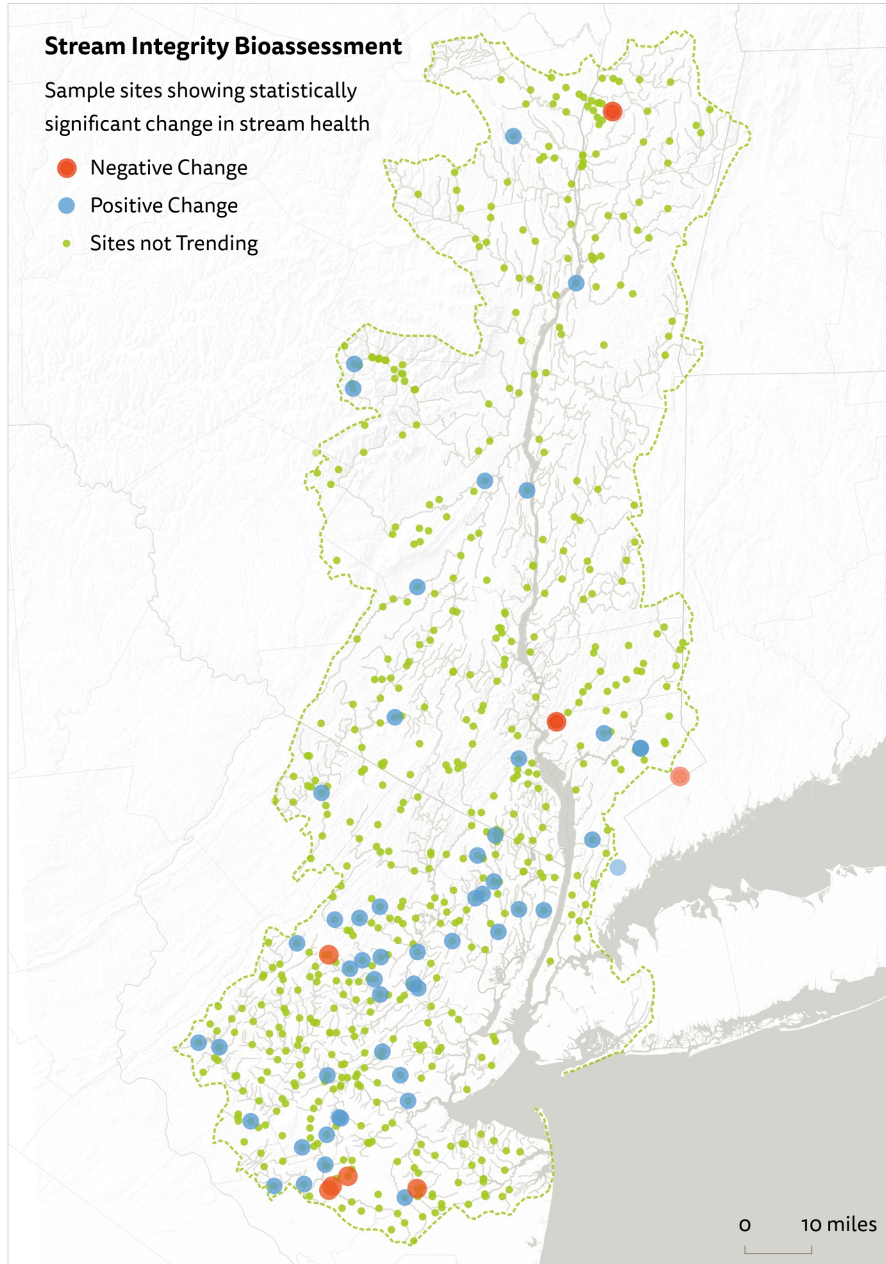
One way that scientists determine the health of streams is by surveying the aquatic macroinvertebrates, underwater organisms that are large enough to be seen with the naked eye including insect larvae and crayfish, that live in a stream sediments. The diversity of species present as well as their pollution tolerance and abundance can help inform us about the environmental condition of the stream. As macroinvertebrates make up the base of the food web in these systems, this indicator can be used to make assumptions about the habitat quality for fish, amphibians and other wildlife.

Analysis

Both New York and New Jersey operate long term programs sampling invertebrates in tributaries. The abundance and community structure of the organisms in the sample is evaluated and given a numeric score rating the habitat condition from poor to excellent. The analysis for this report consisted of comparing those scores over time. The NJDEP Ambient Macroinvertebrate Network (AMNET) dataset has approximately five samples per site taken from 1994–2013 and the NYSDEC Stream Biomonitoring Unit has one to seven samples per site from 1989–2015. Statistically significant trends were looked for on a site-by-site basis.

Findings

Stream health is improving in the entirety of the Hudson-Raritan Estuary. Possible reasons for this improving health include decreasing pollution and proactive habitat restoration. One notable exception is the lower Raritan area in Middlesex and Monmouth Counties. This area has the most sampling stations with declining scores. This area also had low recent condition scores overall.



Data sources: NJDEP Ambient Macroinvertebrate Network. NYSDEC Stream Biomonitoring Unit, Rotating Integrated Basin Study

Shorelines and Shallows

Long Term Trend: Insufficient Data

Short Term Trend: Insufficient Data

The shallow water at land's edge is an important and biologically productive area for fish and wildlife. Aquatic animals use it to spawn. Juvenile fish seek a refuge from predators in shallow waters. Nutritional sources are more plentiful near the shore. Terrestrial animals and birds are drawn to shorelines for foraging, fishing, temperature regulation and nesting. Many of our estuary's charismatic species thrive at the interface of water and land, including turtles, shorebirds and crustaceans.

PERCENT AND DISTRIBUTION OF NATURAL SHORELINES

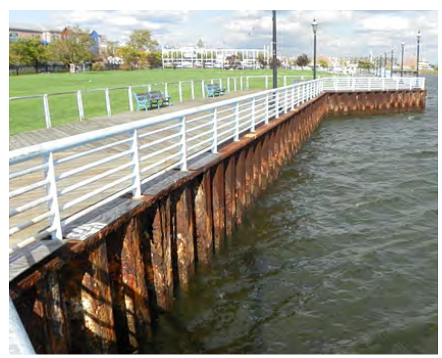
Background

Natural shorelines are those that existed prior to human development, including the naturally rocky shorelines sometimes found along the Hudson River as well as shorelines that have been restored or "naturalized" following previous shoreline development. In the lower part of the estuary, natural shorelines are often characterized by a shallow well-lit nearshore area, a gently sloping intertidal area, and a vegetated adjacent upland (USACE 2016). Intertidal areas include many critical habitat types: low marsh wetlands only exist in intertidal areas, sandy beaches are critical for nesting and foraging areas for birds, horseshoe crabs and turtles, mudflats are important for birds, crabs and shellfish.

As our waterfronts were developed, much of the shoreline was hardened with bulkheads (retaining walls) or riprap (slopes made of boulders) in order to stabilize it for nearshore development or shipping infrastructure. Shoreline hardening allows wave and current action to limit settlement of sediment, deepening the nearshore areas and decreasing the extent of intertidal areas available to wildlife. Nearshore areas are also dredged for maritime use. Because of their ecological value and relative scarcity in this urbanized estuary, natural shorelines and associated intertidal areas are critically important habitat.

Analysis

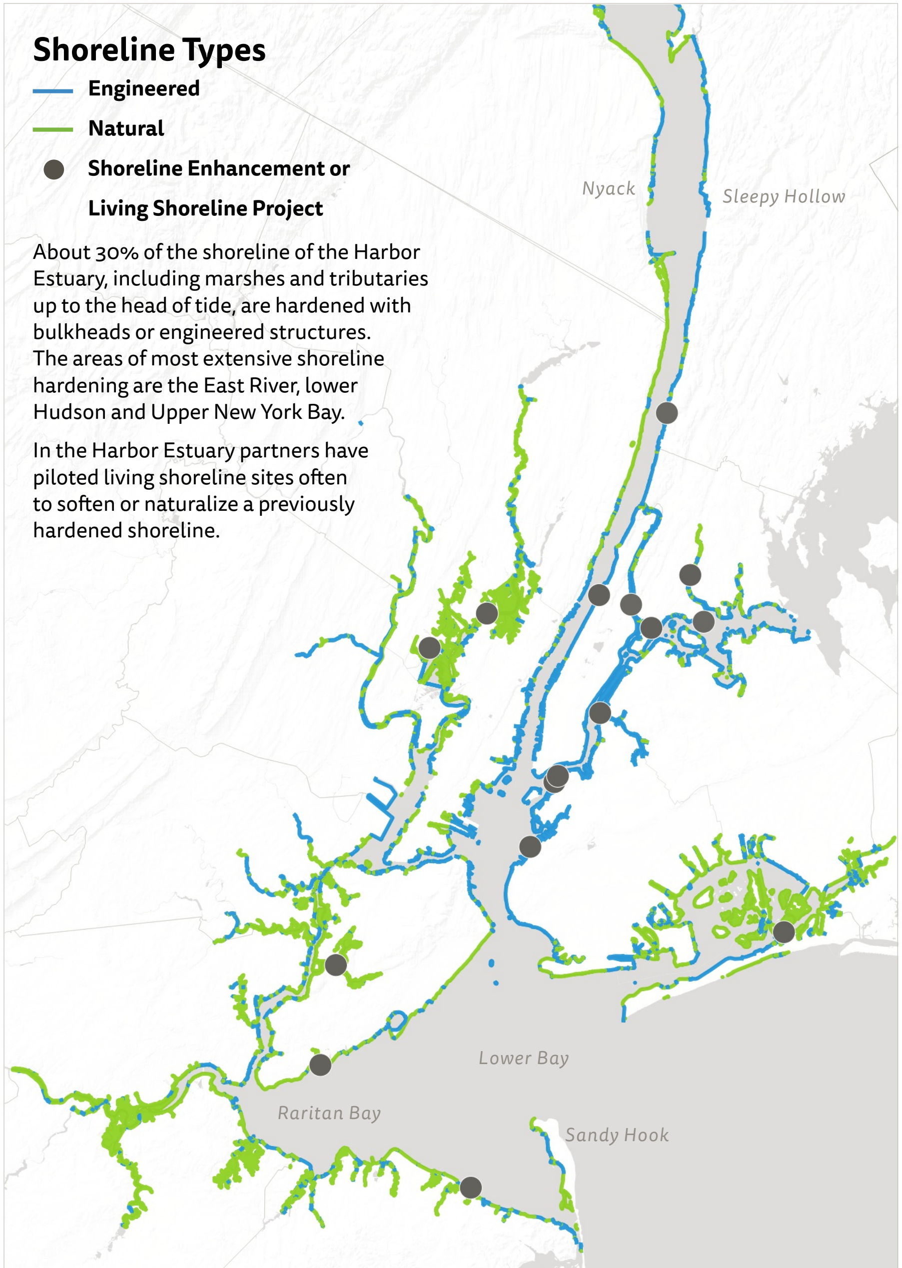
There is little data showing changes in shoreline type with time, but a compilation of a current baseline data set of shoreline type is useful for tracking further changes and prioritizing shoreline restoration or protection. A map created from the NOAA National Geodetic Shoreline Survey was updated with more recent data, where available, from Rutgers University scientists as well as the NYC Economic Development Corporation Waterfront Facilities Maintenance Management System. The Hudson River National Estuarine Research Reserve and NYSDEC also mapped and shared shoreline type for the Hudson River.



Examples of riprap, soft shoreline and bulkheads.

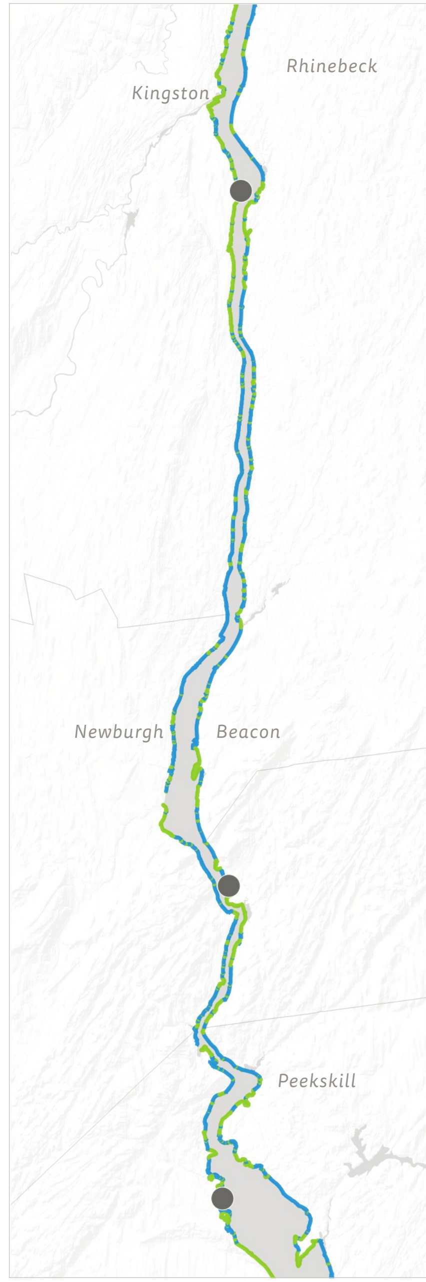
Photos: Isabelle Stinette and Future City Inc.

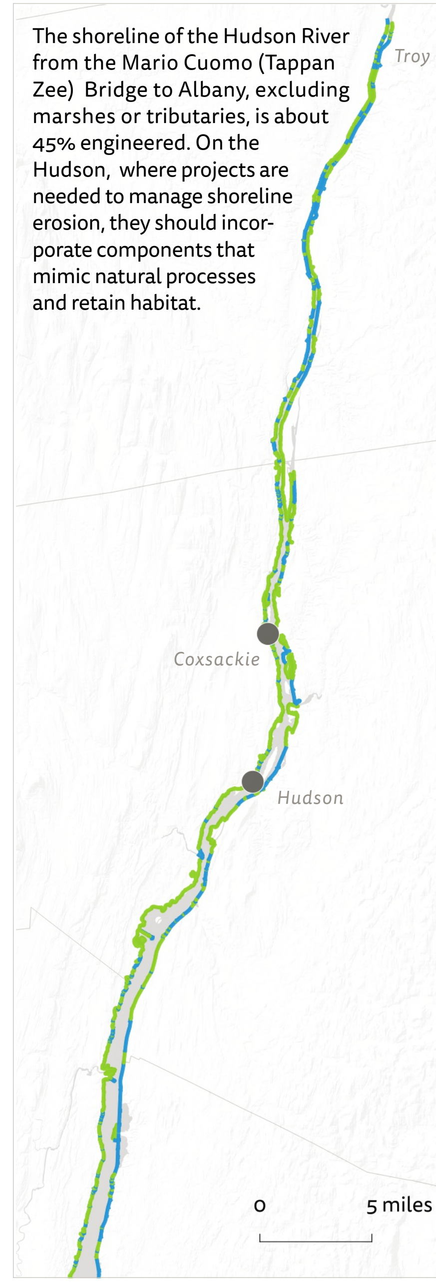
Shoreline Types



About 30% of the shoreline of the Harbor Estuary, including marshes and tributaries up to the head of tide, are hardened with bulkheads or engineered structures. The areas of most extensive shoreline hardening are the East River, lower Hudson and Upper New York Bay.

In the Harbor Estuary partners have piloted living shoreline sites often to soften or naturalize a previously hardened shoreline.





The shoreline of the Hudson River from the Mario Cuomo (Tappan Zee) Bridge to Albany, excluding marshes or tributaries, is about 45% engineered. On the Hudson, where projects are needed to manage shoreline erosion, they should incorporate components that mimic natural processes and retain habitat.

