The State of the Hudson 2020

ENVIRONMENTAL HEALTH AND TRENDS OF THE HUDSON RIVER ESTUARY

NEW YORK STATE | Department of Environmental Conservation

NEIWPCC

CORNELL

NY/NJ HARBOR & ESTUARY PROGRAM

HUDSON RIVER FOUNDATION

Contributors & Acknowledgements

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Cover photo: River Waves, Brandon Pidala

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Executive Summary

This State of Hudson Report presents environmental trends on the Hudson Estuary and in its watershed. By compiling recent data and historical information, it allows program managers, partner organizations and interested members of the public to measure and communicate progress toward state and federal goals for conserving and restoring the estuary ecosystem. Many laws govern the way this ecosystem is managed, but primarily this report has been created for use by the two programs tasked with managing this resource—one federal and one state. The Hudson River Estuary Program was created within the New York State Department of Environmental Conservation (NYSDEC) in 1987 to conserve the river and its watershed. At the same time, the federal New York-New Jersey Harbor & Estuary Program was created by USEPA and the Governors of New York and New Jersey under the Clean Water Act for a similar purpose. These two programs now work very closely together and have joined in preparing this report.

Each chapter in this report compiles the best available data for a variety of indicators of environmental condition. Where the information is available, the report illuminates long-term trends (>30 years) and short-term trends (>20 years). Historic environmental changes are also discussed to put more recent trends in the context of improvements resulting from the passage of the Clean Water Act, Clean Air Act, and other laws of the 1970s and 1980s. Where there is not sufficient data to draw conclusions, the report sets a baseline for future considerations of progress.

Photos: left: striped bass monitoring is a key management tool for a sustainable fishery. NYSDEC. Right: the American eel has suffered habitat loss due to dams and culverts. Collecting data allows stream restoration projects to be prioritized. NYSDEC.

Executive Summary
Findings

Water Quality in the Hudson River Estuary has improved dramatically since 1972 and has remained largely stable in recent years. The historic trends for most water quality indicators show that conditions have improved since passage of the 1970 Clean Air Act and the 1972 Clean Water Act. The clean-up of water quality in the Hudson is one of its biggest success stories. Prior to the Clean Water Act, portions of the Hudson were so polluted that fish were rarely seen. Today those same reaches of the Hudson support the growth and survival of many fish and wildlife species. Cleaner water has made the Hudson an attractive destination for a variety of shoreline and on-water recreational activities.

Habitat and Ecological Health trends for fisheries, oysters, wetlands, streams and forests in the watershed, are variable. Tidal wetlands, in particular, are stable after centuries of habitat loss. However, other critical natural habitats continue to be lost or damaged. Submerged aquatic vegetation, a keystone in-water habitat, has partially rebounded following habitat loss from recent tropical storms. Tributary streams, which have been heavily fragmented by dams and culverts over a period of centuries, are getting new attention, with pilot restoration projects underway. The decline in some fish populations, such as striped bass and herring, may be leveling off, while other species such as shad and sturgeon are still at risk. In recent years, restoration projects are aiding the recovery of oyster populations for the ecological benefits they provide.

Contaminants, such as heavy metals in sediments and PCBs in fish, are decreasing in concentration from highs in previous decades but remain a concern. Though average concentrations of PCBs in striped bass tissues have declined since the 1990s, concentrations have remained stable in recent years and EPA estimates that the advisories for consuming Hudson River fishes may need to remain in place for more than 50 years. Average concentrations of cadmium were much lower in crabs collected in 2004 than those collected in 1979 and will be further assessed soon. The cleanup of contaminated sediments at hundreds of Superfund and brownfield sites along the estuary has reduced many dispersed sources of pollution. Data from the past 20 years indicate that dioxin concentrations in the upper harbor, mostly originating from 1960's contamination of New Jersey waters around Newark Bay, are now leveling after an earlier decline. DDT, a contaminant responsible for the extirpation of many raptor species from the Hudson, is likely no longer problematic.

Photos: left: Hudson River Park Trust, middle: Bob Rightmyer, right: NYSDEC

Executive Summary
Findings

Public Access is a wonderful success story—the result of investments by local, state and federal agencies and programs. As water quality has improved, the number of public parks, boat launches, trails and nature preserves has increased with it. More access to the waters of the estuary exists now than has been the case for generations. About 25% of the shoreline is available to the public, including many new public access sites, walkways and bikeways in New York City. Access across the railroad tracks has vastly increased north of Manhattan, as has the number of Greenway Water Trail sites for canoeing and kayaking. Enhanced access is allowing more people to enjoy the water and is fostering a stewardship ethic in surrounding communities.

Community Engagement and stewardship events are growing in popularity every year. The total number of community members participating in stewardship events has grown dramatically since 2003, and the increased number of hours they commit indicates that people are deepening their engagement in environmental stewardship. People of all ages are having a positive effect on their local waterways and the estuary watershed through a wide range of actions. Community residents contribute their local knowledge and leadership to conservation planning efforts in municipalities large and small. Schools are making stewardship events a regular part of their curriculum. Dozens of organizations throughout the estuary are conducting community science programming and collecting data. Community engagement empowers people to have an impact on where they live.

Climate Change is affecting the Hudson Estuary right now. Key indicators of change (temperature, precipitation, and sea level) that affect ecosystem health are all exhibiting troubling trends. They show that the estuary's waters are warming, annual rainfall is increasing, and sea level is rising. Air temperatures in the region have also increased, and our warming climate has altered the timing of natural events keyed to seasonal change, such as the migratory patterns of fish and birds. Intense storms matter a great deal. Tropical storms Irene, Lee, and Hurricane Sandy left a lasting mark on the estuary affecting habitats and sediment. DEC is using the data contained in this report to better guide and encourage climate change adaptation by communities.

Photos: left: Nancy Beard, middle: NYSDEC, right: Steve Stanne

The Estuary

About the Hudson River Estuary and the State and Federal Estuary Programs

The Hudson River Estuary extends north from New York Harbor to Troy and is influenced for this entire distance by twice-daily ocean tides. In the southern part of the estuary, freshwater mixes with ocean water and is extremely brackish. The estuary gradually becomes a more freshwater tidal environment above the harbor, becoming generally freshwater from Poughkeepsie north to the head of tide at the Troy dam. The watershed is the area of land from which water drains into the estuary from the non-tidal upper Hudson, the Mohawk River and through tributary streams. The amount of freshwater flowing south in the estuary is influenced by the amount of rainwater in the watershed. After heavy rain storms, the zone where freshwater mixes with saltwater may be pushed far to the south into New York-New Jersey Harbor. During droughts the mixing zone may extend well north of West Point, occasionally as far as Poughkeepsie.

The estuary is a unique and highly productive ecosystem that is habitat for a wide variety of fish and wildlife, including some that have provided economic benefit to people for centuries and others that provide inspiration and ecological benefit. In particular, the estuary enables a rich biodiversity of migratory fish—shad, striped bass, sturgeon, and herring—that spawn in the estuary and then spend much of their life in the ocean. Blue crab, a migratory crustacean, and resident fish such as bass and perch are also highly valued. Bald eagles, diamondback terrapin, herons and ducks are just some of the rich wildlife resources of the estuary. All of these species depend on the chemical, physical, and biological characteristics of the estuary, including a complex food web of plants and animals, as well as habitats.

The New York State Hudson River Estuary Program

This program helps people enjoy, protect and revitalize the Hudson River Estuary and its valley. It was created by state law in 1987 and extends from the head of tide at the Troy dam on south to the Verrazzano Narrows, including upper New York-New Jersey harbor. The NYSDEC manages the program in partnership with other agencies and is guided by an advisory committee of stakeholders. An *Action Agenda* specifies measures to be taken by NYSDEC and many public and private partners to conserve and restore the ecosystem. The 1987 law requires the program to provide periodic status reports on the condition and productivity of the estuary, and this **State of the Hudson Report** is a response to those requirements. It describes specific chemical, physical, and biologic characteristics of the estuary and its watershed and shows how they are changing with time. The Estuary Program also provides assistance, grants, and scientific research to empower citizens, communities, and agencies to make informed choices. Its collaborative approach achieves real, on-the-ground progress and produces powerful regional results.

Photos: Diamondback terrapin and Atlantic sturgeon. NYSDEC

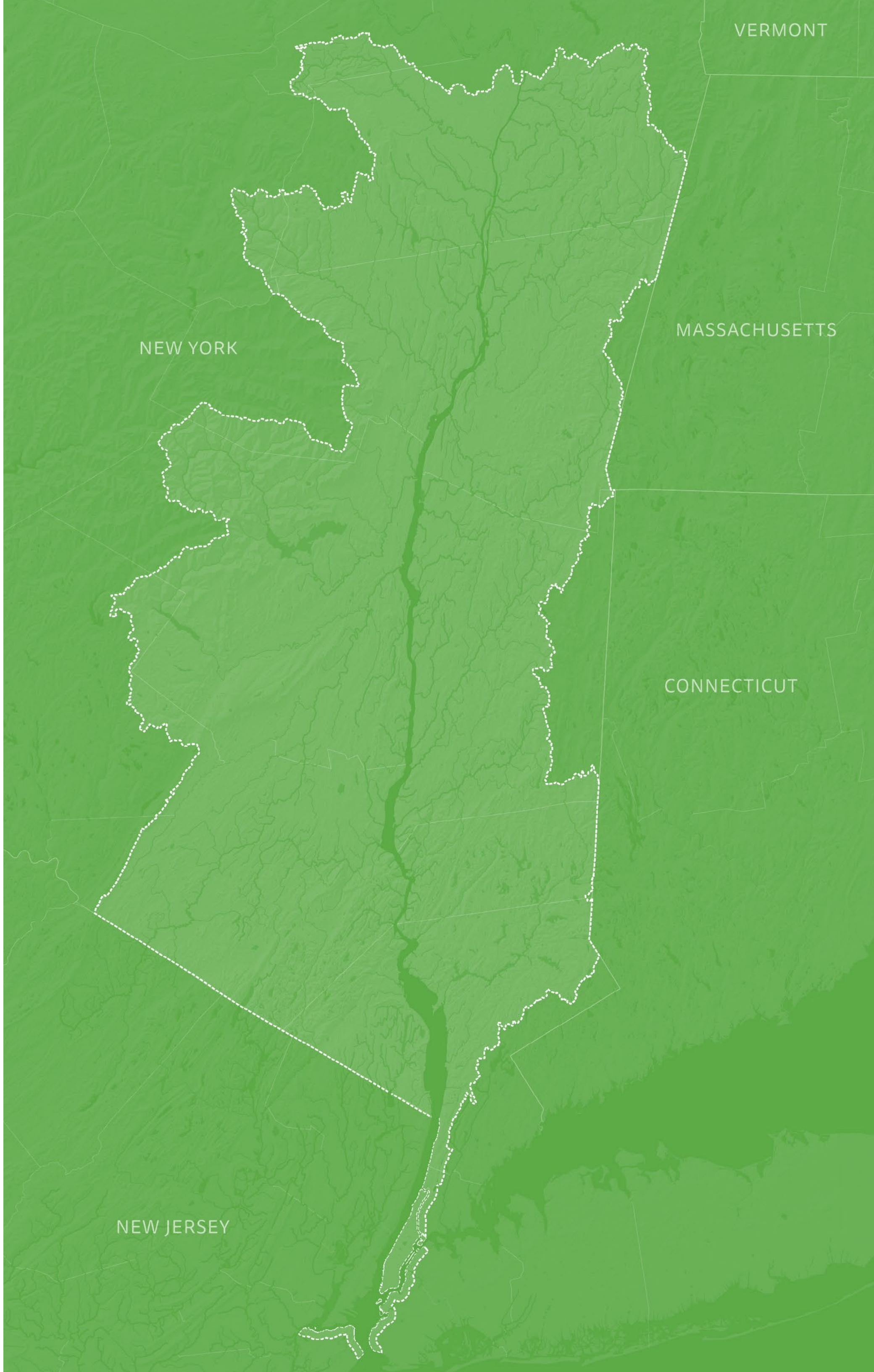
The Estuary

The New York – New Jersey Harbor & Estuary Program (NY-NJ HEP)

NY-NJ HEP helps bring together diverse stakeholders including scientists, citizens, and policy makers to work towards the goal of fishable and swimmable waterways for people and wildlife called for in the Clean Water Act. One of the Nation's 28 Estuaries of National Significance, NY-NJ 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 collaborative and provides the non-federal match to funds received from the EPA under the Clean Water Act. Like the Hudson River Estuary Program, NY-NJ HEP is charged with assessing trends for key indicators of the overall health of the estuary. The data and trends illuminated in this document expands and complements NY-NJ HEP's 2018 State of the Estuary Report that additionally includes the bi-state waters south of the Mario Cuomo Bridge. This scientific understanding will be used by NY-NJ HEP and its partners as we implement the current *Action Agenda* and identify new priorities in the future.