Data sources: NOAA Geodetic Survey. Thomas Grothues, Rutgers University. NYC Economic Development Corporation Waterfront Facilities Maintenance Management System. Hudson River National Estuarine Research Reserve.

Shorelines and Shallows /
PERCENT AND DISTRIBUTION OF NATURAL SHORELINES

Our Changing Shoreline

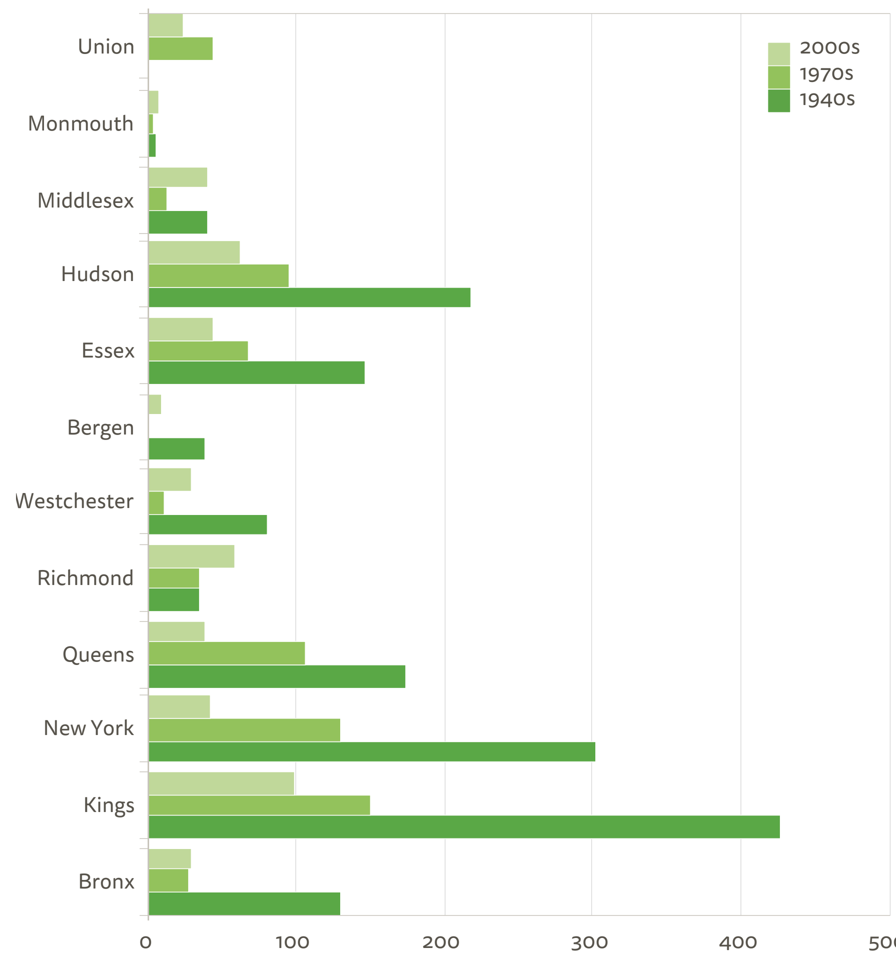
Land use analysis shows that parcels of land are usually converted from natural habitat to developed land. However, in the Harbor Estuary, there is a historical decline of the shoreline needed for piers and port facilities. This is due primarily to the invention and adoption of the shipping container, increased mechanization and other technological advances.

The effect of pier loss on habitat quality of urban shorelines is unclear. While shading devalues shallow water as forage habitat (Able et al., 1999), and piers may block fish passage under them (Able et al., 2013), they may replace some natural features such as land spits, current baffles, and overhangs that were lost to engineered shoreline straightening (Able and Grothues, 2012, Grothues et al., 2016). Some of these historic port features have collapsed, which creates a naturalized feature, for example, mimicking the way a fallen tree adds value to in-water habitats. They may also trap sediment, creating the shallow slope that is beneficial to fish (Able and Grothues, 2018). The changing shoreline land use may represent an opportunity for shoreline restoration that provides more of this rare natural shoreline habitat.

HEP Role:

Shorelines and shallow waters are one of the Target Ecosystem Characteristics outlined in HEP's Comprehensive Restoration Plan. HEP, through its restoration work group and partners such as the Hudson River Estuary Program, initiated an investigation into improving the habitat value of hardened shorelines. HEP and other partners have also undertaken a project to create a statewide protocol for New York to monitor shorelines for resilience services, including ecological function, hazard mitigation and structural integrity and socio-economic outcomes. This protocol aims to help managers make decisions about the appropriate siting of various shoreline types and the efficacy of nature-based shoreline features.

Number of Piers and Port Facilities by County



Data Sources: Smythe, T., 2009. Making Waterfronts Work: Data needs and policy recommendations for preserving water-dependent maritime land uses in New York, New Jersey and Connecticut. Regional Plan Association.

Shorelines and Shallows

Long Term Trend: Insufficient Data

Short Term Trend: Deteriorating

HORSESHOE CRAB ABUNDANCE

Background

Horseshoe crabs are one of our planet's "living fossils." They existed 200 million years before dinosaurs, and continue to be a key species in our ecosystem and human community. They are an important part of the estuary's food web, as their eggs feed migratory shorebirds including the endangered red knot. Historically, horseshoe crabs were overharvested as bait, and harvest for their blood continues to supply the medical industry with a critical component for testing contamination of pharmaceuticals and surgical supplies. Horseshoe crabs tend to have localized populations and return to the same embayments where they were spawned.Thus, shoreline habitat degradation or loss threatens this species.

Horseshoe crab abundance is a good indicator of shoreline habitat quality because they are a key species, and also because they highlight a critical and uncommon habitat. Horseshoe crabs nest on gently sloping sandy intertidal shores: shallow nearshore areas intermittently covered and exposed by the tide. This same habitat is also used by turtles, shorebirds, and marine mammals such as seals. Because of historic shoreline armoring for nearshore development and shoreline protection, there is limited intertidal habitat remaining in the Harbor Estuary. Botton et. al (2006) suggest that it is suitable habitat that controls the distribution and abundance of horseshoe crabs in Jamaican Bay.

Analysis

Data from two monitoring programs were used: the NJ Bayshore Regional Watershed Council (now known as Save Coastal Wildlife), and a partnership between NYSDEC, Cornell University, and NYC Audubon. Both programs have nine years of consistent sampling data and use the same monitoring method (counts of spawning females per area). The NJ Bayshore Regional Watershed Council monitors five sites along the southern shore of Raritan Bay and the NYSDEC/Cornell/Audubon project monitors two sites within Jamaica Bay (other sites were not included in this analysis as the timeline is not consistent). While the two programs do not cover all horseshoe crab habitat in our region, Jamaica Bay represents the most important spawning location in the Harbor Estuary.

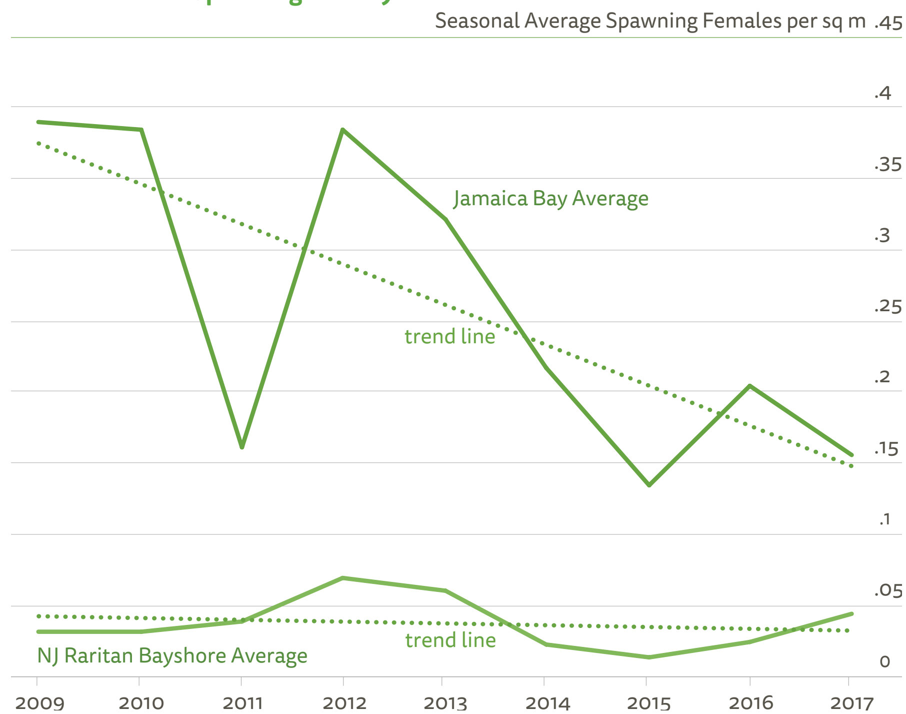
Data sources: NYC Audubon/Cornell/NYSDEC Horseshoe Crab Spawning Activity Survey. Bayshore Regional Watershed Council/Save Coastal Wildlife, Horseshoe Crab Monitoring Program.

Shorelines and Shallows / HORSESHOE CRABS ABUNDANCE

Findings

Horseshoe crab spawning abundance on the Jersey Bayshore is low but consistent. Four of the sampling sites show a similar trend in spawning activity per year, but Cliffwood Beach, the westernmost sampling location, has the largest numbers of spawning females overall. In Jamaica Bay, abundance is declining. However, scientists who conduct this monitoring caution that the Jamaica Bay trend is not likely to be indicative of the entire Estuary. Jamaica Bay has unique problems such as eutrophication, which may affect certain life-stages of the horseshoe crabs. Some of the Jamaica Bay beaches have also undergone replenishment of sand during the study period, which likely affects how horseshoe crabs use the habitat.

Index of Female Spawning Activity



Data sources: NYS Audubon/Cornell/NYSDEC Horseshoe Crab Spawning Activity Survey. Bayshore Regional Watershed Council/Save Coastal Wildlife, Horseshoe Crab Monitoring Program. Photo: Don Riepe

Shorelines and Shallows

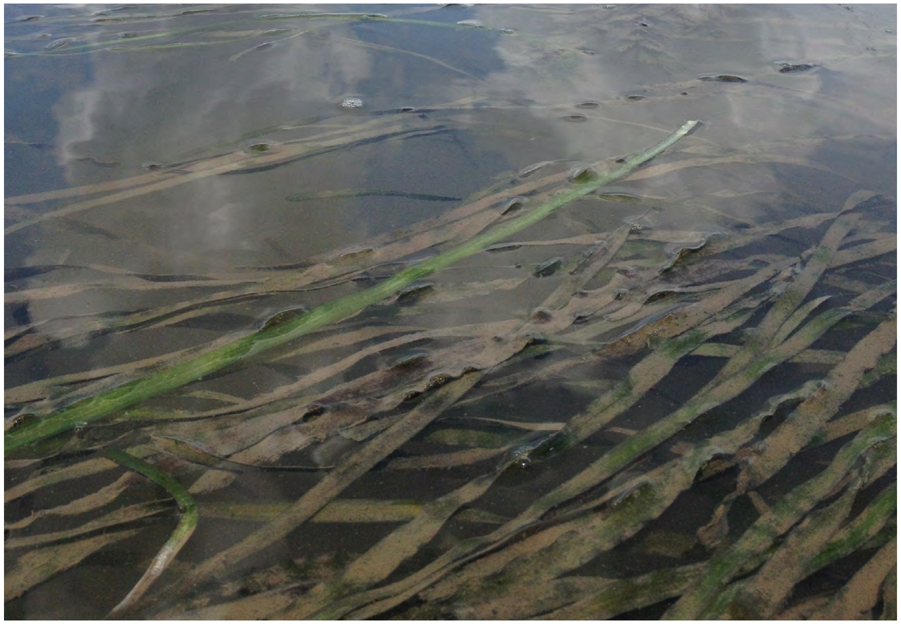
Long Term Trend: Insufficient Data

Short Term Trend: Deteriorating

SUBMERGED AQUATIC VEGETATION

Background

Submerged Aquatic Vegetation (SAV) is a productive nearshore underwater habitat that harbors a variety of fish and crustaceans and was once widespread in this estuary. In the marine section of the estuary, the dominant species is eelgrass, which has been largely extirpated due to poor water quality. SAV is sensitive to loss of light and the input of excess nutrients. Both of these conditions, as well as toxic sediments, characterized the harbor prior to upgrades in wastewater treatment (Simpson and Dahl, 2017). In the Hudson River, however, the dominant freshwater species, wild celery, has shown more resilience and large beds remain.



Analysis

SAV habitat has been monitored by the NYSDEC in the freshwater tidal portion of the Hudson River from just south of the Mario Cuomo (Tappan Zee) Bridge north to the Troy Dam. Aerial photographs of SAV are regularly taken and were used to create coverage maps for 1997, 2002, 2007, 2014, and 2016. Since 2003, volunteer monitors have also collected SAV cover data by making point observations at specific SAV beds of interest to analyze dynamics between the aerial photography collection years. In 2011, hurricanes Irene and Lee negatively affected SAV, reducing the cover by approximately 90%. Since then, monitoring data has been used to gauge the recovery of SAV to determine if restoration action is required.

Findings

Hudson River SAV maps show a decreasing trend in vegetation cover, with the greatest decrease occurring after hurricanes Irene and Lee in 2011. A 30.4% recovery in SAV habitat was seen in the 2016 maps, but the total cover of 2,748 acres is still 1,705 acres lower than the SAV mapped in the inaugural survey in 1997.

Sumberged Aquatic Vegetation Change

Map Year	Acres of SAV	Comparison years	SAV Change (acres)	SAV Change Percent
1997	4453	--------	--------	--------
2002	4350	1997–2002	-103	-2.3%
2007	3316	2002–2007	-1033	-23.8%
2014	1192	2007–2014	-2125	-64.0%
2016	2748	2014–2016	1555	30.4%

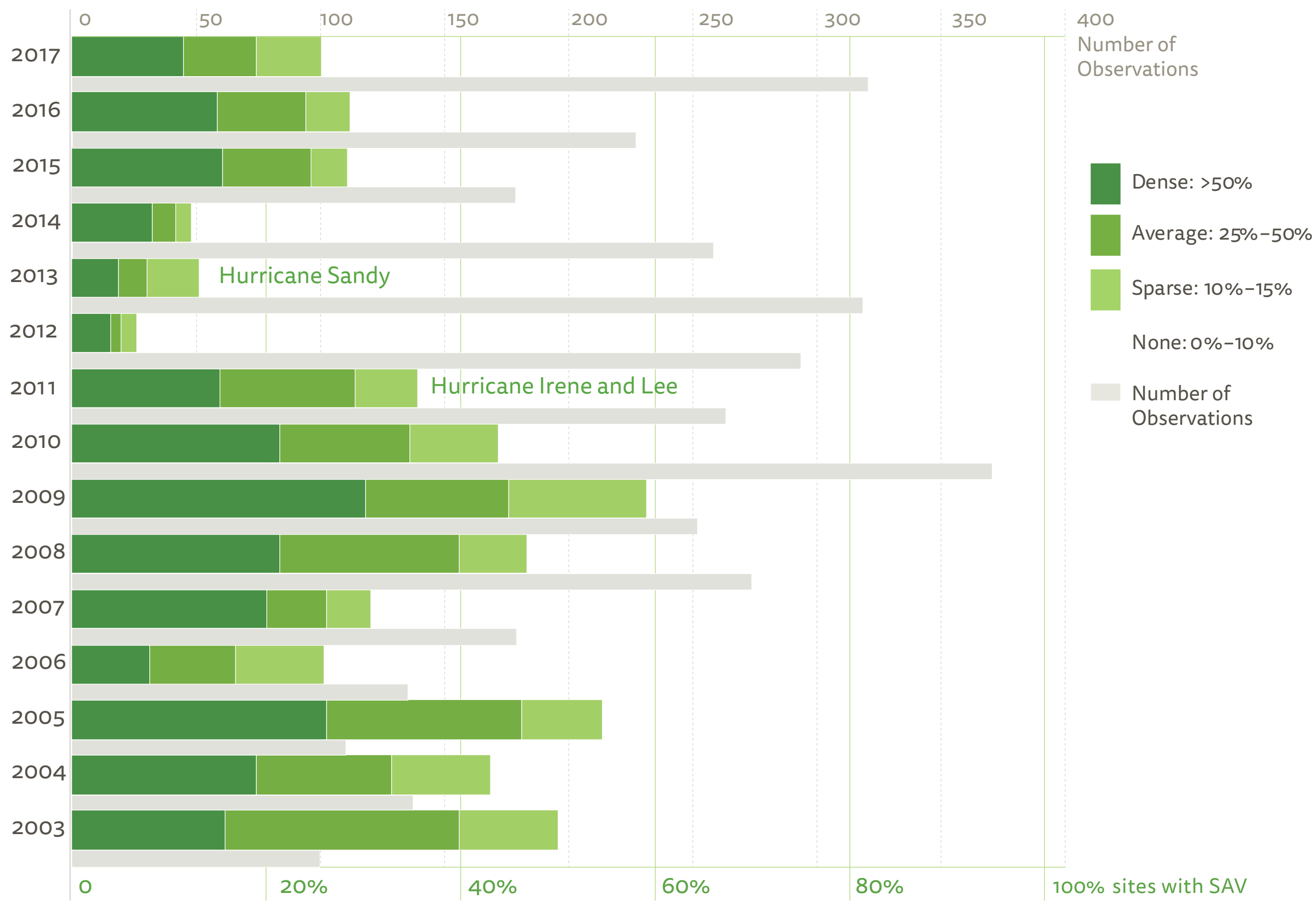
Photo: Submerged Aquatic Vegetation, Sarah Fernald.

Shorelines and Shallows / **SUBMERGED AQUATIC VEGETATION**

Hudson River SAV Volunteer Monitoring data have shown the high variability in SAV cover between the mapping inventories. The number and locations of point observation made is different every year so the Volunteer monitoring data is somewhat inconsistent. However, it is notable that since the impact of Hurricanes Irene and Lee, SAV has been present in less than 30% of the observed sites.

Point observations as well as the aerial maps point towards a rebounding population of SAV in the Hudson following the hurricanes, however it is still too soon to tell if this indicator of ecosystem health will recover. In the marine portion of the Hudson-Raritan Estuary, restoration will likely be needed to return SAV to the ecosystem.

Hudson River Estuary Submerged Aquatic Vegetation (SAV) Volunteer Monitoring Data: Point Observations of Vegetation Density



Terrestrial Habitat

Long Term Trend: Insufficient Data

Short Term Trend: Deteriorating

Terrestrial habitats are any inland and upland habitat utilized by wildlife including forests and grasslands. For the purpose of this report, we focus on those terrestrial habitats that are closest to shore and thereby most affect the Estuary: coastal forests and grasslands.

AREA OF COASTAL FORESTS AND GRASSLANDS

Background

Coastal forests, also known as maritime forests, are forests growing adjacent to the saline portion of estuaries. Along with coastal grass and shrublands, these ecosystems can be rare and even endangered. They support plants and animals that have uniquely adapted to tolerate salt spray, strong winds, and shifting underlying sands (National Biological Service, 1995), many of which are only found in coastal forests and grasslands. As people also like to live and work along shorelines, these ecosystems have often been destroyed for development. Coastal forests and grasslands are perpetually shifting due to natural fluxes in climate, storms, vegetation and the movements of the underlying sandy soils. As such, they are particularly vulnerable to sea level rise when shoreline development halts their natural migration further from the water.

Analysis

This analysis used land cover data from the USGS showing changes in the abundance of coastal forests, grasslands, and scrub-shrub vegetation between 2001 and 2011 within 600 meters of the coast. It is likely that not all of the forests and grasslands selected represent maritime forest habitat as defined by ecologists, but it is the closest approximation using the most recent land-use change data available. Lands that changed from coastal forests to other land uses were counted as habitat loss. This loss of coastal forest or grassland was summed by acreage and by what cover type replaced the lost habitat. New areas of coastal forests and grasslands were also accounted to report net loss for the period.

Findings

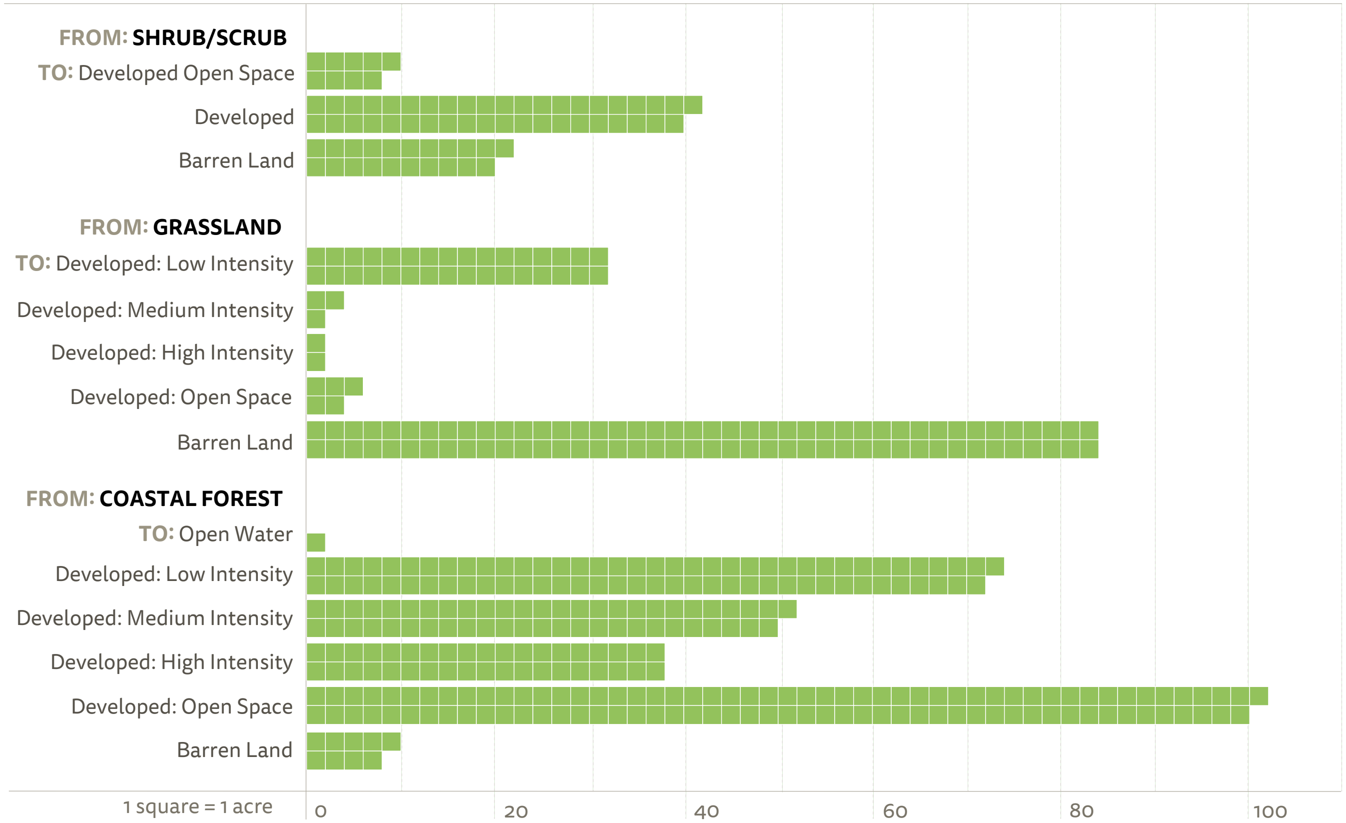
The Harbor Estuary lost 471 acres of coastal forests or grassland between 2001 to 2011, with an average loss of 47 acres per year. The most common type of loss was coastal forest converted to developed open space, such as lawns. This occurred most notably along the Hudson in Rockland County, New York and Bergen County, New Jersey and in southern Staten Island. The second most common type of loss was grassland that changed to barren land, which occurred at several landfills near the Raritan River, Kearny Point on the Hackensack River in New Jersey, and White Island in Marine Park, New York. However, some of these barren areas were revegetated subsequent to the 2011 survey. Other large areas of change were coastal forests that were converted for urban development, including in southern Staten Island, Edison New Jersey near the Raritan River, Spring Creek in Jamaica Bay, Hunts Point in the Bronx, and College Point in Queens.

Terrestrial Habitat / AREA OF COASTAL FORESTS AND GRASSLANDS

Maritime Coastal Forest and Grassland Loss

471 Total acres of coastal and maritime forest and grasslands lost from the Harbor Estuary region between 2001 and 2011

47 Acres lost per year



Data source: USGS National Land Cover Dataset (2001–2011)

Wetlands

Wetlands are either seasonally or continuously inundated with water covering the soil or sediment, such as salt marshes and freshwater swamps. Among the most productive ecosystems on earth, tidal wetlands are a critical habitat for many of the Harbor Estuary's wildlife species, providing nursery, spawning, feeding and nesting areas for fish, birds and other marine life. Wetlands provide an array of ecosystem services, cleaning the water by taking up excess nutrients, sediment, and toxic chemicals; sequestering atmospheric carbon, storing and absorbing floodwaters and, if they are large enough, protecting against storm surges.

Photo: Lemon Creek, Isabelle Stinnette

Wetlands

Long Term Trend: Deteriorating
Short Term Trend: Deteriorating

AREA OF WETLANDS

Background

Historically misunderstood and mistreated, wetlands were once thought of as mosquito-filled dumping grounds that need to be "reclaimed." More than 85% of the Harbor Estuary's historic wetlands have been lost (PlaNYC, 2012), however, federal and state regulations now help protect the remaining wetlands in the Harbor Estuary. Both New York and New Jersey now limit development in wetlands, adjacent buffers and near shore intertidal areas. However, wetland conservation has additional challenges: poor water quality can weaken marsh stability leading to erosion, and sea level rise threatens to drown many of our remaining tidal wetlands.

The low elevation of tidal marshes in the Harbor Estuary makes them one of the first potential casualties of sea level rise. Though tidal marshes are able to move upland with rising sea levels, they cannot do so when they come up against developed areas, which is the case for most of the shoreline. Tidal marshes can also keep up with sea level rise by raising their elevation but need a steady supply of sediment to do so.

Analysis

The scope of this analysis is the fresh and tidal marshes in the Harbor Estuary, the lower, more urban part of the watershed. Land use maps from the NJDEP from 2002–2012 were compared and the changes in cover type were calculated. The changes were broken down by wetland type, (e.g. salt marsh or wooded wetland), and by the land-use type that replaced the wetland area, (e.g. agriculture or development). For the New York portion of the lower estuary watershed, maps created by NOAA's Coastal Change Analysis Program (CCAP) were used to track the change in land cover from 1996–2010. The CCAP maps are nationwide with greater limitations on accuracy.

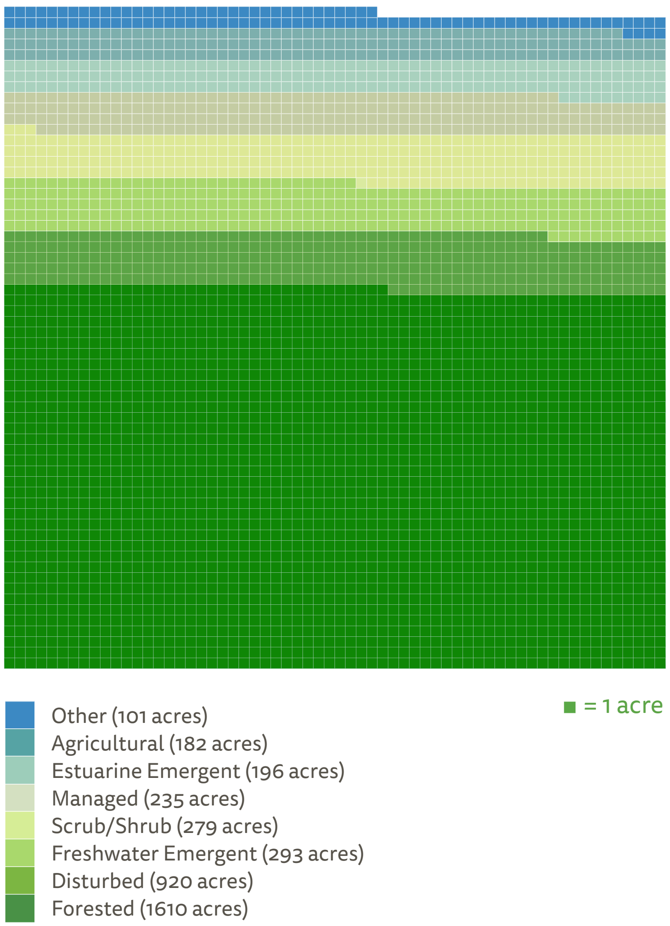
Findings

In New York, approximately 625 acres of wetland were lost between 1996 and 2010, with an average of 45 acres lost per year. Seventy-five percent of the wetland loss in New York occurred in tidal salt marshes, and was largely due to development (88%). Given the accuracy of the dataset, these New York wetland loss numbers may be an over estimation by up to 30% and a statewide wetland mapping effort in New York would allow for a better characterization of the issue going forward. In the New Jersey part of the Harbor Estuary the loss of wetlands is greater, primarily because the state had more remaining wetlands to lose; approximately 3,800 acres were lost in New Jersey between 2002 and 2012 representing a 4% loss in total wetlands. Most of the wetland loss in New Jersey occurred in forested wetlands; 68% of the wetland loss was due to urban development. About 15% of the loss reflects a conversion to open water when freshwater marshes were largely turned into artificial lakes and salt marshes were converted to nearshore unvegetated underwater areas (such as mudflats), possibly due to sea level rise. The wetland loss is the result of many small alternations: only 12% of the patches lost were greater than 2 acres in size. Importantly, a wetland has to be a certain size, which varies by location, in order to be regulated. It is clear that the Harbor Estuary continues to lose wetlands to development despite regulations designed to limit this.

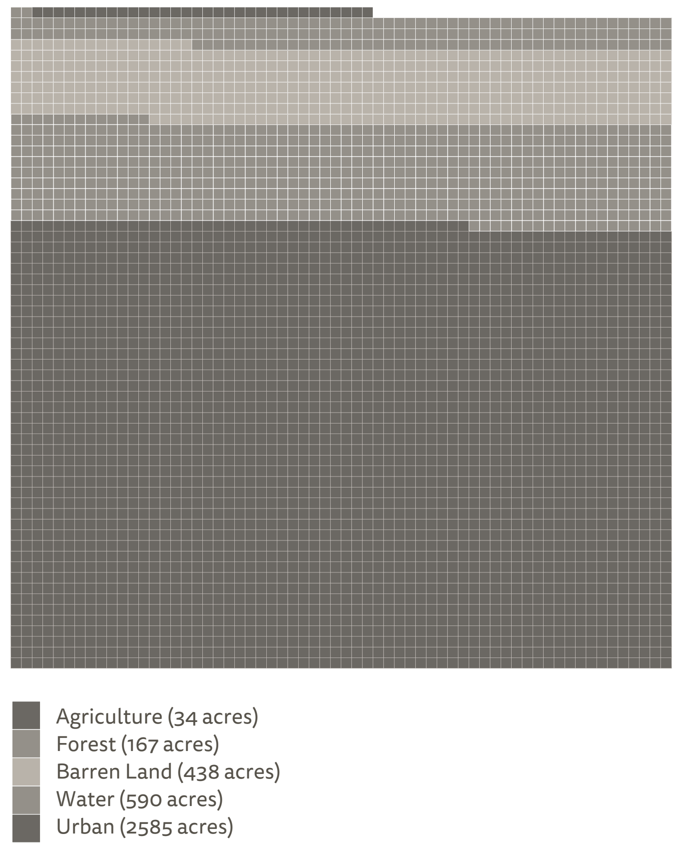
HEP has kept track of wetland restorations since 2009 as part of the Comprehensive Restoration Plan. Though over 250 acres of wetland have been restored in the Harbor Estuary watershed, only about 30 acres are restored each year, which is not enough to keep up with the rate of wetland loss. Further, wetland restoration does not always create more wetlands acreage; often restoration increases a wetland qualitatively through invasive species removal or channel creation.