NEIWPCC

NEIWPCC is a regional commission that helps the states of the Northeast preserve and advance water quality. It engages and convenes water quality professionals and other interested parties from New England and New York to collaborate on water, wastewater, and environmental science challenges across shared regions, ecosystems, and areas of expertise.



Map: New York State Law defines the estuary as the tidal waters within its jurisdiction from the Troy Dam to the Verrazzano Narrows and the associated shorelands. The upper Hudson and the Mohawk River are not shown on this map, nor is the portion of the estuary within the state of New Jersey.

User Guide

Organization of this Report

This report is organized around the following goals: water quality, habitat and ecological health, contamination, public access, community engagement and climate change. The **Water Quality** section is comprised of the following parameters that affect recreational use and ecosystem health: dissolved oxygen, macroinvertebrate communities, nutrients, salinity, pH and bacteria. The **Contamination** section focuses on the issue of legacy chemicals and metals, their sources, and the threats they pose to people and wildlife. The **Habitat and Ecological Health** section addresses changes in the condition of fisheries, estuarine and shoreline habitats, natural areas in the watershed and the connectivity of tributaries. The habitat assessment is done both qualitatively (how is the condition of the habitat changing) and quantitatively (how much of the habitat is there). The **Public Access** section indicates how well people can access the shorelines and waters for recreational purposes. The **Community Engagement** section explores how the public is involved in stewardship of the estuary. Finally, the **Climate Change** section focuses on environmental indicators such as temperature, precipitation and sea-level rise as they affect estuarine health. References and suggested readings can be found at the end of each chapter.

Selection of Indicators

The environmental indicators selected for this report are broadly representative of ecosystem health. An initial list of indicators was developed by NY-NJ HEP for its 2018 State of the Estuary Report and refined by the Hudson River Estuary Program, with input from the members of the Hudson River Estuary Management Advisory Committee (HREMAC). The indicators reflect the priorities of the scientists, managers, educators, and advocates who are most engaged with the conservation of the estuary and its ecosystem, including the staff of the NYSDEC, NEIWPCC, and Cornell University, and members of HREMAC. Data sources for the indicators were suggested by NYSDEC and NY-NJ HEP. The data collection and analysis was performed according to a Quality Assurance Project Plan (QAPP), approved by NEIWPCC, and all sources were recorded. This report also tells many other narrative stories about environmental indicators for which the estuary programs hope to have future monitoring data.

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. Only trends meeting this statistical criterion were reported as an improving or deteriorating trend. 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 and the Hudson River Estuary Program (the late 1980s- early 1990s); short term analysis starts roughly in the early to mid-2000s. Where longer term historical data were available, they were included. Spatially, the analysis was focused on the waters of the estuary as defined in New York State law, from the Verrazzano Bridge to the Troy dam and the surrounding watershed lands within New York State in order to fulfill the reporting needs of the NYS Hudson River Estuary Program.

Going forward, the Hudson River Estuary Program and the NY-NJ Harbor & Estuary Program will continue to track these trends, with regular updates every five years. The data and scientific analysis will be used to identify and address our shared management priorities.

Acronym Key

ADA	Americans with Disabilities Act
CPUE	catch per unit of effort
CSC	Climate Smart Communities
CRRA	Community Risk and Resiliency Act
CSO	combined sewer overflow
DDT	dichlor-diphenyl-trichloroethane
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
HRECOS	Hudson River Environmental Conditions Observing System
HRNERR	Hudson River National Estuarine Research Reserve
HUC	hydrologic unit code
IPCC	Intergovernmental Panel on Climate Change
NGO	Non-Governmental Organization
NEIWPCC	New England Interstate Water Pollution Control Commission
NOAA	National Oceanic and Atmospheric Administration
NOAA NCEI	National Centers for Environmental Information
NRCC	Northeast Regional Climate Center
NRI	Natural Resource Inventory
NYC	New York City
NYCDPR	New York City Department of Parks and Recreation
NY-NJ HEP	New York - New Jersey Harbor & Estuary Program
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
NYSDOS	New York State Department of State
NYSOPRHP	New York State Office of Parks, Recreation, & Historic Preservation
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated piphenyls
PFAS	perfluoroalkyl and polyfluoroalkyl substances
PIPC	Palisades Interstate Parks Commission
PPM	parts per million
PPT	parts per trillion
PSU	practical seawater units
QAPP	quality Assurance Project Plan
REMAP	Regional Environmental Monitoring and Assessment Program
SAV	submerged aquatic vegetation
SBA	significant biodiversity area
SBU	Stream Biomonitoring Unit
SET	surface elevation table
TCDD 2,3,7,8	tetrachloro dibenzo-p-dioxin
TPL	Trust for Public Lands
USFWS	US Fish and Wildlife Service
USGS	United States Geological Society
YOY	young-of-year fish

1. Water Quality

Monitoring water quality.
Hudson River Park Trust

Water Quality
Introduction

A number of key parameters are used to measure water quality. They provide important information on the health of the fish and wildlife living in the waters of an estuary, as well as the human use of the estuary for activities such as boating, swimming, and fishing. For many years, government agencies and scientists have been measuring various water characteristics including the parameters reported below, such as nutrients, dissolved oxygen, pH, macroinvertebrates, temperature and bacteria, in order to better understand how the ecosystem functions and to guide regulatory actions. Turbidity is important for the river and has been monitored as well, but it is highly variable and is not included in this report. Water temperature data can be found in the Climate Change chapter.

Water quality data were first collected by New York City's Metropolitan Sewerage Commission from 1910-1914. Pollution reported from that time and confirmed repeatedly in documents through 1979, showed that discharges of municipal sewage, tannery and paper mill wastes, and industrial chemicals fouled the river from the Capital District at one end of the estuary to the Hudson's mouth at New York City (Hudson River Survey Commission, 1938; Bruce, 1961; Boyle, 1979).

Water quality has improved immensely since then. State and federal actions during the 1960s and 1970s made pollution control a priority. In 1965, New York State voters passed a billion-dollar Pure Waters Bond Act to fund sewage treatment. In 1972, the federal Clean Water Act made clean-up a national priority. In the years following, industrial and municipal discharges gradually came into compliance with these and other laws. However, problems remain. Maintaining good water quality will require addressing on-going infrastructure needs. As of 2017, in the watershed of the estuary north of New York City, about 11% of sanitary sewer pipes were installed before 1925; approximately 26% are over 65 years old. There were also 111 combined sewer overflow (CSO) outfalls discharging into the Hudson River and tributaries during overflow conditions (NYSDEC databases). Communities are on track to fix the CSOs, but it will cost millions.

The water quality data used for this report address more recent trends. They were gathered from several sources, including the Cary Institute of Ecosystem Studies Kingston station, the Hudson River Environmental Conditions Observing System (HRECOS), the Hudson River National Estuarine Research Reserve's (HRNERR) long-term data stations, and data from periodic sampling conducted by the NYSDEC's Division of Water and the US Geological Survey (USGS).

Photo: Swimming in the Hudson. NYSDEC

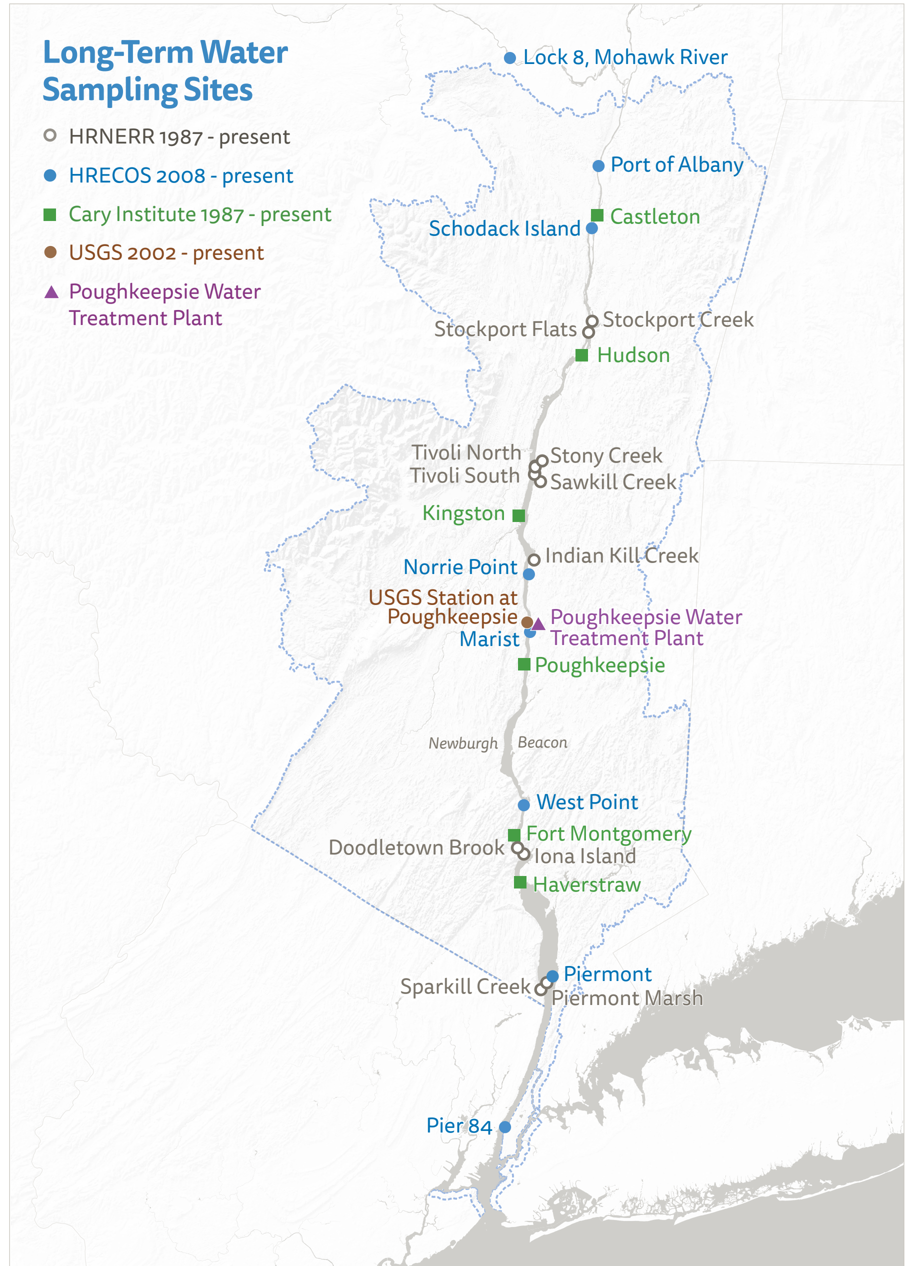
Did you know?