Wetlands / AREA OF WETLANDS

3814 Net Acres Wetlands Lost in New Jersey



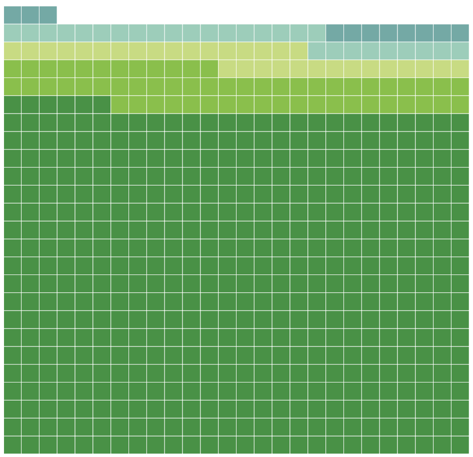
Acres New Jersey Wetlands Replaced by:



Data source: NJDEP, Land use/land cover datasets (2002–2012).

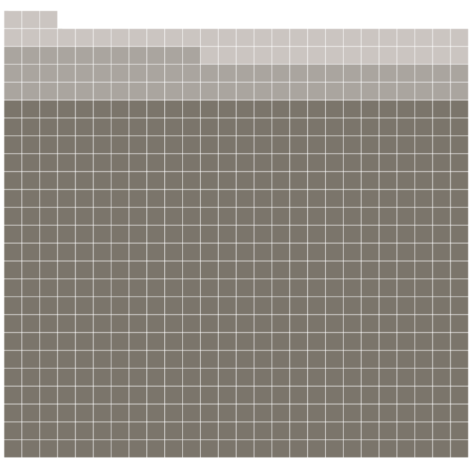
Wetlands / AREA OF WETLANDS

LOSS: New York



627
Net Acres Wetlands Lost in New York

- Estuarine Scrub/Shrub (11 acres)
- Freshwater Emergent (27 acres)
- Freshwater Scrub/Shrub (31 acres)
- Freshwater Forested (58acres)
- Estuarine Emergent (500 acres)



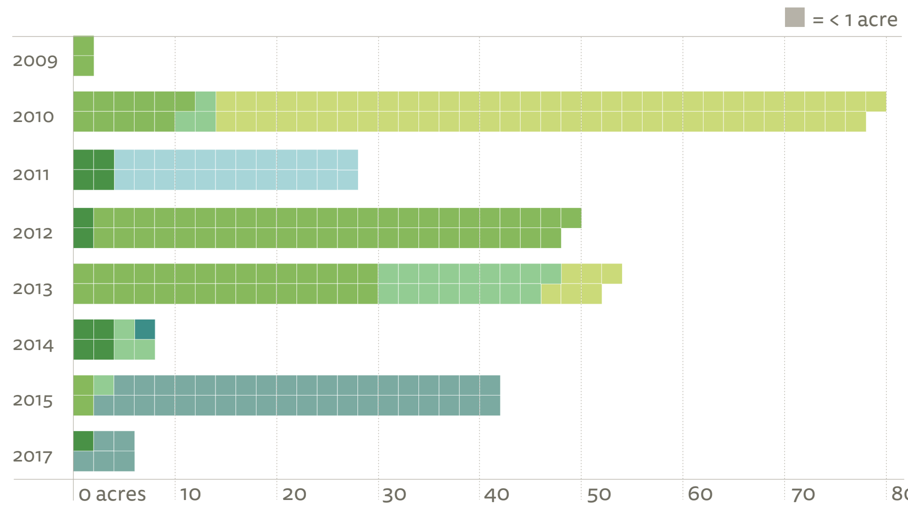
NY Wetland Replaced by

- Bare Land (44 acres)
- Developed Open Space (63 acres)
- Development (520 acres)

1 square = 1 acre

RESTORATION:

262 Acres of Harbor Estuary wetlands restored in NY and NJ between 2009 and 2017



- Bronx (9.7 acres total)
- Brooklyn (70.75 acres)
- Manhattan (.25 acres)
- Queens (91.25 acres)
- Staten Island (23 acres)
- Middlesex County, NJ (43 acres)
- Hudson County, NJ (24 acres)

Data sources: NOAA Coastal Change Analysis Program. NY–NJ HEP, Comprehensive Restoration Plan tracking.

Wetlands

Long Term Trend: Not Trending
Short Term Trend: Deteriorating

NESTING PAIRS OF HARBOR HERONS

Background

Harbor herons is the collective term for a group of wading water birds including herons, egrets, and ibises. These charismatic species are affected by a number of environmental factors, making them a useful indicator of overall habitat health. Birds living in coastal areas are vulnerable to invasive species, food availability issues, human disturbance, and severe storms and tidal flooding during the nesting season. They are near the top of the estuary food web, and as such they are vulnerable to contaminants that move from the water column and sediment to their prey items, collecting in their tissues and affecting reproductive health.

Analysis

New York City Audubon has been monitoring mixed-species nesting colonies of water birds breeding in the New York Harbor since 1982. Researchers visit 19 uninhabited islands in the Harbor Estuary surveying for possible nesting sites for nine different species of harbor herons. The number of nesting pairs of harbor herons per island per species is counted each year during the breeding season between May and July. Black crowned night herons, great and snowy egrets, and glossy ibis tended to be the numerically dominant species in the colonies.

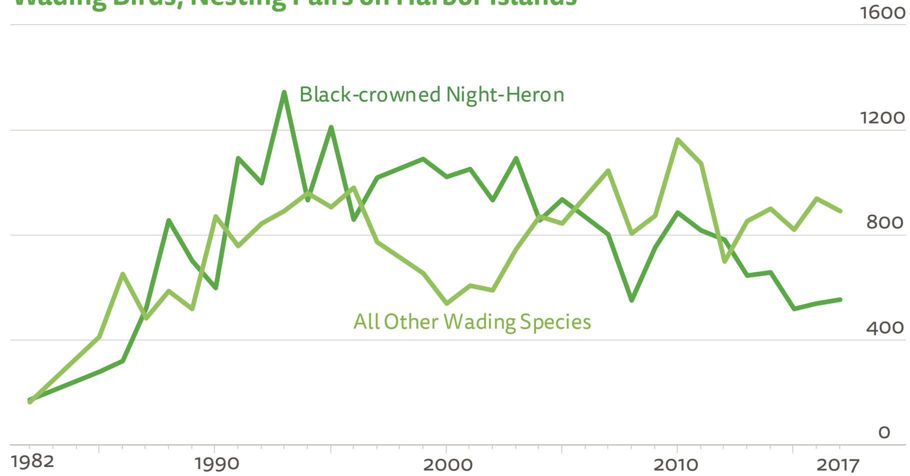
Findings

The total population of all wading birds in the Harbor Estuary grew steadily in the 1980s and early 1990s. The general influx of water birds in the New York Harbor reached a peak in 1993, but the number of birds has since declined. The overall water bird nesting population is currently stable, but there have been dramatic decreases in some species. The black crowned night heron, which represents about half of all wading bird nests in the HRE, is declining significantly in the short term. Fortunately, many egret species and other herons are increasingly present and nesting abundance is improving in both the short and long term analysis for these less-abundant heron species.

There has also been a shift in the herons' use of island habitats. Birds have abandoned once-thriving colony sites on Isle of Meadows, Prall's and Shooters Islands in the Arthur Kill and Kill Van Kull, Goose Island in the Long Island Sound, and Canarsie Pol in Jamaica Bay to establish colonies on previously unused islands on the east side of Staten Island, the East River, and Jamaica Bay. Some known causes of these habitat shifts include an oil spill in the Arthur Kill, habitat restoration efforts that disturb the colony, or the appearance of great-horned owls. More often, the reason for the shifting nesting sites or leaving of the Harbor Estuary is unclear.

Despite the colony's long term stability, harbor herons still face a great many challenges to survival in the Harbor Estuary. Mammal predation, especially by raccoons, human disturbance by unauthorized visitors, and drowning of low-lying ground nests from storms and sea level rise are just some of the issues that could partially explain the decline in wading bird species. Furthermore, previous studies of metal contaminants in waterbirds in the Harbor Estuary have shown that metals accumulate in the feathers and eggs of species nesting (Burger and Elbin, 2015). For the most part, the concentrations are at sub-lethal levels, but more work is needed to curb the influx of metal contaminants into the estuary to conserve harbor heron species.

Wading Birds; Nesting Pairs on Harbor Islands



Data source: NYC Audubon. Written in part by Susan Elbin, Director of Conservation and Science, NYC Audubon.

3. Port and Maritime

Goal Statement: Support port and associated maritime operations so that they are both economically and ecologically viable.

Toxic Contamination

Long Term Trend: Not trending

Short Term Trend: Insufficient Data

The presence of toxic contaminants in sediments is a major factor in the economic and ecological health of the Port. The Hudson-Raritan Estuary has a legacy of toxic contamination due to years of unregulated pollution. Dumping of toxic chemicals such as polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (dioxins), polycyclic aromatic hydrocarbons (PAHs) and heavy metals into the water and shorelines used to be common practice. These chemicals settled into the river sediments and in the case of some contaminants, proceeded to find their way to plants and animals. As they pass from prey to predator up the food web, these contaminants can bioaccumulate in larger fish and birds. They are toxic to much of our marine life and make local seafood largely unsafe to eat. The required dredging of navigation channels and anchorages is greatly impacted by the presence of these toxic chemicals; there are few beneficial uses for contaminated sediment and the costs of disposal are expensive.

METALS IN SEDIMENTS

Background

Certain metals can be toxic to both human and non-human life in high concentrations. Mercury, cadmium, chromium, and lead were identified by HEP's Science and Technology Advisory Committee (STAC) as the most problematic metals in the Harbor Estuary. Each of these metals has a negative effect on the health of benthic animals; in particular, mercury and cadmium are both capable of bioaccumulating (building up in biological tissues), and organic mercury biomagnifies (increases in concentration as chemical contaminants move from prey to predator species). These properties make them especially problematic for larger fish and mammals, including people who eat local seafood.

Heavy metal contaminants have numerous sources throughout the Harbor Estuary. One of the largest sources of cadmium to the Hudson River came from Foundry Cove in Cold Spring, New York. Between 1952 and 1979, the Marathon Battery Company released approximately 179,000 kg of cadmium hydroxide into the Hudson River as a byproduct of the manufacture of nickel-cadmium batteries for military and commercial use (Levinton, 2018). The extent of contamination made Foundry Cove the most cadmium-polluted site in the world. The US Environmental Protection Agency (EPA) cleanup and dredging in the 1990s removed most cadmium contamination from Foundry Cove sediments, and marsh restorations are ongoing. Cadmium tends to bioaccumulate in the kidneys, with continued exposure leading to kidney, blood, and bone disorders.

Mercury is a pollutant that has both liquid and vapor forms. Liquid mercury enters sediments through improper disposal of mercury-containing products such as thermometers. Coal, cement, and other industrial plants emit mercury into the atmosphere, which is then deposited back to earth through precipitation of particles. Fish absorb mercury from the water, which accumulates in their tissues in the form of methylmercury. High exposure to mercury in humans, especially children, can adversely affect the nervous system and kidneys.

Toxic Contamination / METALS IN SEDIMENTS

Chromium is a transitional metal contaminant known to cause cancer, rashes, and kidney and liver damage in humans and animals. From 1905–1976, Hudson County in New Jersey was a major center for chromite ore processing; the industry generated up to 2 million tons of chromium residue (Chromium Cleanup Partnership, 2018). Manufacturers created landfills in the Meadowlands with thousands of kilograms of chromium-contaminated waste, which leaches into soil and waterways through runoff.

Lead is a common contaminant in many communities throughout the Harbor Estuary. The primary source of lead in the Harbor Estuary is lead paint, which was banned in 1978 but is still found in homes and in contaminated soils (Fecht, 2017). Other common sources of lead include leaded gasoline, which was phased out of use in the 1990s, as well as trash incineration and lead smelting facilities. Lead does not biodegrade, and lead dust can leach into waterways causing neurological and developmental problems, especially in children.

Metal contamination in Harbor Estuary sediments is primarily the result of pollution from the pre-Clean Water Act time (before 1972). The surface concentrations of heavy metals decreased by an order of magnitude from the 1970s to the early 2000 (Steinberg et al., 2004). As regulations and changing industrial uses have limited the amounts of metals being discharged to the Harbor Estuary, the concentrations that we see today therefore reflect the rates of sedimentation that bury the toxic chemicals as well as how much they are resuspended back into the water column and transported to other areas of the Estuary.

Analysis

The EPA Regional Environmental Monitoring and Assessment Program (REMAP) tested surface sediment samples throughout the Harbor Estuary five times: in 1993, 1998, 2003, 2008 and 2013. The concentrations of each metal was averaged by region: Jamaica Bay; Newark Bay, which includes the Arthur Kill and Kill Van Kull; Raritan Bay, which includes the lower harbor; and Upper Harbor, which includes the lower Hudson, and East River.

Photo: The Brookfield landfill in Staten Island has recently been remediated for contaminants that were illegally dumped in the 1970s including heavy metals. NYCDEP.