High frequency monitoring is now wide spread along the estuary.

The Hudson River Environmental Observing System (HRECOS) is an environmental monitoring network operated and managed by a consortium of governmental, academic, and private institutions with shared interest in high-frequency monitoring within the lower Hudson River watershed. HRECOS monitoring stations are broadly distributed along the lower Hudson and Mohawk rivers, and are equipped with sensors that continuously record a suite of water quality and weather conditions every 15 minutes, with most stations operating year-round. The system started operating in 2008 and has added stations over time. Remote telemetry at each station transmits real-time data that are stored in remote databases and made easily accessible with the HRECOS mapper application. HRECOS stations which had 5-10 years of data collected constantly from the same sampling locations are Lock 8 (Mohawk River), Port of Albany, Schodack Island, Tivoli North Bay, Tivoli South Bay, Norrie Point, Marist College, and Pier 84 (Manhattan).

Photo: HRECOS display for Norrie Point, see Further Reading for website.

Map: In addition to the HRECOS stations, water quality is monitored by HRNERR, a partnership between the National Oceanic and Atmospheric Administration (NOAA) and the NYSDEC that manages four tidal wetland reserves along the lower Hudson. Their long-term water quality data have been collected monthly at 10 different sites within the wetlands since 1991. The Cary Institute of Ecosystem Studies has sampled several stations along the mainstem 1987. A USGS station at Poughkeepsie has provided continuous water discharge and suspended sediment data, along with turbidity, water temperature, specific conductance, and stage height monitoring since 2002. The Pough-keepsie Water treatment plant has measured water temperature daily since 1940.



Dissolved Oxygen

Long-term Trend (1987-2019): Not trending

Short-term Trend (2008-2019): Not trending

Background

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 can be stressed by areas of low dissolved oxygen. Acute hypoxia (very low dissolved oxygen), can result from eutrophication under certain conditions. Acute hypoxia can cause fish kills. Chronic hypoxia can affect predator-prey relationships in the estuary (Yozzo, 2018).

Low dissolved oxygen may be caused by discharges of organic matter and nutrients from sewage treatment plants as well as from algae blooms. When algae or other types of organic matter decompose, they can cause biochemical reactions that reduce oxygen. Excess nutrients in the water can cause an overgrowth of algae, known as an algae bloom, and this process is called eutrophication. When the algae die, bacteria consume them, using available oxygen. However, the Hudson Estuary is naturally turbid (cloudy) from the presence of both sediment and plankton. This turbidity, combined with vertical mixing, is thought to be a factor that currently suppresses algal blooms in the tidal Hudson, thereby preventing excess growth and potential oxygen depletion. In addition, native aquatic plants, primarily American eelgrass *(Vallisneria Americana)*, provide a source of oxygen to the estuary through photosynthesis (Findlay et al. 2006; also see habitat chapter). Hypoxia is most problematic in slow-moving tributaries to the Hudson, deeper parts of the estuary where the water is not well mixed, and in some of the largest water chestnut beds, where this non-native aquatic plant contributes to oxygen loss (see habitat chapter). Nutrient-laden water flowing from the Hudson into the ocean is also a concern for oxygen conditions off-shore in New York Bight.

Historic conditions have been reported in documents that pre-date the 1972 Clean Water Act (see suggested reading). In the summer of 1970, a consultant study on the upper reaches of the Hudson Estuary found only a few living fish, and those were seen "swimming slowly at the surface, gulping air, and disturbing an oil film which covered the water surface" (Quirk et al., 1971). By 1987, however, when the Hudson River Estuary Program was established, the benefits of clean water laws, enforcement actions and state and federal sewer infrastructure investments were already showing results. Improved oxygen levels and conditions for fish have persisted ever since and are monitored by HRECOS sites and NYSDEC.

Analysis

A long-term analysis was conducted using data from a station at Kingston maintained by the Cary Institute of Ecosystem Studies starting in 1987. A short-term analysis was conducted with HRECOS data (taken every 15 minutes since 2008) and HRNERR main stem station data collected monthly since 1991. HRNERR stations in tidal marshes were not used for this analysis since wetlands naturally remove oxygen during tidal exchange (Findlay and Fischer, 2013). HRECOS data were summarized to monthly median values, which represent the middle value of the observed data and will not be skewed by a small subset of extreme low or high values, as would be the case with the mean (average). Annual cycles of oxygen levels were then compared to the EPA standard 4.8 mg/L (US EPA, 2000).

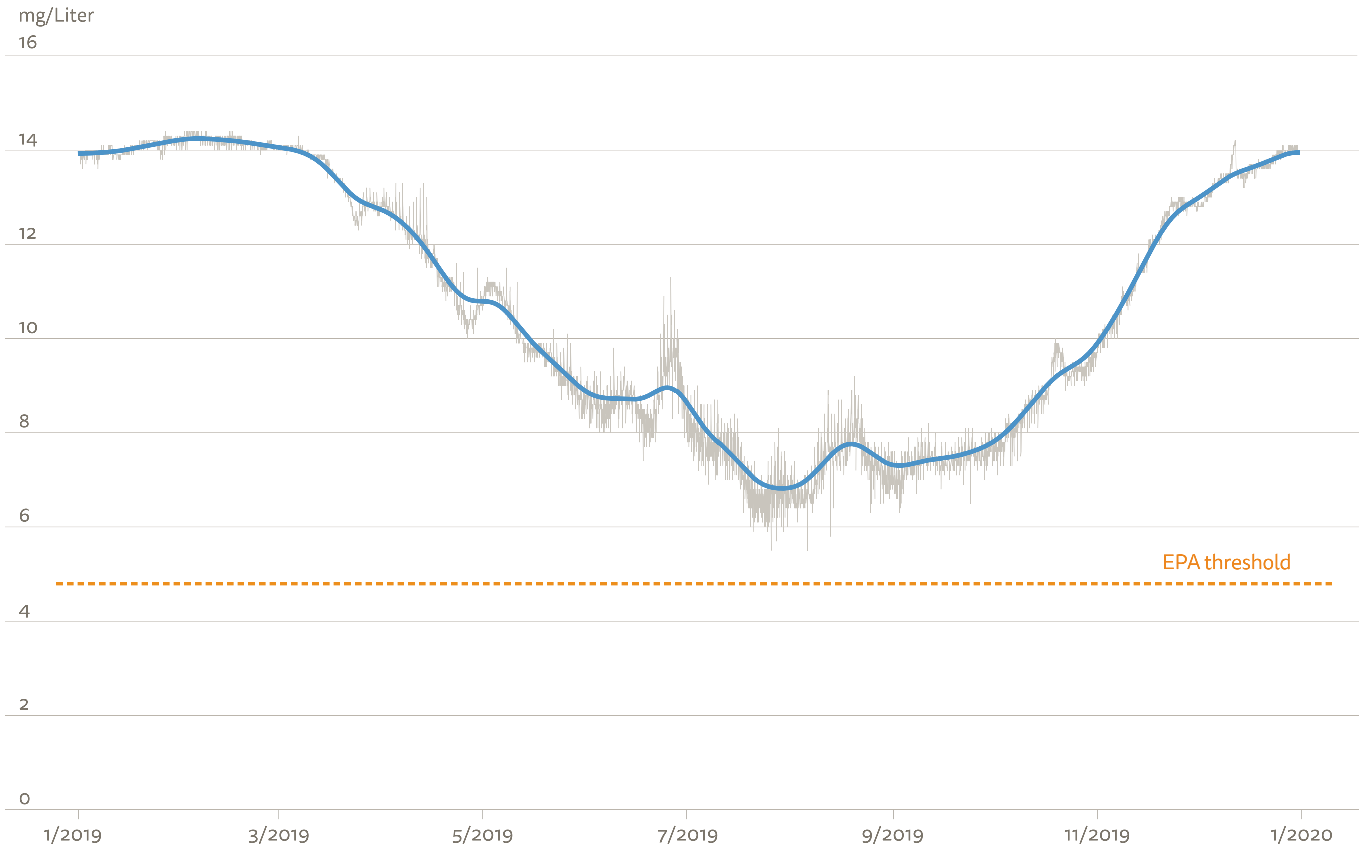
Photo: Water celery *Vallisneria americana* fronds can grow several feet long in large beds, providing oxygen to the river. NYSDEC.

Dissolved Oxygen

Findings

For the period of record oxygen levels at all main stem Hudson River stations were above 4.8 mg/L, even in the summer months when oxygen levels are lowest, as shown in the example graph provided from the Norrie Point HRECOS station. 4.8 mg/L is the EPA designated threshold below which continuous exposure hinders growth of marine life (US EPA, 2000). None of the mainstem Hudson stations showed a short-term or long-term trend that would be considered significant.

Norrie Point Dissolved Oxygen



Graph: Annual cycle of oxygen levels at the HRNERR Norrie Point station are typical of dissolved oxygen levels at HRECOS and HRNERR stations on the main stem of the Hudson. Note that even in August (typically time of minimum values) levels are well above the threshold of 4.8 mg/L.

Data Source: HRECOS, HRNERR

Macroinvertebrates

Did You Know?
Tiny Creatures are Excellent Indicators of Water Quality!

The NYSDEC Stream Biomonitoring Unit (SBU) was initiated in May 1972 as mandated by the Federal Water Pollution Control Act. The unit evaluates the relative biological health of the State's surface waters through the collection and analysis of macroinvertebrate communities. Macroinvertebrates are larger-than-microscopic invertebrate animals that inhabit stream, river, lake, and wetland bottoms. Freshwater forms are primarily aquatic insects, worms, clams, snails, and crustaceans. Macroinvertebrates are widely used in biomonitoring because they provide an accurate means of water quality assessment. The SBU operates on a 5-year rotational cycle and collects macroinvertebrate community data at sites of agency, regional and/or public interest, in support of clean water planning and improvement programs and for spatial and temporal trend monitoring.

Assessments of stream and river water quality use a four-tiered system of impact categorization based on the macroinvertebrate community known as the Biological Assessment Profile (BAP) score. For rivers like the Hudson, the BAP score is calculated based on four metrics, but a key one is the combined species richness of mayflies *(Ephemeroptera)*, stoneflies *(Plecoptera)* and caddisflies *(Trichoptera)*, collectively known as EPT richness. The EPT are considered to be mostly clean-water macroinvertebrate organisms. Increasing diversity of EPT follows improvements to water quality (Lenat, 1987). In general, a higher EPT richness score indicates better water quality. A BAP score of 7.5 - 10 or better is indicative of non-impacted water quality, while a score of 5.0 - 7.5 indicates slightly impacted conditions, and a value below 5 indicates moderate (2.5 - 5.0) or severely impacted (0 - 2.5) conditions and suggests biological impairment.

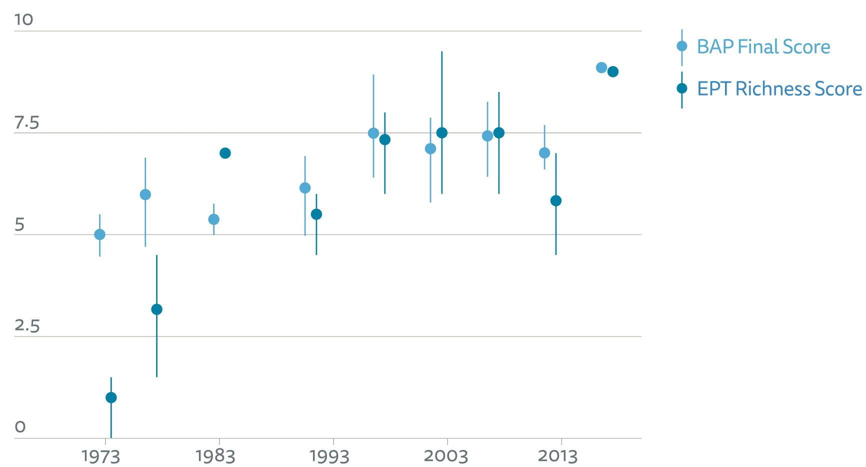
Since monitoring began in 1972, sections of the Hudson have shown substantial water quality improvement. The first stoneflies in the lower Hudson were recorded by the SBU in 1997. These improvements are in stark contrast to anecdotal field records from the 1970s, indicating a "gross[ly]" polluted, "slime" and "sewage" filled location, where human hair was found wrapped around the multi-plate bricks (NYSDEC, 1970).



Photos: Stonefly, Caddisfly, Mayfly, larval stage macroinvertebrates. NYSDEC.

Graph: The Capital District site on the Hudson at Troy has specifically shown positive improvement since 1973 (Lenat, 1987) and improved consistently through 2017 where BAP scores were 9.1 (slightly or non-impacted). Similarly, the Ephemeroptera, Plecoptera and Trichoptera (EPT) richness score at the Troy site has improved from severely impacted in 1973 to slightly impacted in 2017. In 2012, a slight drop in BAP scores was most likely caused by Hurricane Irene and disruption of macroinvertebrate communities measured in that year.

Biological Assessment Profile (BAP) and EPT Richness



Data Source: NYSDEC Stream Biomonitoring Unit

Nutrients

Long-term trend nitrate (1987-2019): Improving
Long-term trend phosphorus (1987-2019): Not trending
Short-term trend, both nutrients (2000-2019): Not trending

Background

Nutrients are essential for the growth of aquatic plants such as the phytoplankton and rooted submerged aquatic vegetation that serve as important contributors to the food webs of the Hudson River. Large amounts of nutrients, however, can contribute to several water quality problems, most commonly, excess growth of algae in the water column, and ultimately, loss of oxygen from bottom waters as dead algae decompose (see dissolved oxygen). In most freshwater systems, including the upper estuary, phosphorus is considered the nutrient of greatest concern. However, nitrogen is often the greatest concern in marine ecosystems. Nitrogen from the Hudson is also transported to the more saline portions of the estuary as well as off-shore marine waters, so nitrogen is important to understand for its impact on the larger ecosystem. Phosphorus inputs to the Hudson River come from wastewater effluent and fertilizer run-off. Nitrogen also derives from these sources but also is supplied by snow and rainfall in the watershed.

The observed levels of nutrients in the Hudson are generally high and would cause much higher levels of algal growth, including algae blooms, than are observed. However, algae are currently limited in abundance by strong light limitation due to turbidity (Cole et al., 1992). The turbidity of the Hudson combined with continual vertical mixing means that algal cells are carried deeper than sunlight penetrates and spend most of the daylight hours below the top 1-2 meters where light is available. However, there is still the potential for stratification (lack of vertical mixing) under certain weather conditions or in shallow areas, and this could allow excess algal growth. These conditions have not been observed frequently in the mid-Hudson, but warmer conditions in the future could make them more common. In addition, since the mid-1990s, filtration by the non-native zebra mussel (*Dreissena polymorpha*) has limited algal abundance (Strayer, 2011). Nutrients from the Hudson River are delivered to the harbor and beyond into the NY Bight, and these loads, especially nitrogen, represent a significant nutrient supply to downriver and coastal waters that are likely more vulnerable to excess algal growth.

Total Phosphorus (Kingston Station, NY)

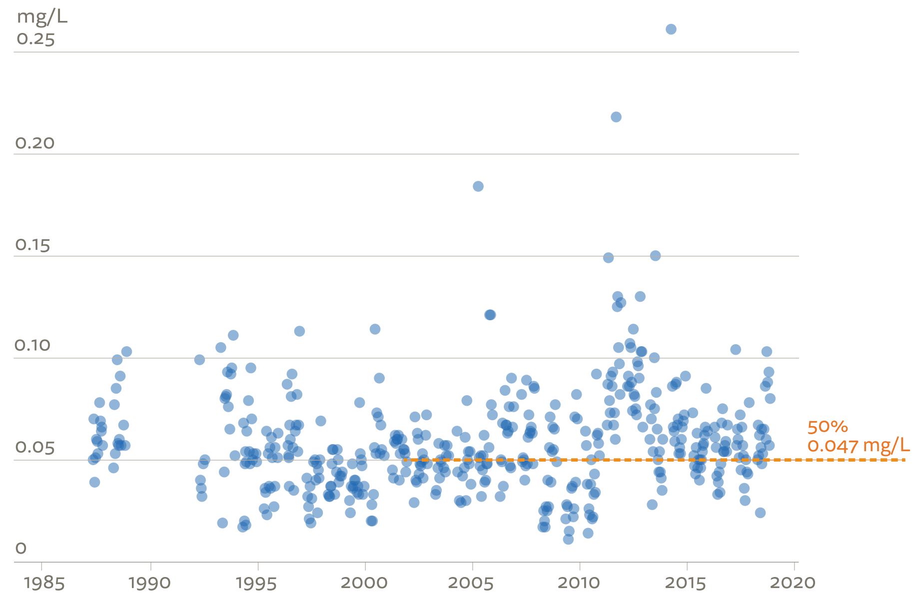


Photo: Sewage treatment plant, Newburgh, NY. NYSDEC.

Graph: Total phosphorus (mg/L) measured during the ice-free season at a station near Kingston NY. The line shown represents the 50th percentile (equivalent to the median), to provide context of how the Hudson River data at the Kingston station compares to other sites in the lower Hudson River watershed. The figure shows that the values for the Hudson are similar to values for other waterbodies in the lower Hudson River watershed.

Nutrients

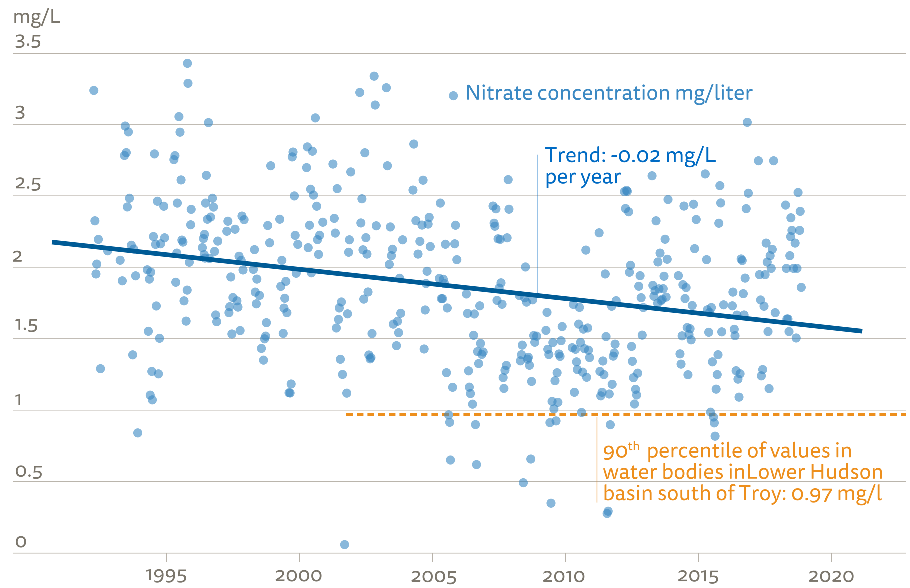
Analysis

Nutrient data used for this analysis are from the Cary Institute of Ecosystem Studies. Cary scientists have collected nutrient samples over the past 25 years at a main-channel location near Kingston, NY (sampled every two weeks during the ice-free season). The Kingston station is considered representative of the mainstem Hudson, as there is small variation among Cary Institute stations. Several forms of nitrogen (organic, nitrate and ammonium) are routinely measured, but since nitrate (NO3) is the most abundant bio-available form, it is used to represent nitrogen availability. For phosphorus, Cary measures both phosphate (the most bio-available) and total phosphorus, which includes phosphorus contained in microscopic organisms like algae (Ohrel and Register, 2006). Comparison data were also collected from the NYSDEC Rotating Integrated Basin Studies (RIBS) dataset between 2002-2019 to create percentiles shown on the graph. This total phosphorus and nitrate data represent a mixture of routine and random sampling locations broadly characterizing the tributaries and mainstem of the lower Hudson River Basin.

Findings

Concentrations of both nitrogen and phosphorus in the Hudson above the Tappan Zee area were moderately high compared to other rivers/estuaries (Lampman et al., 1999), with long-term mean concentrations of ~ 2.0 mg nitrate/L and 0.06 mg phosphorus/L as total phosphorus. There was a consistent drawdown of both nitrogen and phosphorus during the warmer growing season, most likely related to biological uptake and denitrification in wetlands and vegetated habitats (Tall et al. 2011; Caraco and Cole, 2002; Findlay and Fischer, 2013). There were long-term fluctuations in concentrations of both nitrogen and phosphorus with no consistent trend in phosphorus but an improving trend in average nitrate concentrations. Most values for total phosphorus were between the eutrophic range of 0.03 - 0.1 mg/L, which is capable of supporting high algal biomass. However, in the tidal Hudson River algal growth is limited by water turbidity and vertical mixing. Total phosphorus at the Kingston station is similar to the average RIBS results from the greater watershed, while nitrate is much higher than average. Thus, the concentrations at the Kingston station may be reflecting the combined load of nitrate from all the tributaries to the main stem of the Hudson.

Nitrate Concentration (Kingston Station, NY)



Nitrate levels were below the NYSDEC and EPA guidance values/standards of 10 mg/L for the protection of (Class A) drinking waters in this stretch of the Hudson River. However, even nitrate values of 1-2 mg/L can promote the growth of algae, including the potential for harmful algae blooms (HABs). Further impacts to aquatic life are usually associated with these concentrations as well. However, there are many factors that influence the suppression of algal growth and related impacts in the Hudson Estuary.

Graph: Long-term mean concentrations are ~ 0.4 mg nitrogen/L as nitrate, well below the 10 mg/L drinking water standard for this stretch of river, but high enough to cause concern for ecological impacts. The line shown represents the 90th percentile, which represents the lower bound of the highest 10% of values observed at other sites in the lower Hudson River watershed. Therefore, nitrate values in the Hudson are clearly higher than the majority of other waterbodies in the region.