Toxic Contamination / **METALS IN SEDIMENTS**

Effects Range Median (ERM) and Effects Range Low (ERL)

***ERM** and **ERL** are numbers used to correlate the concentration of a given toxic chemical with its effects on biological organisms. Originally created by NOAA, the values are usually determined by using a number of studies on a given contaminant. Effects Range Median (ERM) indicates the concentration at which adverse biological effects have been observed (the median being the value in a data set that has an equal number of values on either side). Effects Range Low (ERL) is the concentration at which 10% of the organisms are adversely affected. Concentrations below the ERL are likely non-toxic for the given contaminant. These values are not regulatory guidelines and are only used as a way to display and gauge the relative toxicity of the concentrations presented.*

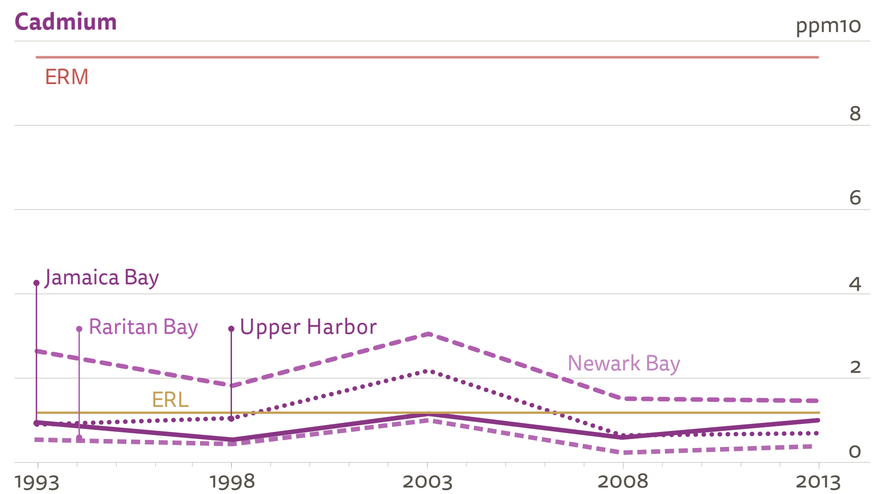
Findings

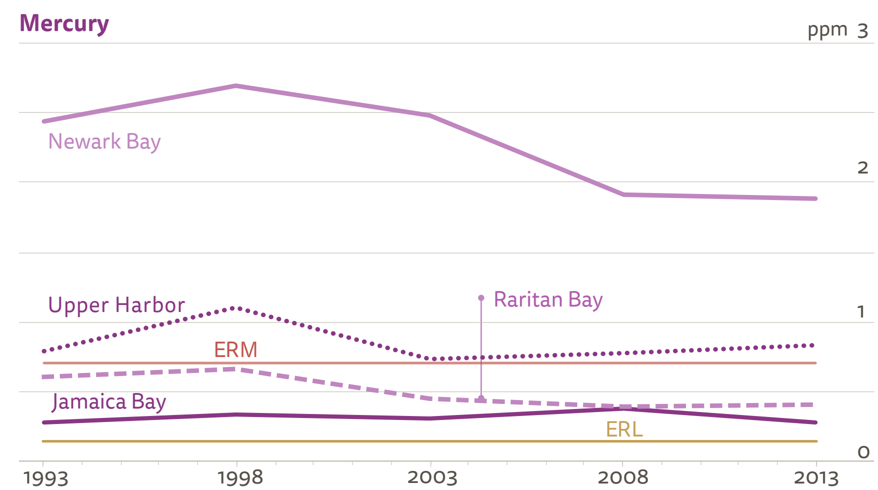
Cadmium (Cd)

Average cadmium concentrations in sediments of the Harbor Estuary are decreasing with time, but the trend is not statistically significant, and concentrations remain variable. A slight increase in concentrations was observed in 2003, the cause of which is unknown. Cadmium concentrations in Jamaica and Raritan Bays are likely nontoxic, while concentrations are slightly higher in Newark Bay and the Upper Harbor.

Mercury (Hg)

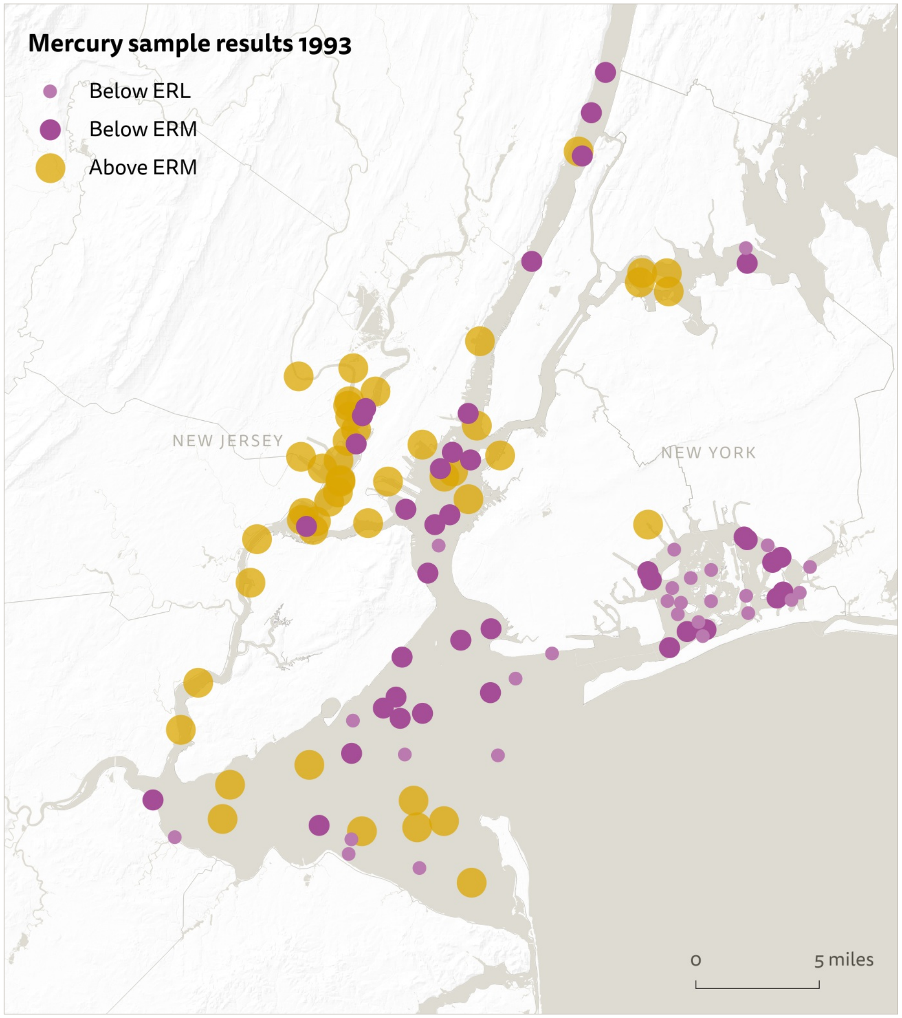
Average mercury concentrations are variable throughout the Harbor Estuary, but are decreasing significantly in Raritan Bay. The averages in Newark Bay are much higher than the other regions, but the two most recent samplings yielded lower concentrations than the first three. Newark Bay and the Upper Harbor are both consistently above ERM value, making them very likely to have toxic levels of mercury contamination in the sediments. Raritan and Jamaica Bay averages both remain above the ERL value. These high mercury concentrations throughout the Harbor Estuary indicate that it still poses a significant toxic threat to marine life.

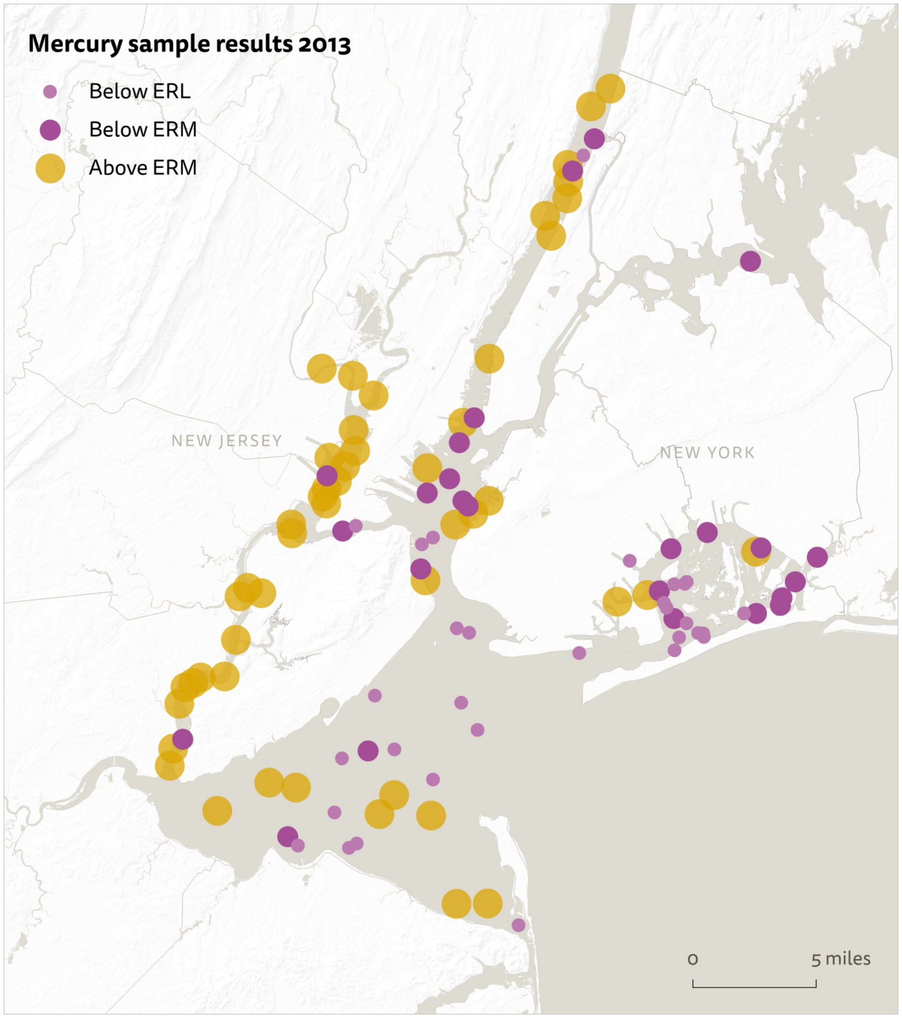




Toxic Contamination / **METALS IN SEDIMENTS**

Mercury concentrations from 1993 and 2013. REMAP samples are randomized with the same number of stations per year. Samples below the ERL are likely non-toxic whereas samples above the ERM are likely to be toxic.





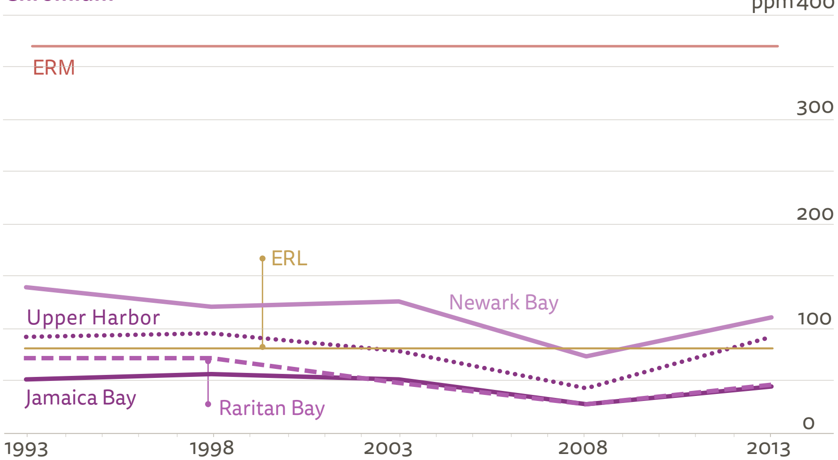
Data source: EPA Regional Environmental Monitoring and Assessment Program

Toxic Contamination / METALS IN SEDIMENTS

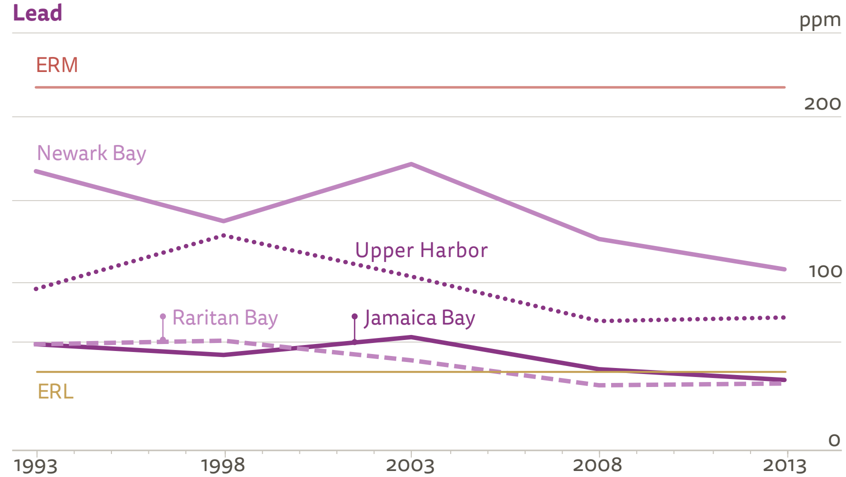
Chromium (Cr)
While sediment chromium concentrations do appear to be decreasing with time, the trend is not decreasing significantly due to an upswing in 2013. This upswing may represent a remobilization of toxic sediments from hurricane Sandy. Averages for Newark Bay and the Upper Harbor are still regularly above the ERL, but Jamaica Bay and Raritan Bay are likely non-toxic for chromium.

Lead (Pb)
Although too variable to determine a significant trend in most regions, average lead concentrations are decreasing with time, especially in Newark Bay. Raritan Bay is the only region with statistically significantly decreasing concentrations. However, much like mercury, lead concentrations remain high; almost all average concentrations across the study period in each region are still above the ERL.

Chromium



Lead



Data source: EPA Regional Environmental Monitoring and Assessment Program

Toxic Contamination

Long Term Trend: Improving

Short Term Trend: Insufficient Data

PAHS IN SEDIMENTS

Background

PAHs (polycyclic aromatic hydrocarbons) are contaminants created as a byproduct of burning wood, waste incineration, and vehicle emissions. They also occur naturally in petroleum and coal. PAHs have most likely entered the estuary via oil spills and stormwater runoff from roads, although there was also historical pollution of coal tar into the waterways such as in the Hudson River and Gowanus Canal (NYSDEC, 2015, NYCDEP, 2018). PAHs continue to enter the ecosystem through atmospheric deposition as they adsorb onto soot and ash particles following combustion, which then fall back to the earth (National Research Council, Committee on Pyrene and Selected Analogues, 1983). Because PAHs are toxic to the small animals that live in the estuary's sediments and bottom feeding fish, they decrease the health and diversity of the base of the marine food web.

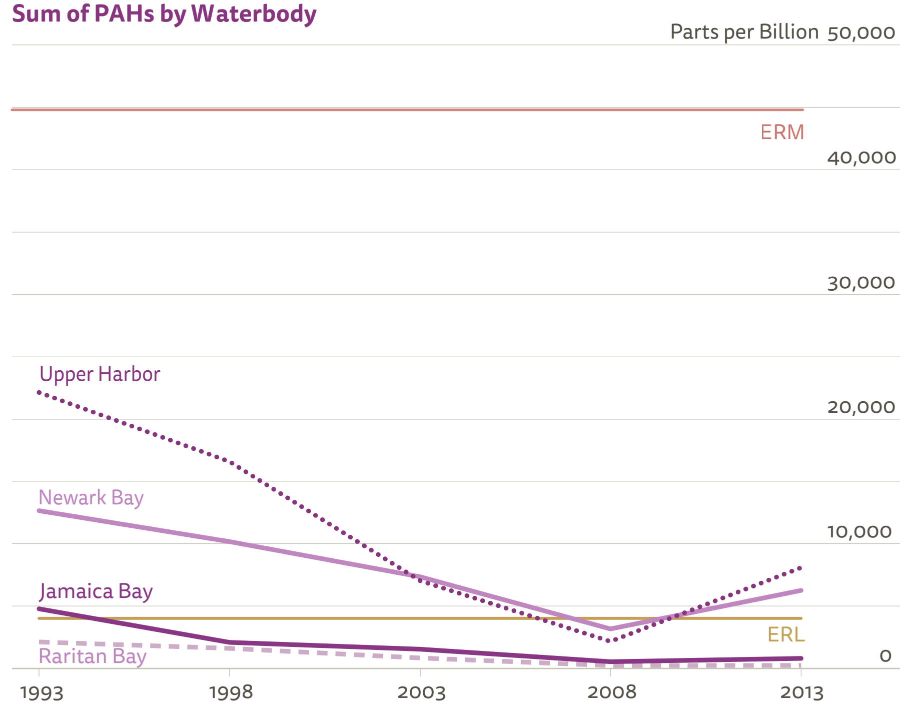
Analysis

The EPA REMAP program tested surface sediment samples throughout the Harbor Estuary five times: in 1993, 1998, 2003, 2008 and 2013. The concentrations of 23 different types of PAHs were reviewed individually and all together. The summed concentrations were averaged by region: Jamaica Bay; Newark Bay, which includes the Arthur Kill and Kill Van Kull; Raritan Bay, which includes the lower harbor; and upper harbor, which includes the lower Hudson, and East River.