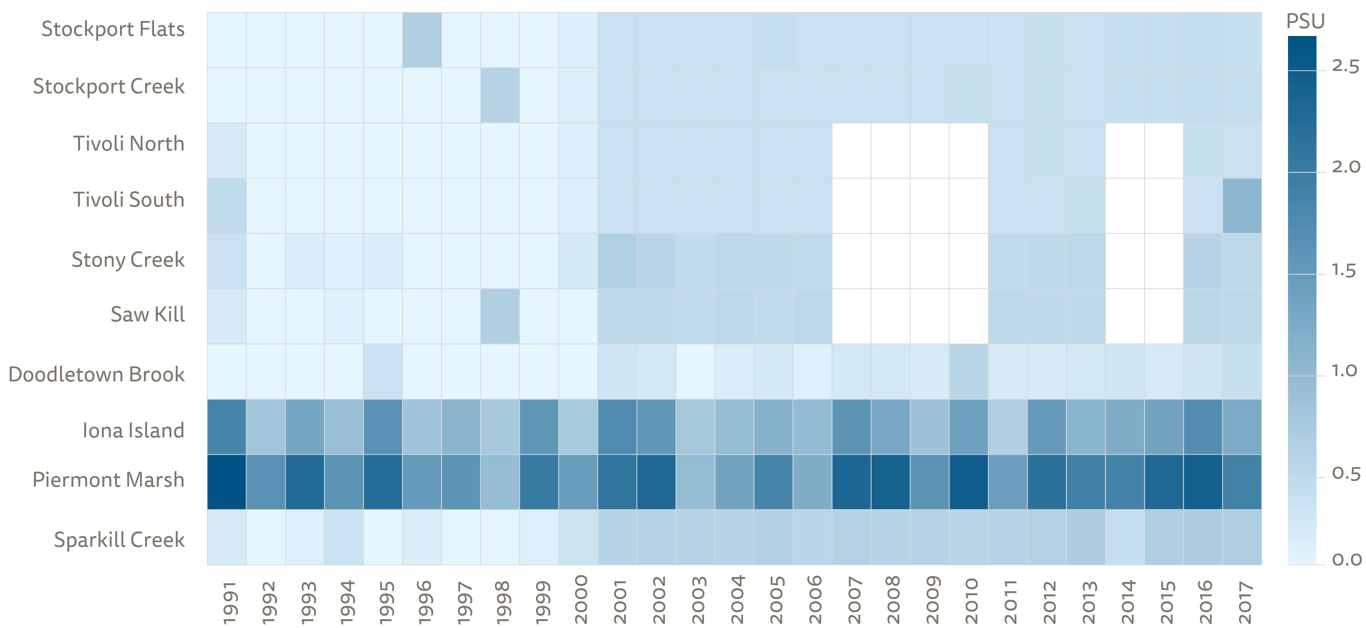
Data Source: Cary Institute of Ecosystem Studies, RIBS

Salinity

The Hudson River from NY Harbor to Troy is an estuary where saltwater from the ocean meets and mixes with freshwater from the watershed. The very southern end in NY Harbor can be almost completely ocean water with high salinity (> 30 PSU; practical salinity units) especially during times of low freshwater run-off. However, most of the estuary is much less saline. The estuary between NY Harbor and Newburgh is brackish, and during low flow, brackish conditions are detectable as far north as Poughkeepsie. The edge of this saline environment, which moves up or downstream depending on the amount of freshwater flows, is called the salt front. Above Poughkeepsie and north to Troy, the Hudson Estuary is a freshwater tidal environment.

Changes in salinity can be the result of movement of the salt front due to weather and tides. Localized changes not associated with the movement of the salt front may reflect human activity, including road salting, wastewater overflow, and agricultural runoff. Seasonal inputs of rain or snow that freshen the water tend to push salinity south in the estuary. Drought tends to allow water with higher salinity to move north in the estuary. Most aquatic organisms have limited tolerance to wide or rapidly changing ranges of salt content. The impacts of climate change on sea level, rainfall and snowmelt may affect the position of the salt front. Understanding the impacts of climate change on salinity will have important implications for people and ecosystems.

Salinity: annual averages from mainstem, marsh and tributaries determined from HRECOS and HRNERR observations, 1991-2017



Graph: HRECOS data taken every 15 minutes since 2008 and HRNERR data (shown here; taken monthly from 1991) suggest small changes in salinity which are unlikely to cause ecosystem disruption. The freshwater tributaries have become slightly more saline with time as indicated by the slightly darker shades of blue starting in 2000 (note Stockport Creek and Stony Creek in particular). The consistent darker shades of blue at Iona Island and Piermont Marsh are indicative of the more saline waters in the southern portion of the estuary. Salinity will continue to be monitored to detect changes that might be anticipated due to climate change. Blank cells indicate no data was collected for those years.

Data Source: HRNERR Monitoring Program

pH (Acidity)

Historic Trend: see text below

Long-term Trend (1987-2019): Improving

Short-term Trend (2000-2019): Improving

Background

Acidity (pH) is represented by a measure of the concentration of hydrogen ions (H^+). The pH spectrum is generally depicted as ranging from 0-14, where a pH of 7 is considered neutral, pH values below 7 become increasingly more acidic, and values above 7 become increasingly more basic. In freshwater rivers and estuaries, the expected range of pH is between 6.5 and 8.5. Most aquatic organisms are only tolerant of a specific pH range. Rapid increases or decreases in pH could alter the composition of the organisms found in a given ecosystem. Globally, most water bodies became increasingly acidic from the 1970s until early this century (Sullivan et al., 2018). In almost all freshwaters the major changes in pH have been due to acidic deposition from power plant emissions and cars (acid rain). In New York State, dramatic declines in pH were reported from streams and lakes in the Adirondack region due to acid rain. With the Clean Air Act amendments of 1990, deposition of hydrogen and other ions has decreased dramatically in New York State and elsewhere, including the Adirondack lakes and streams, and pH has increased, representing a clear success of environmental regulation targeted at sources of acid rain. Because the Clean Air Act does not regulate CO_2, however, ocean waters are becoming more acidic, as high CO_2 levels in the atmosphere from burning fossil fuels upset the pH balance. Though this impact could extend to estuaries, fortunately, the Hudson River Estuary is considered to be fairly well-buffered due to limestone geology in parts of the watershed. Changes in pH are therefore less dramatic in the Hudson Estuary than sensitive lakes and streams.

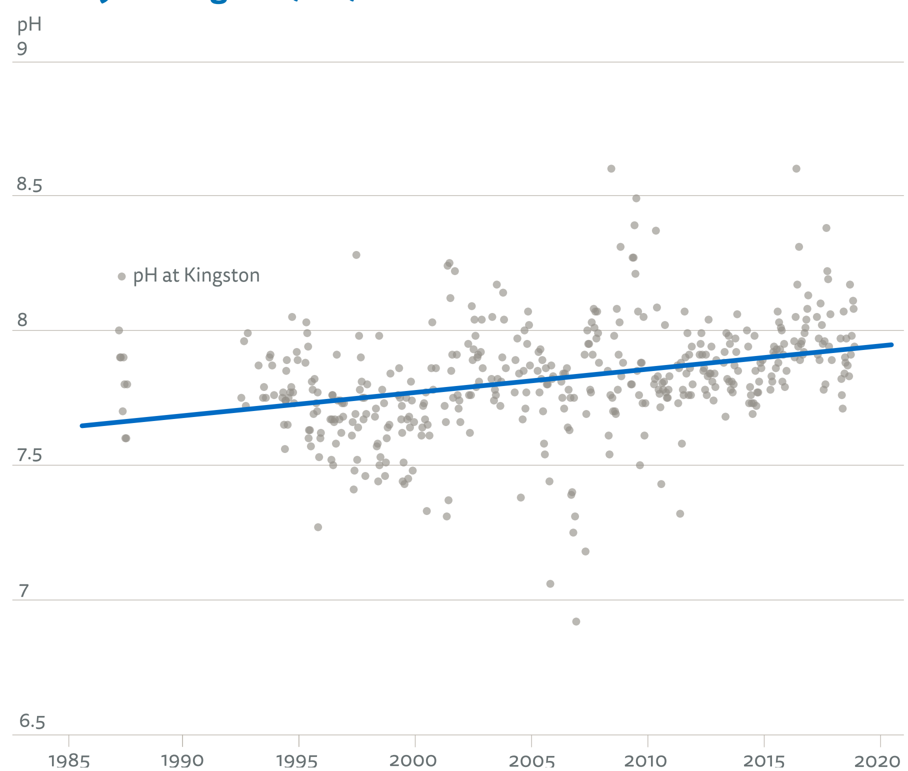
Analysis

Data for pH were provided by the Cary Institute from their monitoring at Kingston which has tracked pH during the ice-free season using an Accumet pH meter in the laboratory on air sealed samples. Trends were determined by using a linear regression with time. HRECOS stations will be a good source of pH data once the data record is long enough to determine a trend.

Findings

Records collected show an improving trend (more basic) since 1987. Values remained in the 6.5 - 8.5 range considered healthy for an estuary. This upward trend may be a response to recovery from acidification as has been seen in many smaller steams and surface waters in New York State in response to the Clean Air Act decreasing sulfur and oxidized nitrogen deposition (Sullivan et. al, 2018).

Acidity at Kingston, NY, 1987-2019



Graph: pH values in the mainstem at Kingston have been increasing which may be related to recovery from acidification in the watershed.

Data Source: Cary Institute of Ecosystem Studies

Bacteria

Did you Know?
Bacteria connected to swimming-related illnesses have declined in the harbor area.

When people swim or kayak in rivers and estuaries like the Hudson, they may come in contact with bacteria or other harmful organisms that can cause disease and sickness. Bacteria enter our waterways via sewage and stormwater outfalls flowing into the estuary, especially in urban areas. In less populated parts of the estuary, animal waste can be a source of bacteria, as well as failing septic tanks and illegal sewage hookups to storm sewers.

Fecal coliform bacteria are commonly used as an indicator to measure levels of pathogenic (disease-producing) organisms from fecal contamination in freshwaters. Fecal coliform information is typically used as an indicator in waterbodies that are deemed suitable for primary contact like swimming as well as secondary contact, including on-water recreational activities like kayaking or rowing. *Enterococcus* are another type of indicator bacteria and are used by New York State in some of the marine waters of the estuary.

The state and local health departments test for fecal coliform and *enterococcus* regularly at designated swimming beaches. Monitoring for bacteria has been conducted regularly in the waters surrounding New York City since 1985 through the city Department of Environmental Protection's Harbor Survey. It shows a significant long-term decrease in bacteria harbor wide. There have been no significant trends since 2007 but seasonal averages were largely below the EPA criteria for offshore sampling stations (Stinnette et al., 2018). There are limited long-term data available for bacteria that would allow assessment of trends in the Hudson River north of Yonkers at this time.

Water temperature:

At Poughkeepsie, the river's annual average water temperature increased by more than 2ºF between 1940 and 2011 (Seekell and Pace, 2011). See Climate Chapter.

Success Story
Improving Water Quality in the Major Metro Areas

Improvements to water quality are the result of specific actions on the part of local, State and federal government actions. The North River sewage treatment plant on the Hudson in New York City came online in 1986 and by 1991 was treating 170 million gallons per day to levels of secondary treatment, a major victory for water quality in the lower estuary. In recent decades, because of such actions, conditions have significantly improved for fish and other river creatures. (New York City Department of Environmental Protection, Harbor Survey Program). However, combined sewer overflows (CSOs) have been a persistent problem for water quality on the Hudson, especially in the most urbanized areas of the metro New York region and the Capitol District. When it rains, combined sewer systems, which collect both storm water and wastewater, cause sewage treatment plants to exceed their capacity and overflow.

In 2012, NYSDEC and New York City signed an agreement to develop 10 waterbody-specific, long-term control plans, plus a city-wide plan for CSOs. This agreement should reduce CSO discharges into New York City waters by approximately 8.4 billion gallons annually. In 2008, NYSDEC partnered with the Capital District Regional Planning Commission to address more than 100 CSOs in Albany and the surrounding area. Updated permits now require municipalities in this area to achieve improved water quality. The plan, announced early in 2014, is expected take 15 years to implement and cost $136 million.

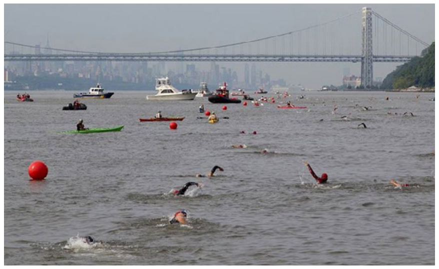


Photo: Swimming near the George Washington Bridge, New York-New Jersey Harbor. Angus McIntyre, Riverkeeper

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2. Habitat and Ecological Health

A bald eagle feeds an eel to its chick from a nest on the shores of the Hudson. Bob Rightmyer.

Habitat and Ecological Health
Introduction

Habitat is the environment in which plants and animals live. The habitat of the Hudson River Estuary and its watershed can be described in terms of the distribution of the plants and animals including people that live in the watershed. In a 2013 habitat restoration plan the NYS Department of Environmental Conservation (NYSDEC) described the unique habitats and ecological health of the estuary as follows:

> The tidal Hudson River is home to a host of fish, from hogchokers to eels, river herring and stripers and the river's resident giant, Atlantic sturgeon. The Hudson's waters and wetlands feed magnificent raptors, including bald eagles and osprey, and graceful waders, such as the great blue heron and snowy egret. River habitats support animals on the move: noisy clouds of blackbirds that settle in Hudson River marshes in the fall, and glass eels—tiny see-through swimmers—that arrive in spring from the Sargasso Sea. A complex web sustains all life in the Hudson River estuary. The Hudson's ecosystem is linked to its vast watershed through tributary streams, adjoining uplands at the shoreline and the Atlantic Ocean through currents and tides that reach far inland, all the way to Troy. The center-piece of this ecosystem is the estuary's mosaic of diverse habitats.
>
> Despite recent improvements to the Hudson River and its generally healthy condition, there is a profound need for habitat restoration. The river is vastly different from what it was like when Europeans first settled the valley. The estuary's habitats and ecological processes were disrupted by human activities, especially between 1800 and 1972. Shorelines and wetlands have been altered, relocated and eliminated along the 152-mile length of the estuary. Between Catskill and Troy, the river's flow has been directed to a single channel and over a third of the river's historic surface area has been filled with sediments dredged from the federal navigation channel. Hundreds of dams have been built in tributaries leading to the Hudson, many preventing migratory fish movement and degrading water quality. Water and sediments have been contaminated with toxins, and invasive plant and animal species have established and spread throughout the estuary. As a result of these and other factors, many populations of native fishes and wildlife have declined, and several have been listed as threatened or endangered.
>
> Fortunately, there have been many positive developments in the last 40 years since the passage of the Clean Water Act. Thousands of acres of Hudson River habitats have been protected and enhanced. Dramatic improvements in water quality in the estuary have benefited a host of aquatic and terrestrial species. Both tidal and freshwater wetlands protection laws and regulations have substantially reduced direct losses of Hudson River habitats. Several important habitat complexes have been acquired by New York State, municipalities and conservation organizations and are now managed for public access and habitat protection. Additionally, some highly contaminated sites have been remediated.
>
> —Miller, 2013

This chapter describes some of the key indicators that are representative of the overall health of the estuary ecosystem. It addresses fish abundance, oyster beds, shoreline habitats, tidal wetlands, and submerged aquatic vegetation. It also addresses the condition of natural areas in the watershed and tributary streams that flow to the estuary.

Photo: Tivoli North Bay. NYSDEC

Fish Abundance
Migratory Species

Historic trend: See text below

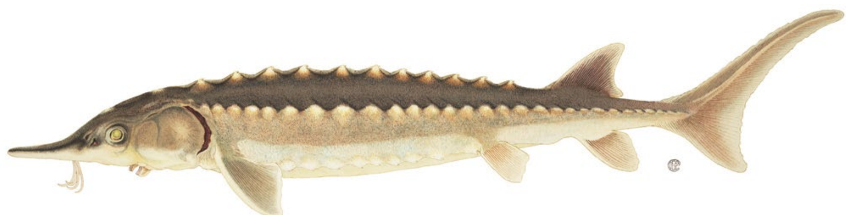
Long term trend (1983-2018): Declining

Short term trend (2000-2018): Not trending

The analysis for this indicator focuses largely on migratory ocean fishes that use the estuary ecosystem for spawning and as nurseries during important parts of their life cycle. These species are the foundation of historic commercial and sport fisheries for the Hudson, and sufficient data are available to track trends in abundance over time. To a lesser degree, freshwater resident species, invasive species, and ecological relationships are discussed.

Background

Historical accounts of the estuary from precolonial times through World War II describe our waters as teeming with fish. Native Americans thrived along the estuary, utilizing fish as an important food source. Robust fish populations supported a booming commercial fishing industry during the late 1800s through the 1950s. Today, fish populations are a fraction of what they once were and only a few commercial fisheries currently exist. Fish populations can be influenced by habitat modifications such as dramatically altered shorelines, extensive wetland loss, a proliferation of dams on tributaries, as well as water quality and impacts related to climate change. However, fish populations are also affected by factors beyond habitat quality, such as directed fishing and by-catch, disease, species invasions, and shifts in predator-prey distribution. Historic overfishing in the river and on the coast, as well as contaminants such a PCBs have been major contributors to the closure of commercial fisheries within the Hudson River. The presence of power plants and other facilities that withdraw river water for cooling have also had an enormous impact on fish populations.



Illustrations: left: American shad, NYSDEC; middle: Atlantic sturgeon, Kraft et al, *Inland Fishes of New York*, 2006; right: striped bass, NYSDEC.

Fish Abundance
Migratory Species

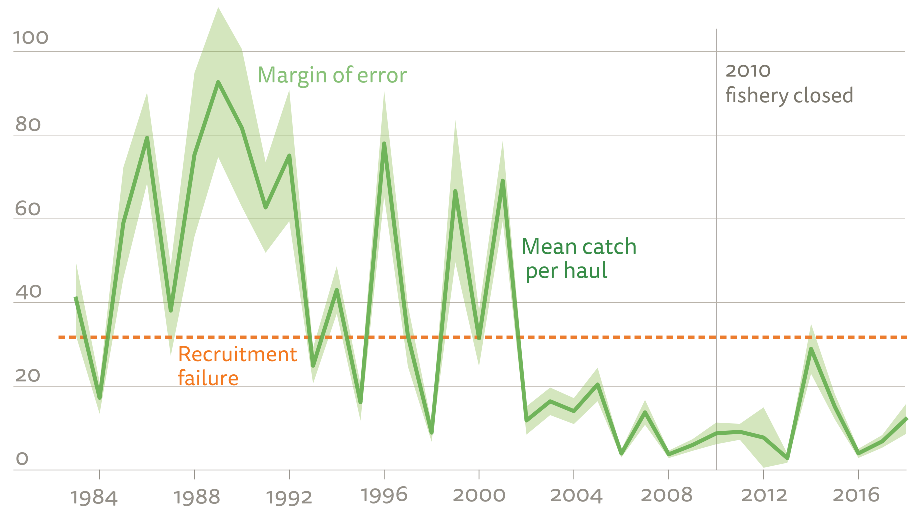
Analysis

Four abundance surveys conducted by the NYSDEC were used to describe trends in the relative abundance of Hudson River fishes. Two of these surveys are long-term, designed to monitor the relative abundance of young-of-year (YOY) fishes, in freshwater or brackish water, from Albany to the George Washington Bridge. Standardized methods for the YOY surveys were established in the early 1980s with annual seine sampling occurring biweekly from June through November. The third survey, starting in 2004, is designed to monitor the abundance of juvenile Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) in the lower river with annual gill net sampling occurring from February through May. The mean number of fish collected each year is graphed, with the error estimates depicting the 95% confidence intervals (an estimated range of values that is 95% likely to contain the true mean). A line depicting recruitment failure, defined as three consecutive years lower than 75% of all other values in the data series, is provided for species that are managed by the Atlantic States Marine Fisheries Commission and is used as a metric to assess juvenile fish production over time (ASMFC, 2009). The fourth survey is a community-science led effort to monitor American eels (*Anguilla arostrata*) through the migration of young "glass" eels into tributaries. Utility-sponsored fisheries surveys have also been conducted since the early 1970s to assess the ecological impacts of electric generating plants operating along the Hudson River. The ownership of this important data set is currently being transferred to Stony Brook University and may be available for future reports.

Findings

Overall summary: The relative abundance of migratory fishes remained stable or declined since monitoring began, with the exception of a few species, as shown in the following graphs. Disentangling the complexities of fish population dynamics, in light of environmental variability is difficult, yet patterns emerged from long-term data that better inform conservation and management decisions for Hudson River fish populations. Directed fishing and by-catch are likely the primary causes of declines, except where noted.

American Shad
Young-of-Year Freshwater Tidal Index of Abundance



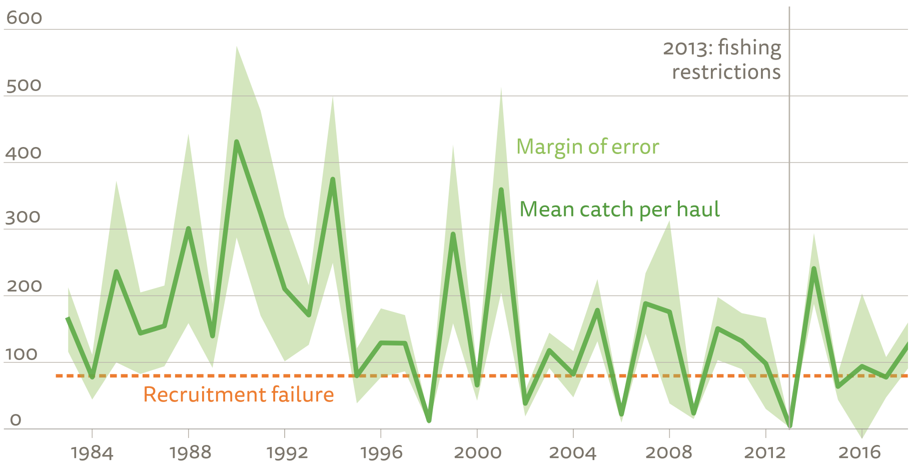
The abundance of YOY American shad (*Alosa sapidissima*) declined over time, with a severe decrease in abundance in the early 2000s corresponding to other stock declines observed along the coast as a result of overfishing and habitat degradation. Small increases in abundance were observed in recent years, however, recruitment failure is still occurring. The Hudson River shad fishery was closed in 2010 to promote population recovery, however, American shad abundance remains low. This delay in recovery is not necessarily unexpected as American shad take up to 5-7 years to mature before returning to spawn for the first time, therefore, it may take several generations before shad begin to show signs of recovery.