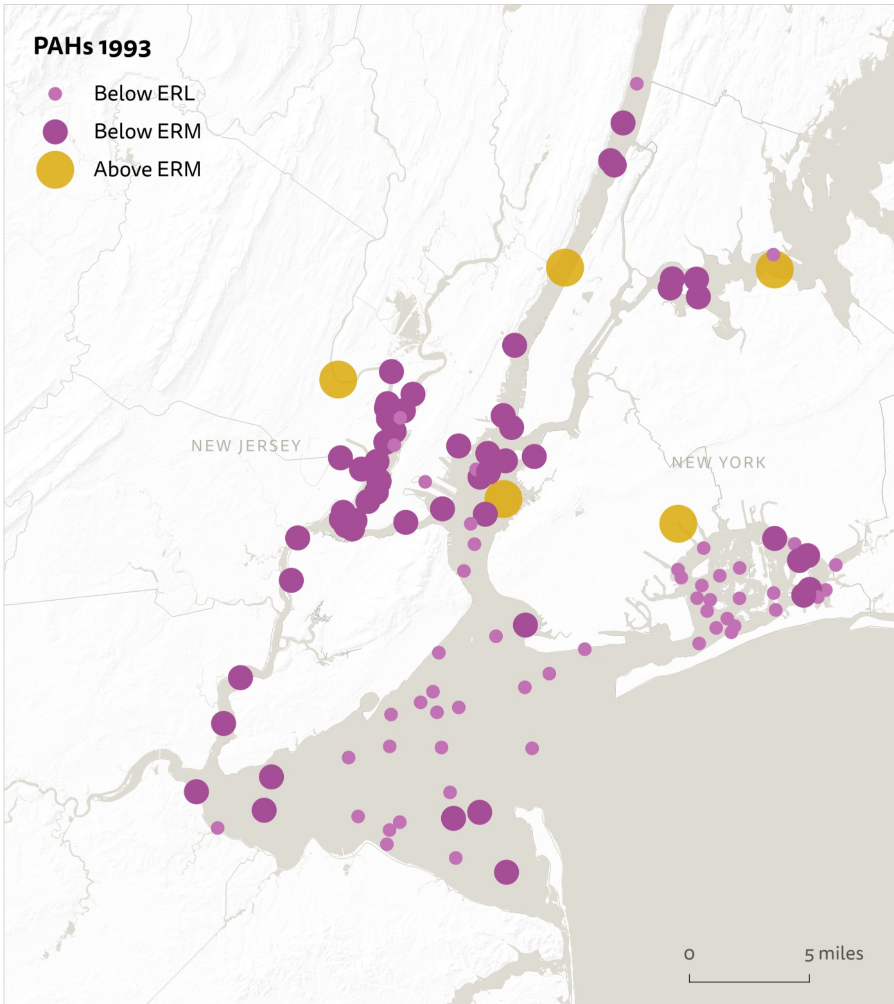
Findings

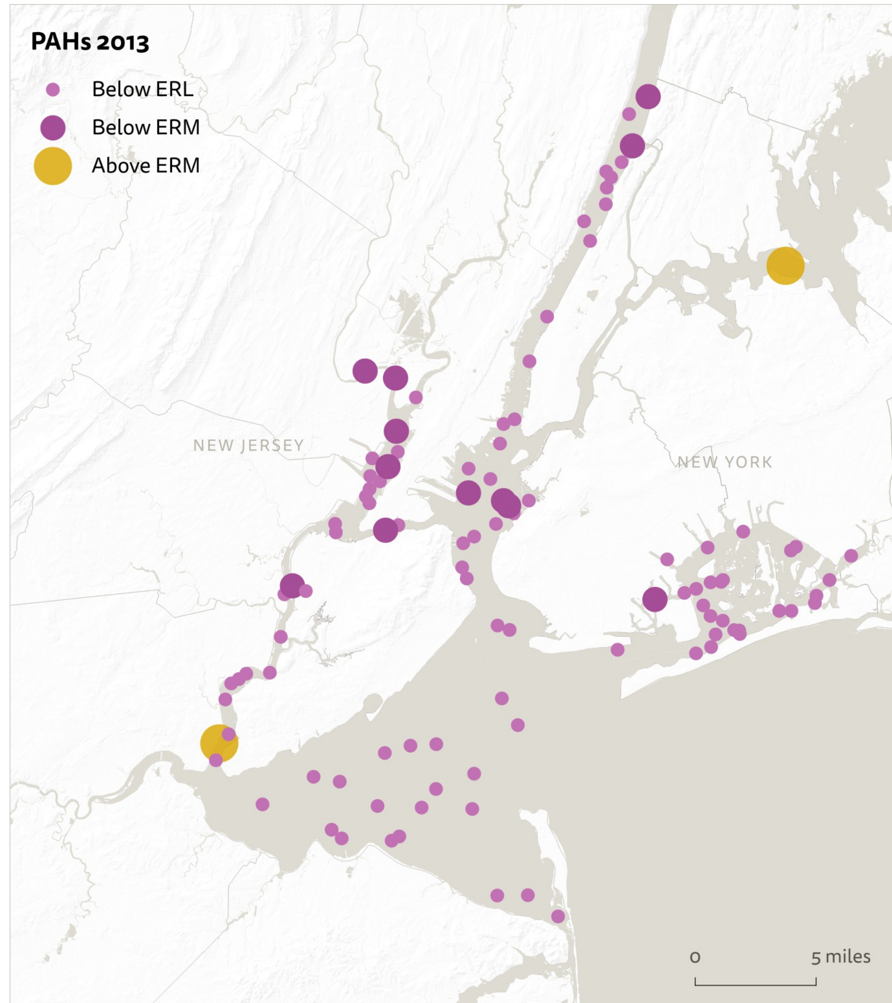
Average concentrations of the summed PAHs showed a statistically significant reduction with time in each of the regions. In 2008, all basins had an average concentration that was below the ERL or likely nontoxic.While some of the PAHs are higher in concentration than others, there are no particular PAHs that can be singled out to help identify a point source of the historical problem. This reduction indicates a curtailing of PAH pollution into the Harbor Estuary.

Sum of PAHs by Waterbody



Toxic Contamination / **PAHS IN SEDIMENTS**





Data source: EPA Regional Environmental Monitoring and Assessment Program

Toxic Contamination

Long Term Trend: Improving

Short Term Trend: Not trending

DIOXINS IN SEDIMENTS

Background

Dioxins are persistent organic chemicals that can, with long-term exposure, cause cancer and impair functioning and development of the reproductive and immune systems. The dominant historical source of dioxins to the Harbor Estuary was the production of Agent Orange in New Jersey in the 1960s. Though there are many harmful dioxins present in the sediments of the Passaic River and Newark Bay, one in particular called 2,3,7,8 TCDD was chosen as an indicator because it has the greatest toxicity and represents a large part of the total dioxin concentration in sediments of the Passaic River-Newark Bay system.

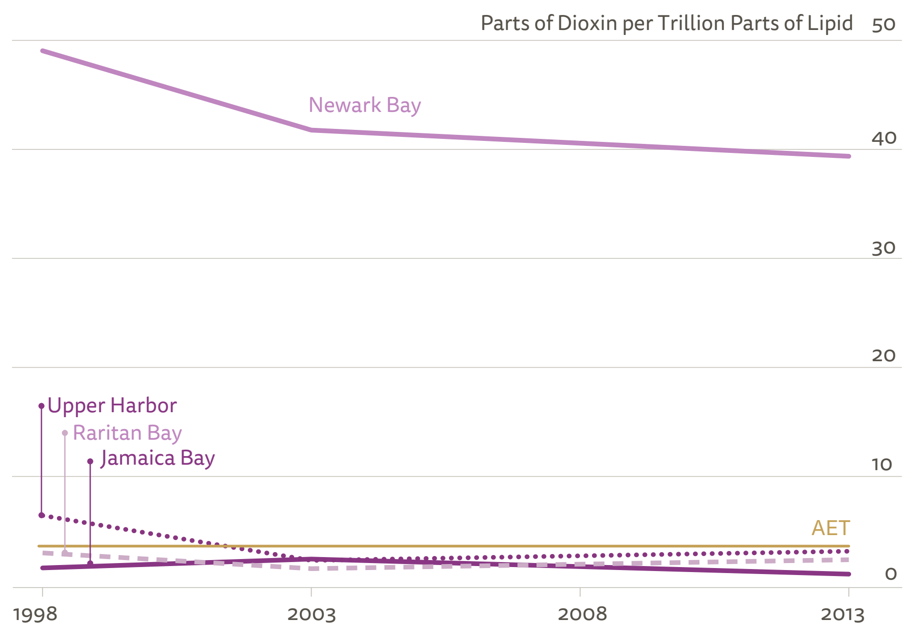
Analysis

The EPA REMAP program tested surface sediment samples from throughout the Harbor Estuary for dioxins in 1998, 2003 and 2013. The concentrations of 2,3,7,8 TCDD was averaged by region of the Harbor Estuary: Jamaica Bay; Newark Bay, which includes the Arthur Kill and Kill Van Kull; Raritan Bay, which includes the lower harbor; and upper harbor, which includes the lower Hudson, and East River. There are no ERL and ERM values for dioxins. Instead, many scientists use an Apparent Effects Threshold (AET) value. This threshold value is similar to the ERM in that it is determined by toxicity testing of various concentrations to determine effects on marine invertebrates. The AET represents the highest concentration that had a non-toxic result.

Findings

Sediment concentrations of 2,37,8 TCDD showed very little change over the entire REMAP sampling period. The pattern is the same when the sum of all the dioxins are analyzed together. Dioxin levels in Newark Bay sediments remained high with basin-wide sediment averages of 39–49 ppt. Since 2003, all other regional averages were below the AET of 3.6 ppt and likely nontoxic for dioxins. The REMAP data from the past 20 years indicate that dioxin concentrations are now leveling after earlier decline in superficial dioxins. In the mid 1980's, sediment 2,3,7,8 TCDD concentrations in Newark Bay averaged around 300 ppt and in the 1960s, the average was even higher at about 2,000 ppt (Bopp et al., 1991). TCDD does not biodegrade, so the relatively stable recent concentration of dioxins in Newark Bay sediments may indicate that the sediment is being disturbed, preventing burial of the toxic substances. The 2013 REMAP sampling occurred shortly after Hurricane Sandy, which may have re-suspended toxic sediments.

2, 3, 7, 8, TCDD Dioxin Totals per Waterbody



Data source: EPA Regional Environmental Monitoring and Assessment Program

Toxic Contamination

Long term trend: Improving
Short term trend: Improving

PCBs

Background

PCB (polychlorinated biphenyls) are industrial chemicals that were widely used as fire suppressors and electrical insulators because of their ability to withstand high temperatures. In 1977, the EPA banned PCBs because of strong evidence that these chemicals caused risks to human and ecological health. PCBs are particularly dangerous because of their capacity to bioaccumulate (get absorbed and concentrated in the bodies of fish and other animals) and biomagnify (increase in concentration as they move up the food chain, leading to high contamination in predator species). When PCBs enter a water body, they typically bind to organic particles in the water column, which then descend and incorporate into bottom sediments. Environmental factors, including elevated temperature and resuspension from high flow events, can mobilize PCBs from sediment.

The dominant source of PCBs to the Harbor Estuary came from discharges from General Electric plants located in Fort Edward and Hudson Falls, New York. These plants discharged more than 1 million pounds of PCBs into the upper Hudson from the 1940s through the 1970s. During the period of direct discharge, and continuing into today, these PCBs remain the dominant source (approximately 75%) of PCBs to the lower Hudson River and New York Harbor (Bopp et al., 1981, Lodge et al., 2015). Other sources of PCBs include runoff from contaminated sites, damage or disposal of equipment containing PCBs, wastewater, and atmospheric deposition (Panero et al., 2005).

The EPA designated the 200-mile stretch of the Hudson River a Superfund Site in 1984. In 2002, GE was ordered to conduct environmental dredging of PCB-contaminated sediment in a 40-mile stretch of the Upper Hudson River, which lasted from May of 2009 through October of 2015 (Farley et al., 2017). 2.76 million cubic yards of PCB-contaminated sediments were removed from the Upper Hudson. Loadings of PCBs from the Upper Hudson to the Lower Hudson River have declined dramatically since their peak in 1973. However, the effectiveness of the remediation project in reducing PCB burdens to fishes in the Estuary has yet to be determined.

Estimation of PCB load (dissolved and suspended sediment) from Upper Hudson to the Lower Hudson:

Amount in Kg / year	Year(s)	Source
2500	Early 1980s	Thomann et al. 1989
300	Early 1990s	Farley et al. 1999
107.7	2004–2008 (pre-dredging)	Farley et al. 2017
37	2016	Farley et al. 2017

Analysis

One way to evaluate the extent of PCB contamination in the Harbor Estuary is to quantify PCB concentrations in fishes. The NYSDEC samples fishes in the lower Hudson, from the Troy Dam south to the George Washington Bridge, annually. This analysis looked at total PCBs in fish tissue of two resident species—white perch and pumpkinseed—because they spend their whole lives in the Hudson River or Harbor and their contaminant loads can be attributed solely to our waters. Though there is a consumption advisory for striped bass from the Hudson River, striped bass data was also reviewed because they are one of the most popular for fishing and eating.

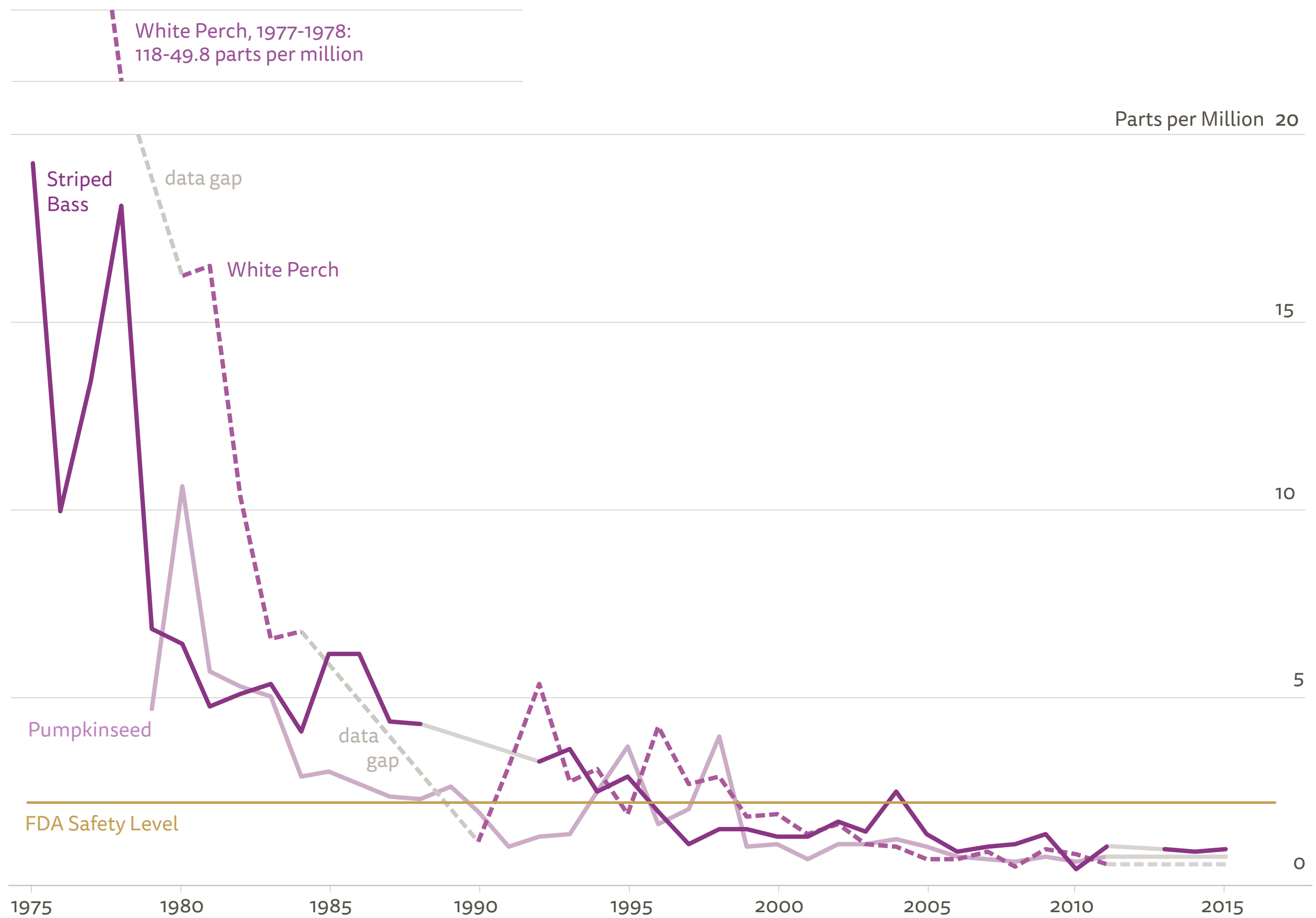
Data sources: EPA Regional Environmental Monitoring and Assessment Program.
NYSDEC, Contaminant Monitoring Program

Toxic Contamination / **PCBS**

Findings

Both resident species as well as striped bass showed statistically significant declines in annual average PCB concentrations since the PCB ban in the 1970s. Though not universally recognized by public health experts, the FDA fish consumption recommendation for PCBs in fish is two parts per million (ppm). Annual averages for striped bass fell below 2 ppm for the first time in 1996, while white perch and pumpkinseed averages dropped under 2 ppm in 1999 and have not exceeded the standard since then. However, consumption advisories are not based on averages and individual white perch, striped bass and pumpkinseed caught still regularly have concentrations of greater than 2 ppm. There continues to be a similar statistically significant decline in annual averages when analyzed on a shorter time scale (since 2000). The annual average concentrations of PCBs in fish caught in the section of the river furthest north, and closest to the original contamination sites, showed the highest rate of decrease in concentration with time for all three species.