Photo: Monitoring American shad. NYSDEC.

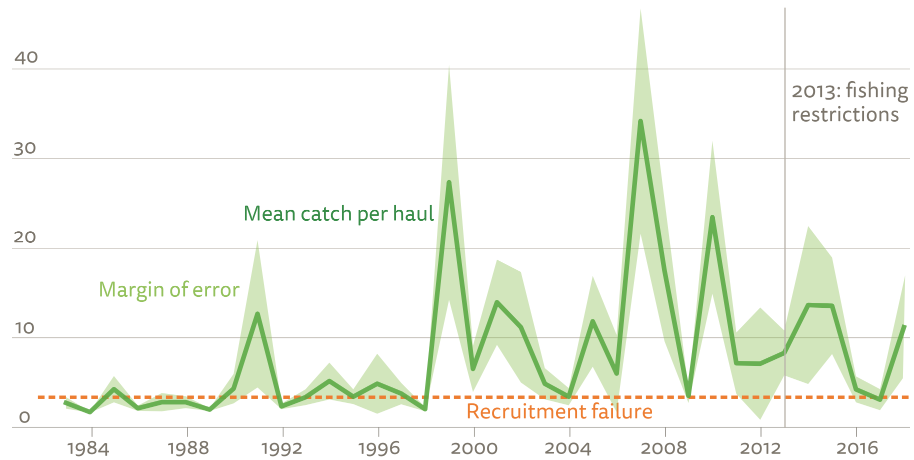
Data Source: NYSDEC Juvenile Anadromous Surveys, annual arithmetic mean of all hauls or net sets.

Fish Abundance
Migratory Species

Blueback Herring
Young-of-Year, Freshwater Tidal Index of Abundance



Alewife
Young-of-Year, Freshwater Tidal Index of Abundance



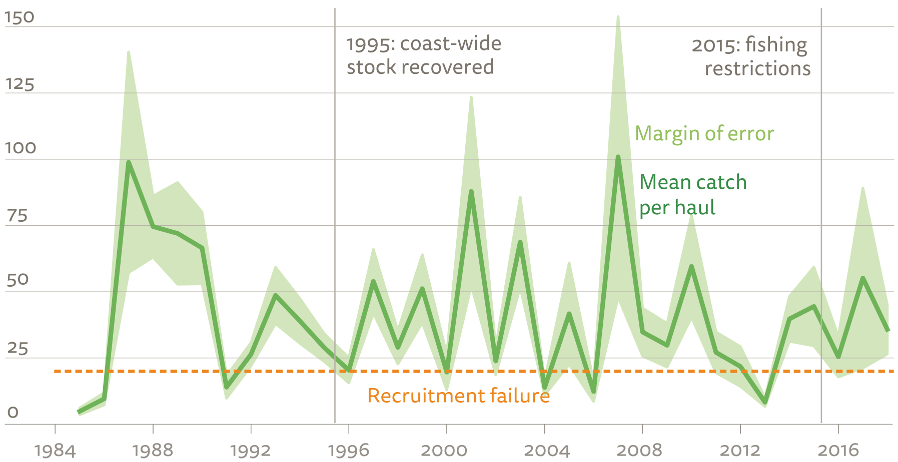
The abundance of YOY **blueback herring** (*Alosa aestivalis*) was highly variable from year to year but remained relatively stable over time, whereas the abundance of YOY **alewife** (*Alosa pseudoharengus*) increased and has exhibited slightly less interannual variability. The underlying reason for the wide inter-annual variation in river herring (a collective term for alewife and blueback herring) YOY abundance is not clear, and further investigation into temporal and environmental variables that may contribute to this variability is necessary. Fishing restrictions on river herring (e.g. no nets in tributaries, mandatory reporting) were imposed in 2013 in response to declining trends in river herring abundance along the coast. River herring are one of the last commercial fisheries still operating in the Hudson River.

Photo: Alewife, Kate Brill.

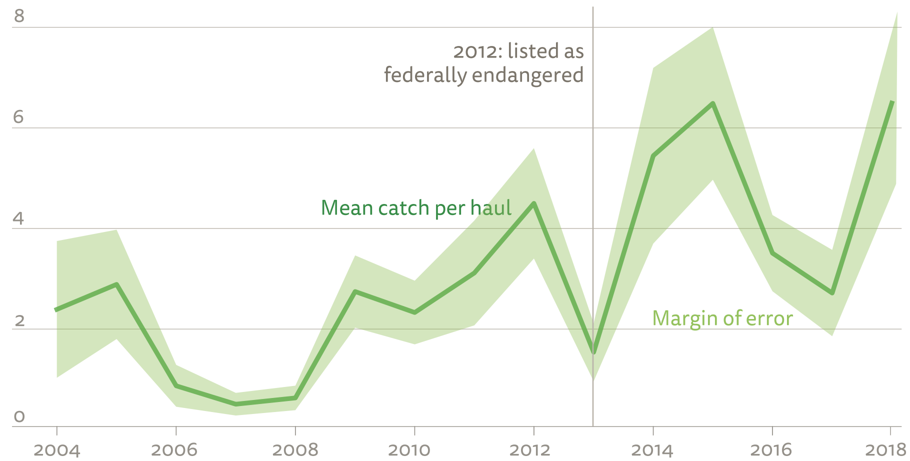
Data Source (graphs): NYSDEC Juvenile Anadromous Surveys units, annual arithmetic mean of all hauls or net sets.

Fish Abundance
Migratory Species

Striped Bass, Young-of-Year, Brackish Tidal Index of Abundance



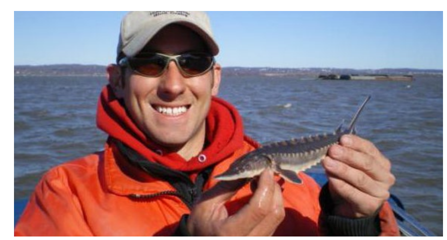
Juvenile Atlantic Sturgeon, Index of Abundance



In the early 1980s, **striped bass** began to decline coast-wide, and the Atlantic States Marine Fisheries Commission began to closely regulate the size and number of fish that could be harvested every year—a process that continues to this day. In 1995, the coast-wide stock was declared recovered after years of mandatory regulatory action. Over the last several decades, the abundance of YOY striped bass (*Morone saxatilis*) remained stable, although periods of high and low year classes were observed. Within recent years, YOY abundance was average or above average. In 2015, fishing regulations (length of season, size limit, slot limit and bag limit) were imposed in the Hudson River and along the coast to reduce fishing mortality and increase the spawning stock biomass.

Following decades of declining trends in abundance as a result of historic overfishing, New York imposed a harvest moratorium on **Atlantic sturgeon** in 1996 followed by a coast-wide moratorium in 1998. Ultimately, the species was listed as federally endangered in 2012. Atlantic sturgeon are slow to reach sexual maturity (12-20 years), thus the effects of the moratoriums and federal protection were delayed as expected. Overall, a positive trend was observed in the abundance of juvenile Atlantic sturgeon since the survey started in 2004, and averages catches were higher in recent years. This is an indication that conservation actions are likely benefiting the species.

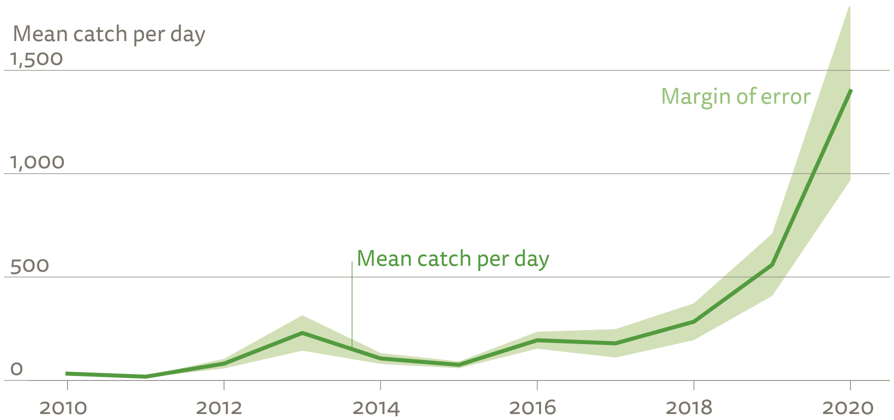
Photos: Juvenile striped bass and sturgeon. NYSDEC.



Data Source (graphs): NYSDEC Juvenile Anadromous Surveys: annual arithmetic mean of all hauls or net sets.

Fish Abundance
Migratory Species

American Eel, Young-of-Year Glass Eel Stage
NYS Community Science Eel Monitoring



Since the NYSDEC Community Science Eel Monitoring Project started in 2008, over a million juvenile "glass "eels were caught, counted, and released upstream from over a dozen tidal tributary monitoring sites. The six sites with the longest and most consistent data collection showed an uneven but overall rise in **American eel** catches per day. Awareness of the benefits of stream connectivity, coupled with dam removal 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, coast-wide commercial fishing restrictions, and more abundant prey species (USFWS, 2001).

Photo: Glass eels and the eel monitoring project. NYSDEC.

Data Sources: Community Science Eel monitoring project.

Fish Abundance
Non-native and Resident Species

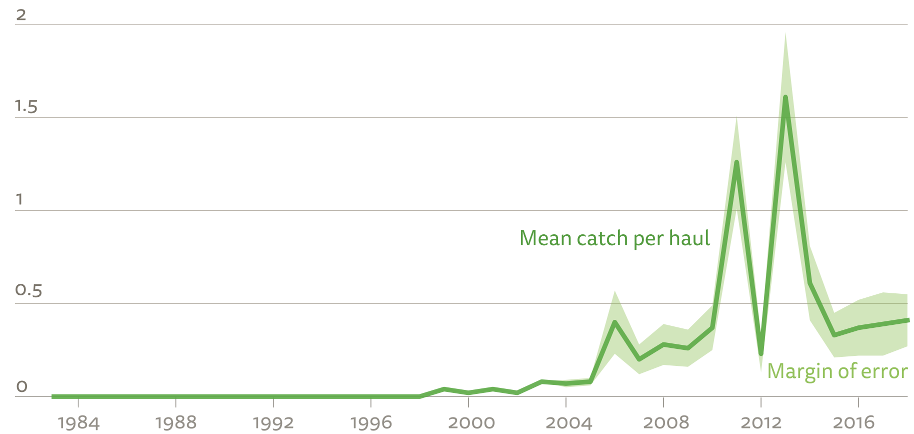
Did you know?
Populations of both native and non-native resident fishes are changing.

Non-native fishes have been introduced in the Hudson River for centuries. One example is **channel catfish** *(Ictalurus punctatus)*, a species which began to appear in the 1970s and its abundance has increased in the estuary over the past several decades. Channel catfish is just one of many non-native/invasive aquatic species in the Hudson River that have been introduced through human activity. These introductions have occurred both intentionally and unintentionally through activities such as release from bait buckets, ballast water exchange by international cargo ships, and direct release or stocking. The New York State Canal System that artificially connects watersheds that would otherwise be separated is another prime pathway for non-native species to move into and out of the Hudson ecosystem. Some of the species that are introduced can become invasive and can threaten the survival of native fish populations.