PCBs in Fish: Annual Average Total PCBs by Species (data skips some years)



Data sources: EPA Regional Environmental Monitoring and Assessment Program. NYSDEC, Contaminant Monitoring Program.

4. Public Access and Stewardship

Goal Statement: Improve public access to the waters of the Estuary and the quality of experience at public spaces along the waterfront.

Public Access

Long Term Trend: Insufficient data

Short Term Trend: Improving

The New York–New Jersey Harbor Estuary is the biggest public space in the nation's largest metropolitan area. Access to the estuary's waters influences the quality of life for its millions of residents, and has been positively correlated with physical activity levels and public health. Additionally, public access to the water is essential for fostering a connection with and stewardship of the estuary among residents, and youth in particular.

PUBLICALLY ACCESSIBLE WATERFRONT

Background

In recent years, the Harbor Estuary's waterfront has seen a remarkable transformation. Better water quality, the redevelopment of industrial sites for parks and housing, and an increased public desire for outdoor activity has led to the creation of new parks and other public spaces along the waterfront. These spaces provide both physical access to the water as well as the opportunity to provide on-water activities like boating and swimming and educational and stewardship programs. HEP and the Hudson-Raritan Estuary Comprehensive Restoration Plan (USACE, 2016) share the goal that by 2050, all waters of the Harbor Estuary are accessible to all residents within a short walk or public transit trip. Understanding this goal relative to socioeconomic need is an important measure of success.

Analysis

Waterfront public access (in linear miles) and the relationship of this access to need was collected by HEP in partnership with the USDA Forest Service and its Public Access Work Group (Boicourt et al., 2016). This assessment involved mapping parks and other public access sites and analyzing that information relative to socioeconomic characteristics available from the US Census. This analysis represents a baseline dataset that can be updated as progress continues. In addition, HEP tracks acreage of newly created public access sites as part of the Comprehensive Restoration Plan.

Most public access occurs in park lands owned and managed by federal, state, and local park agencies or private conservation entities. Access also occurs in regular but limited ways on other public and private property, such as privately-owned esplanades and piers with public easements, as well as improved street ends and civic plazas that are owned by a variety of public agencies. Spatial data for these types of publicly accessible waterfront spaces were compiled, verified and corrected as needed.

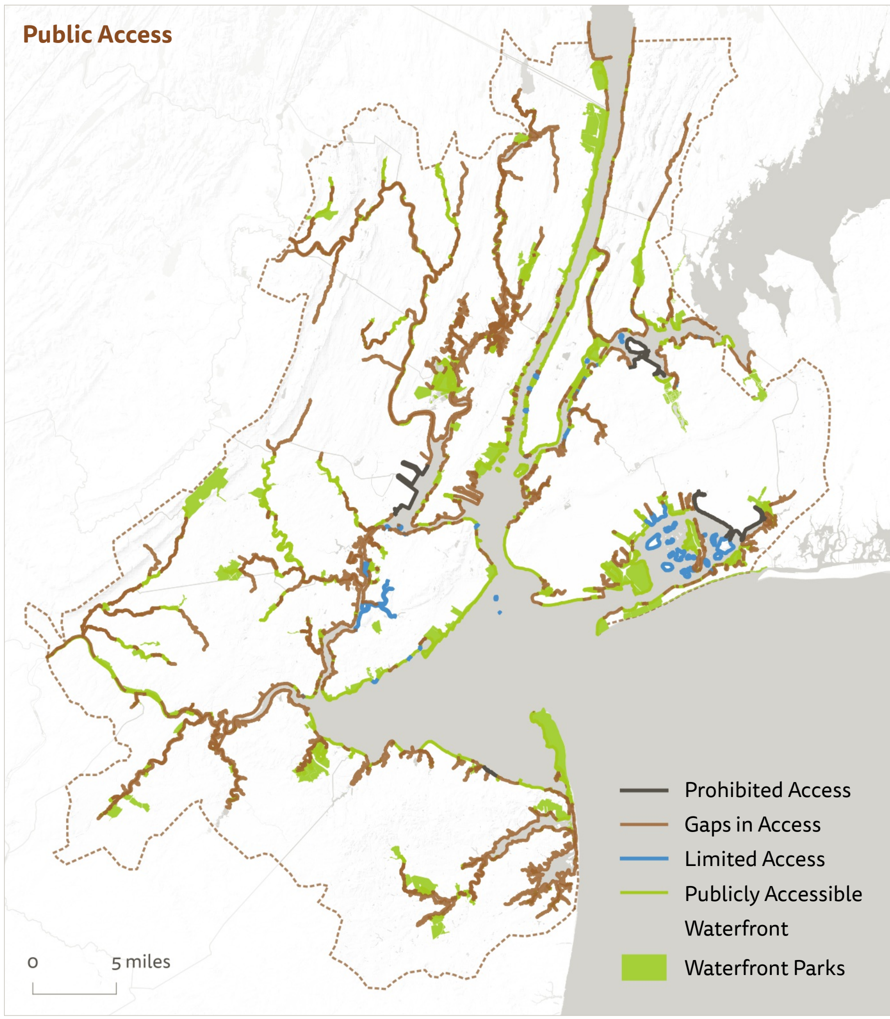
To understand the relative need for improved public access, HEP developed a Need Index comprised of five key indicators: the number of people lacking public access to the waterfront, the percentage of people under the age of 14, how fast the population is growing, communities of color, and median household income. The combination of these metrics allows for the definition of parts of the waterfront that are areas of higher need—areas with fewer options for outdoor recreation, of particular importance for engaging youth—and where additional resources are most critical to improve access through programming or improved facilities.

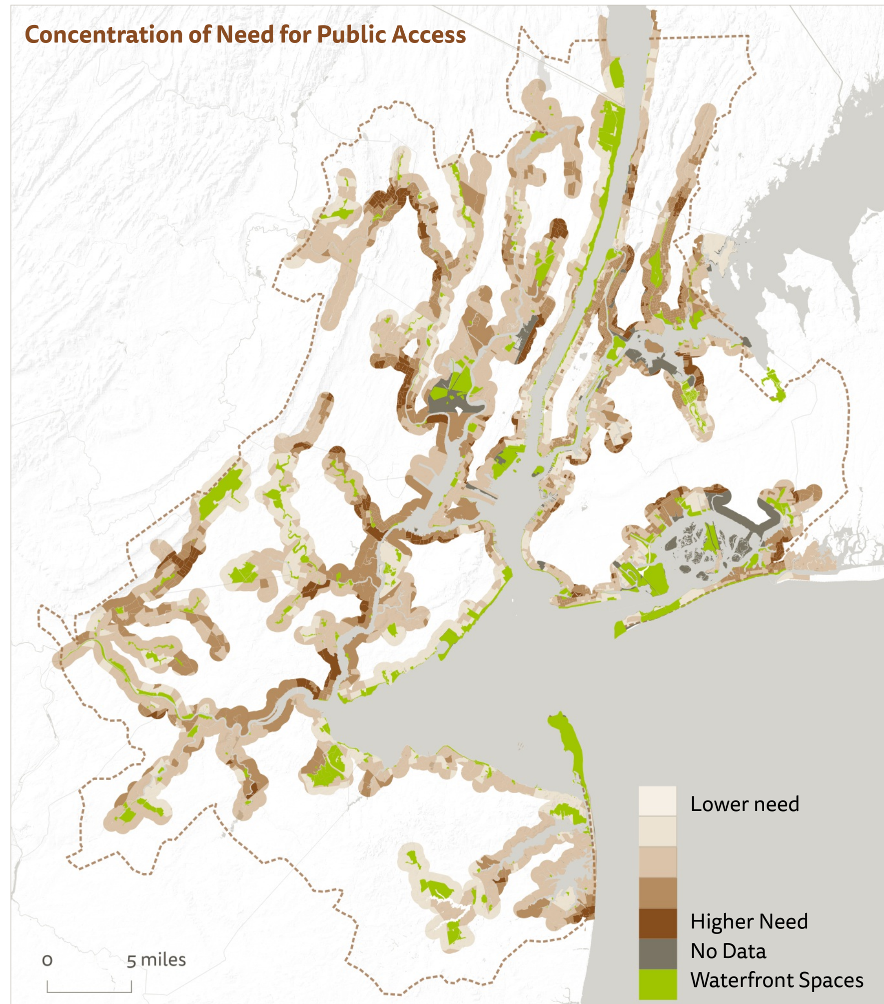
Findings

Of the 1,592 miles of waterfront in the Harbor Estuary, about 595 miles or 37% of the waterfront is publicly accessible through public parks and other public spaces. The other 63% of the estuary has limited or no access, though in some cases this is because maritime industrial uses, port and airport security concerns, sensitive wildlife, and other considerations prohibit access to the water.

This percentage reflects large number of new parks and public spaces that have been developed. Between 2009 and 2014, more than 500 acres of new waterfront public access were created throughout the Harbor Estuary (Boicourt, 2015).Unfortunately, the parks and public spaces with waterfront access in the Harbor Estuary are not evenly distributed with regard to socioeconomic characteristics. Twelve waterfront areas in New York and New Jersey are identified as higher need due to the limited number of waterfront parks, high population growth rate, and a disadvantaged population. There are 260 miles of waterfront in these higher need areas, but only 24 miles (9%) are publicly accessible to the more than 500,000 people that live within one half mile of the water. In the Passaic River watershed, for example, 50% of residents living within one half mile of the waterfront lack access.

Publicly Accessible Waterfront / PUBLICALLY ACCESSIBLE WATERFRONT





Data sources: NYC DPR, NYC DCP, NJDEP, SeaGrant; See: Boicourt et al., 2016 (left). US Census 2000, 2010, ACS 2013; See: Boicourt et al., 2016 (right).

Publicly Accessible Waterfront

Long Term Trend: Insufficient data
Short Term Trend: Improving

ON-WATER ACCESS

Background

Direct access, where one can safely touch and travel to and from the water, is an indicator of the public's ability to interact with and enjoy the resource. Direct access to and from the Harbor Estuary can take many forms. In some cases, public access includes the ability to safely swim, boat, or otherwise touch the water. In other places, access is limited to the shoreline due to safety concerns, poor water quality, a lack of facilities for boating or swimming, or other management considerations. To address this indicator, lists of human powered boat launches, marinas, swimming beaches, and ferry landings were compiled and documented.

On-water access in the or Estuary

	Past	Present (2018)
Boat Launches	114 (2011)	**139**
Bathing Beaches	15 (2015)	15
Marinas	Unavailable	31
Ferry Landings	27 (2006)	49

Analysis

To understand the increase in human powered boat launches, HEP compiled results from a 2011 paddling guide, Going Coastal Inc. that surveyed over 100 municipalities across 14 counties in both New York and New Jersey to quantify the total number of legal human-powered boat launches in the Harbor Estuary (Going Coastal Inc., 2011). This was compared with data from HEP's 2016 Public Access Report.

HEP identified current marinas and bathing beaches by compiling data from a number of sources including NYC Water Trail Association, NYC Parks, New Jersey Department of State and New Jersey Division of Travel and Tourism, among other sources.

To understand the growth in ferry landings, HEP compared the data from an assessment by Regional Plan Association (RPA, 2006) with information from a variety of public agencies to quantify the current status of ferry landings in the Harbor Estuary. Both analyses counted only ferry landings used for transit purposes and excluded recreational cruises.

Findings

Between 2011 and 2018, the number of boat launches in the HRE increased from 114 to 139, indicating an increase in the number of opportunities for people to access on-water programs at public boathouses as well as the success of efforts like the NYC Water Trail. With the launch of the new NYC Ferry Service in 2017, the number of ferry landings in the Harbor Estuary almost doubled from 27 in 2006 to 49 in 2018, allowing for more opportunities for both transportation and direct on-water access. The number of bathing beaches has remained consistent. No historical data on marinas in the Harbor Estuary was available, but 31 were identified in this analysis.

Data sources: Data for direct access sites were sourced from the NY-NJ Harbor & Estuary Program, NYC Water Trail Association, NY/NJ Baykeeper, Hackensack Riverkeeper, ANJEC, Bronx River Alliance, the National Park Service, Going Coastal, NYC Dept. of Parks & Recreation, Waterfront Alliance, and the Passaic Valley Sewerage Commissioners, NYCEDC, NJDOT, NYDOT, NJ Department of State Division of Travel and Tourism, and the Regional Plan Association.

On-Water Programs

Long Term Trend: Insufficient data
Short Term Trend: Improving

Background

Throughout the NY–NJ Harbor Estuary, there are dozens of organizations providing on-water programs that get people on the water in human-powered boats such as canoes, kayaks, and paddleboards. Some organizations additionally provide environmental education and other supplemental programs. These on-water programs are critical for fostering a connection with and stewardship of the estuary, especially for young people.

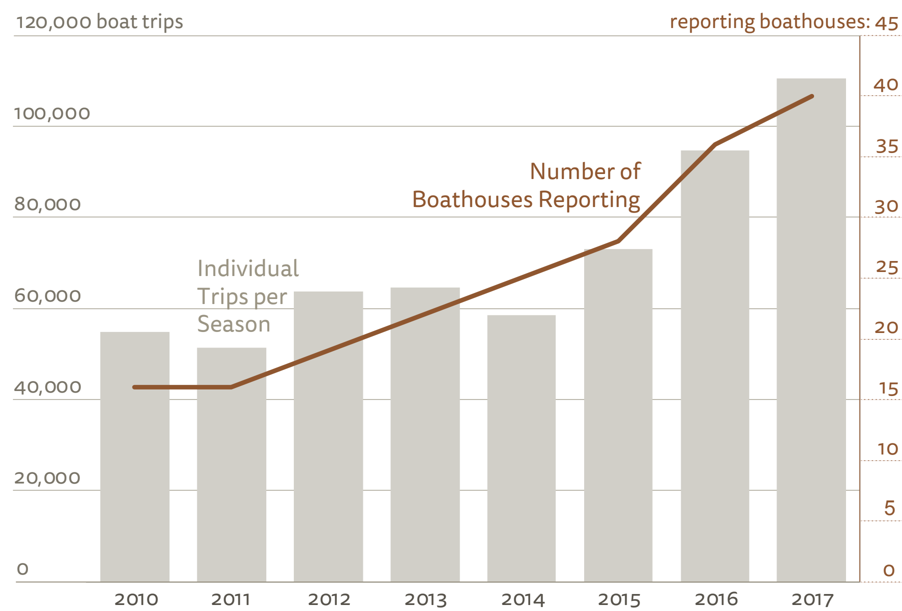
Analysis

In 2017, the Waterfront Alliance surveyed boathouses providing on-water activities in the Harbor Estuary. Organizations were asked to report the types of programs they provide, their fees, and number of participants over time.

Findings

The number of individual human-powered boat trips is increasing annually as is the number of operating boathouses. In the Waterfront Alliance survey, 43 organizations reported putting 110,400 community members on the water in human-powered boats in 2017. This is more than double the number of people on the water in 2010. It is important to note that these numbers are counting individual boat trips, not unique participants. However, this estimate may be an under-representation as several high-capacity boathouses did not participate in the survey. Programs offered included kayaking, canoeing, stand up paddleboarding, rowing, environmental education, surfing, sailing, pontooning, and surf skiing.

Annual Human-Powered Boat Trips



The number of annual boat trips offered by 43 responding organizations around the estuary. Data does not account for repeat individuals.

Data Sources: Waterfront Alliance Boathouse Survey, 2017

5. Community Engagement

Goal Statement: Foster community stewardship and involvement in decisions about the Harbor Estuary.

Civic Engagement

Long Term Trend: Insufficient data

Short Term Trend: Insufficient data

Civic organizations and the events they host are critical to the stewardship of the Harbor Estuary, improving public access to its waters, and engaging community members in knowledge of and interaction with their local resources. Civic organizations complement the work of local, state and federal parks departments and other landowners by identifying opportunities and advocating for the development of new parks and access points. Stewardship events bring the public together to interact with local water resources, which is especially important for introducing people to the estuary and engaging young people in outdoor activity.

CAPACITY OF STEWARDSHIP ORGANIZATIONS

Background

Effectively engaging the public in decisions about the estuary relies on an informed and active public. By incorporating deep local knowledge and community values, public agencies can arrive at better decisions that are more in tune with needs and aspirations of local residents and businesses. Civic and community-based organizations that understand and are deeply committed to the estuary can provide a trusted vehicle for informing the public and engaging communities in these decisions. Their membership is an indicator of their ability to get the word out and to improve policy and management decisions, while their numbers of staff and volunteers indicate people engaging in direct stewardship of the Harbor Estuary.

Analysis

In 2015, the US Forest Service Urban Field Station and HEP surveyed over 500 stewardship organizations in the New York – New Jersey Harbor Estuary inquiring about their stewardship work and their capacity. These organizations self-identified as conducting stewardship. While the definition of what constitutes a "member" was also self-determined, it was assumed that these organizations had the ability to reach their members through emails, newsletters, or other communications tools. The number of volunteers and staff was also collected; the accounting of these individuals provides a basis for understanding capacity for doing stewardship work.

Findings

Number and membership in stewardship groups

A total of 146 civic organizations responded to the survey, indicating that they were engaged in estuary stewardship activities. Of these, 82 organizations responded to the question of membership. These civic groups had 131,121 members, with an average of 1,599. Notably, two of the larger organizations (Citizens Campaign Fund for the Environment and The Nature Conservancy) comprise over 100,000 of these members. Therefore, a more useful statistic is the median number of members, which is 54 and normalizes for the presence of larger stewardship groups.

Staff and volunteers in stewardship groups

The 146 stewardship groups that responded to the survey had a total of 1,539 full-time staff, 888 part time staff, and 88,012 volunteers. On average, they have 15 full-time staff, 9 part time staff, and 807 volunteers. The median numbers are: two full-time staff, two part-time staff, and 50 volunteers.

Findings	Sum of responses	Average	Median
Full-time staff	1,539	15	2
Part-time staff	888	9	2
Members	131,121	1,900	100
Volunteers	88,012	807	50

Data source: 2015 HEP Stewardship Survey.
Photo, previous page: City of Water Day, Joaquin Cotton.

Civic Engagement

Long Term Trend: Insufficient Data

Short Term Trend: Improving

PARTICIPATION IN STEWARDSHIP EVENTS

Background

Participation in stewardship events in the Harbor Estuary is important for bringing community members together to celebrate the estuary and engage the public in its management. Stewardship events can cover a range of purposes, including recognition, stewardship, and data collection efforts; they can enhance environmental learning among volunteer participants, generate knowledge, and lay the foundation for environmental stewardship that can sustain future movements (Asah and Blahna, 2012). Participation in stewardship events is therefore an important indicator of the public's desire to engage in conservation of and learning about our shared waters.

Analysis

Many stewardship events happen throughout the estuary each year. Three of the largest and most consistent were selected for this analysis: City of Water Day organized by the Waterfront Alliance, Riverkeeper Sweep organized by Riverkeeper, and A Day in the Life of the Hudson & Harbor organized by NYSDEC's Hudson River Estuary Program and the Lamont-Doherty Earth Observatory of Columbia University.

City of Water Day is a celebration of waters throughout the New York and New Jersey Harbor and Estuary and includes activities such as kayaking, boat tours, science demonstrations, and activities for children. The event takes place in Lower Manhattan as well as in dozens of locations organized by community groups in all five boroughs, Yonkers, and New Jersey. The goal of the festival is to get people to, on, and in New York Harbor and its surrounding waterways thereby creating a movement to unlock waterfront access for everyone.

The Riverkeeper Sweep is an annual day of service throughout the Hudson River and its tributaries dedicated to removing debris and invasive species as well as planting trees and native grasses. Over the last 6 years, 495 projects have spanned hundreds of miles of Hudson River shoreline between Brooklyn and the Adirondacks. Attendance is captured by Sweep Leaders, who report on the number of volunteers at each project site.

A Day in the Life of the Hudson and Harbor is an annual event where students and teachers throughout the estuary collect scientific data to create snapshots of the river and understand how each small piece of the estuary fits into the larger Hudson estuary ecosystem. Each site's findings are displayed on an open access website with a searchable database. Attendance is captured through an online registration process whereby teachers input the number of sites and students that they will be responsible for. When possible, online registration numbers are superseded by data received via follow-up conversations with teachers after the event, or by records taken when NYSDEC is able to visit sites on the day of the event.

City of Water Day – Waterfront Alliance. Photo: Ian Douglass

Civic Engagement / PARTICIPATION IN STEWARDSHIP EVENTS

Findings

Overall, the total number of community members participating in these stewardship events has grown dramatically over the past 10 years. Since their start, these three events have together increased their attendance by 770%. While comparison of changes from year-to-year and between the events is difficult to assess, the overall growth in attendance, indicating that the capacity for stewardship groups to engage the public for a variety of recreational, stewardship, and educational purposes has grown substantially.

City of Water Day

City of Water Day has been happening annually since 2008. Attendance has increased by 393% from over 7,000 participants in the festival's first year to more than 35,000 participants in 2018.

Riverkeeper Sweep—Riverkeeper

The Riverkeeper Sweep has been happening annually since 2012. Attendance has increased by 411.11% from 450 volunteers across 30 projects in 2012 to 2,300 volunteers across 120 projects in 2018.

A Day in the Life of the Hudson & Harbor—Hudson River Estuary Program

A day in the life of the Hudson & Harbor has been happening annually since 2003. Attendance has grown by 1513.5% from 341 student and adult participants in the program's first year, to nearly 45,000 participants in 2017. The program's geographic scope has also increased by 543%, with 14 sites in the program's first year and 90 sites in 2017.

Communtiy Participation

	A Day in the Life of the Hudson & Harbor		City of Water Day	Riverkeeper Sweep	
Year	Sites	Participants	Participants	Sites	Participants
2003	14	341			
2004	16	1175			
2005	26	695- lots of rain			
2006	34	1329			
2007	49	2500			
2008	53	2800	7,200		
2009	61	3000	11,000		
2010	54	3336	13,000		
2011	59	3487	25,000		
2012	67	3765	26,000	30	450
2013	60	3271	26,000	70	1,400
2014	54	3220	25,000	82	1,900
2015	80	5121	25,000	102	2,000
2016	81	5297	26,000	109	2,200
2017	90	5502	35,000	102	1,790
2018			35,000	120	2,300
Growth rate	**543%**	**1514%**	**393%**	**300 %**	**411%**

Data sources: Riverkeeper. Hudson River Estuary Program. Waterfront Alliance.

Citizen Science

Long Term Trend: Insufficient Data

Short Term Trend: Insufficient Data

Citizen science programs bring together stewardship organizations, the academic community, and members of the public to conduct scientific research on the health and ecology of the Harbor Estuary. Also known as participatory or community-led science, citizen science is a term designed to encompass the diversity and broad range of individuals, schools, and non-profit and community-based organizations conducting these activities throughout Harbor Estuary. Citizen science programs improve management and maintenance of shared water resources by building active constituencies and engaging volunteers in stewardship of the Harbor Estuary.

PARTICIPATION IN CIVIC SCIENCE

Background

Expanding and improving the quality of citizen science programs in the Harbor Estuary directly raises awareness about the need to protect and restore shared waterways. Citizen Science programs advance scientific literacy, especially among youth, and can fill critical gaps in monitoring and stewardship data for managers, scientists, and policy makers. Some examples of citizen science programs include surveying water quality for kayakers, monitoring artificial oyster reefs, or analyzing the amount and sources of marine debris. The relative abundance of civic science programs is an indicator of community interest and capacity to help conserve our waterways and wildlife.

Analysis

A 2017 survey by members of the NY–NJ Harbor & Estuary Program Citizens Advisory Committee (CAC) found forty-nine organizations that conduct civic science, many of which operate multiple monitoring and data collection programs. The survey asked groups which parameters they monitor, their goals for collecting data, where they monitor, whether they have a Quality Assurance Project Plan (QAPP), if they use standardized protocols and their greatest needs. Respondent's monitoring locations for citizen science programs were then mapped and grouped in several ways: by common programmatic goals (e.g., public education/program management or informing management decisions), the level of formality of the monitoring protocols being followed, and major programmatic needs (e.g., recruiting volunteers, data visualization, and funding).

HEP Role

HEP is providing support for the needs identified in the civic science survey in a number of ways. Our Environmental Monitoring Plan will highlight existing efforts by waterbody, helping connect groups that share a waterbody or monitoring interest. HEP is working with its CAC and university partners to help recruit and retain volunteers. We have produced workshops focused on protocols and parameters that would be especially useful for groups seeking to develop quality assurance protocols. Finally, HEP has provided small grants to civic organizations seeking to implement programs for pathogens, sources of floatable debris, and a variety of other parameters.

Citizen Science / PARTICIPATION IN CITIZEN SCIENCE

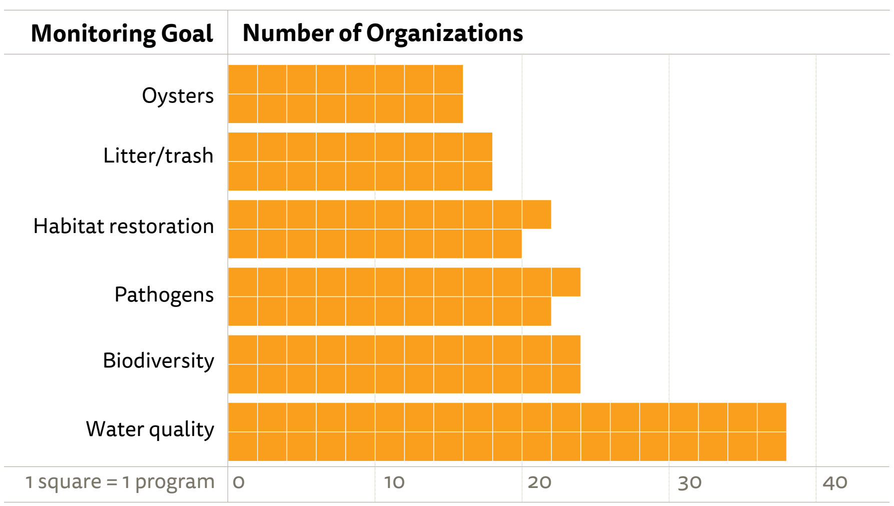
Findings

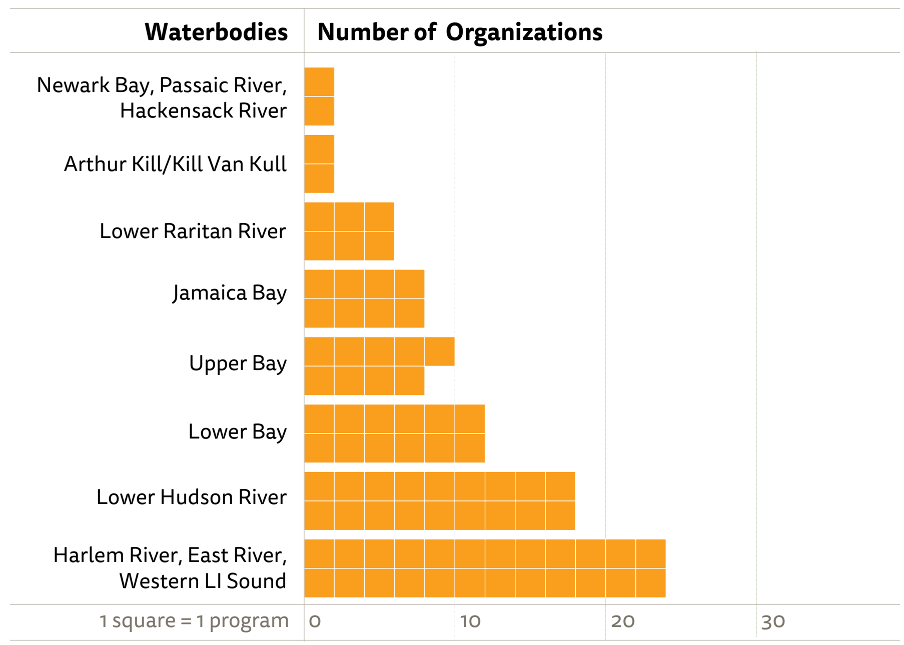
Many organizations throughout the Harbor Estuary are conducting citizen science programming for a variety of purposes. The most common indicators being measured are water quality, biodiversity, fecal pathogens, habitat restoration success, litter/trash, and oysters. These programs are monitoring a total of 31 different water bodies throughout the Harbor Estuary, but a majority of sampling is occurring in the Harlem River, East River, lower Hudson River, and the Lower Bay region.

About half (55%) of organizations surveyed currently have some kind of quality assurance/control measures in place to ensure the accuracy and quality of data collected, however, only 29% of organizations have a formal Quality Assurance Project Plan (QAPP) approved by EPA. Although the production of accurate scientific data (as opposed to creating opportunities for youth and community members to explore science) is not the intent of every monitoring effort, 23 organizations specifically stated a need or interest in learning how to create formal quality assurance protocols to help standardize and improve the reliability of their monitoring.

Organizations also cited several other needs to improve their programming. Eight groups listed needs for recruitment and retention of volunteers; six groups characterizing sites listed needs for assistance with data visualization and analysis. Importantly, 24 groups (49%) stated that the biggest hindrance to their organization's growth and success is access to funding.

49 Citizen Science Organizations





Data source: 2016 HEP Citizens Advisory Committee Survey

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