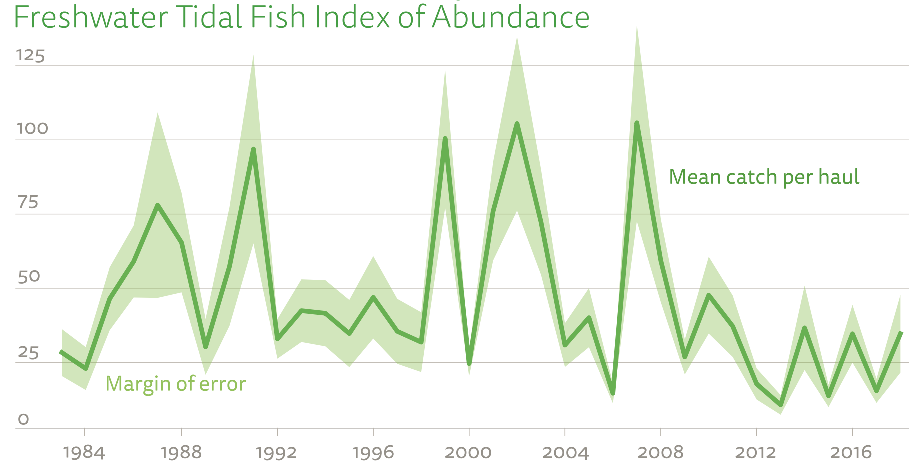
Among certain **freshwater** resident estuarine species (e.g. spottail shiner, tessellated darter, white perch, black bass, and sunfish), declines in abundance have been observed since 2011 that may be related to the powerful tropical storms of Irene and Lee and subsequent 90% loss of submerged aquatic vegetation (SAV) that provides important nursery habitat. SAV is slowly reestablishing itself in the estuary according to an analysis by the Hudson River National Estuarine Research Reserve (HRNERR —see the SAV indicator). Resident fish abundance is increasing slightly in recent years and may be related to SAV, but resident fishes are increasing at a slower rate than the SAV.

Photo: Channel catfish (non-native). NYSDEC.

Channel Catfish (non-native),
Freshwater Tidal Index of Abundance



Freshwater Fish (all resident species),
Freshwater Tidal Fish Index of Abundance



Data Source (graphs): NYSDEC Juvenile Anadromous Surveys: annual arithmetic mean of all hauls or net sets.

Fish Abundance
Impacts From Water Withdrawals

Did you know?
Cooling Water Intakes Affect Fish Mortality

In 1962, the potential withdrawal of 13.4 billion gallons of water per day from the Hudson River for the proposed Storm King Pumped Storage facility led to one of the longest environmental battles in the United States and established new policies for water use and for environmental review. Pumped storage electric generating facilities pump water to an elevated reservoir during times of low energy demand. When energy demand is higher, the water is released into raceways that lead to a series of power generating turbines. After passing through the turbine field, the water is returned to the original water source. Though the Storm King pumped storage facility was never built, other power plants have long relied on water withdrawals from the Hudson River Estuary. In the 1970s, over six billion gallons of water were used for non-contact cooling each day by the steam electric generating industry.

Along with the water being withdrawn from the river, fish of all life stages are also pulled into the intakes. Larger juvenile and adult fish tend to be caught, or impinged, on intake debris screens if the intake velocities are too fast. Many of them die if screens and flow velocity management strategies are not properly designed to return fish safely to the Hudson. This mode of fish mortality is called impingement. The smaller life stages of fish, namely eggs and larvae, pass through the screens, travel through the cooling system and are discharged back to the Hudson in the facilities thermal discharge. This process is known as entrainment mortality. Though most of the entrained organisms die, some species and life stages of fish (e.g., striped bass larvae) can survive the trip depending on physical characteristics of the cooling system and the maximum temperature of the water being discharged.

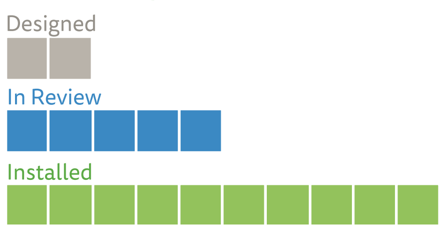
The potential to kill billions of fish annually was a factor in rescinding the Federal Energy Regulatory Commission license for Storm King and led to new regulations on the use of river water for cooling. Since the 1970s, the steam electric industry has reduced the amount of water withdrawn by over 20 percent through the closure of older, less efficient power plants and by building new steam plants that are cooled by closed-cycle cooling technology (e.g., cooling towers). In addition to the steam electric generating industry, other industries (e.g., cement manufacturing, sugar refining, and large office building cooling) also use Hudson River water for cooling.

Section 316b of the Clean Water Act requires EPA to issue regulations on the design and operation of intake structures, in order to minimize adverse impacts. In New York State, all existing industrial facilities using water from the Hudson River Estuary must install and operate technologies on their cooling water intakes that will minimize impingement and entrainment. These technologies include retrofitting the facility with a closed-cycle system, flow management and water conservation, installing fine screening on the intake, replacing debris screens with fish-friendly screens and operating a fish return system. All new industrial facilities are required to operate a closed-cycle cooling system.

Of the 17 industrial facilities known to use Hudson River Estuary water for cooling, ten are operating technologies to minimize mortality to fish, five are currently reviewing options, and two have been designed and will be installed within the next five years. Today, over four billion gallons of water are permitted to be withdrawn from the Hudson River each day. The planned closure of the Indian Point Nuclear Power Plant in Peekskill in 2022 will further reduce the water used for cooling by an additional 2.0 billion gallons per day.

Photo: Indian Point nuclear power plant. Steve Stanne.

Industrial Facilities Operating Cooling Water Intakes with Fish Protective Technologies



Data Source: NYSDEC, Division of Fish & Wildlife, Bureau of Ecosystem Health.

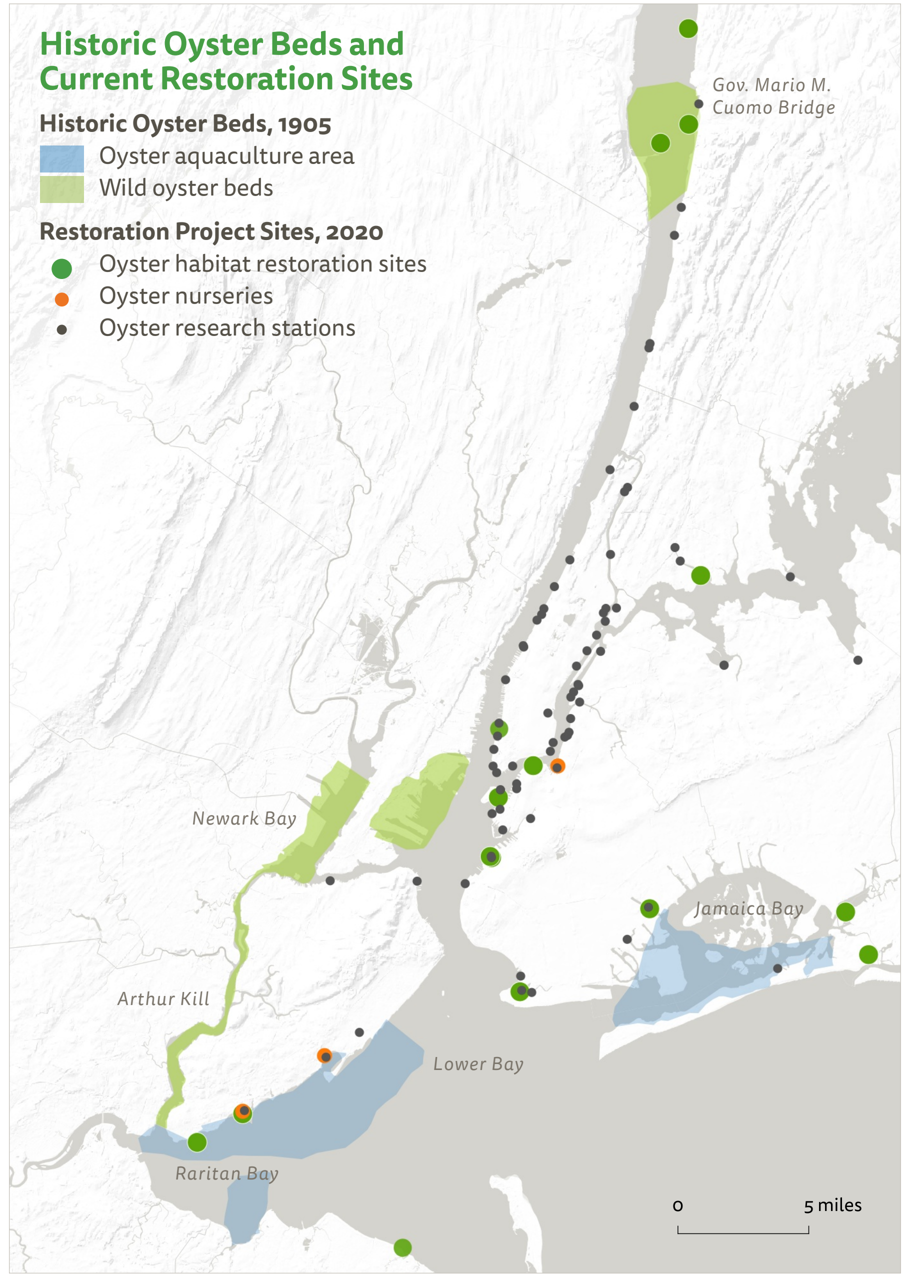
Estuarine Habitats
Established Oyster Beds

Did you know?
Oysters Benefit the Ecosystem.

When Henry Hudson first sailed into the Hudson River Estuary in 1609, massive reefs of the eastern oyster *(Crassostrea virginica)* spanned more than 35,000 acres of the NY-NJ 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 uniquely productive and biodiverse. The remarkable capacity of oysters to clear water—one adult oyster can filter up to 50 gallons of water a day—provided additional ecosystem services to the estuary and its residents. However, 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. No oyster reefs remain in the Harbor area.

In recent years, there has been a renewed interest in recovering the estuary's oyster populations—not for food, but for the ecosystem services they supply. Oyster reefs are now being recognized not only for their ability to provide habitat and filter water, but also to attenuate wave action and stabilize shorelines from erosion (Coen et al., 1999). In the last decade the number and scale of oyster restoration projects in the estuary has grown from small pilot-scale research studies to several-acre reef restoration efforts. Oyster habitat 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 educational programing.

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.



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

Estuarine Habitats
Established Oyster Beds

Furthermore, combined sewer overflow (CSO) events continue to contaminate the estuary. Sewage, excess nitrogen, heavy metals, and polychlorinated biphenyls (PCBs) all make their way to the estuary from CSOs, contaminating the water and making oysters more stressed and susceptible to disease (Medley, 2010). Harvesting oysters from the Hudson for human consumption is prohibited, due to such contamination.

Water quality in the Harbor has improved immensely since the passage of the NYS Pure Waters Bond Act in 1965 and the federal Clean Water Act in 1972, creating waters that may be capable of supporting oyster populations in much of the brackish portion of the estuary. Many restoration and research projects exist throughout the Harbor, most of which are collaborative partnerships that bring together public agencies, non-profits and academia.

One promising area is near the Governor Mario M. Cuomo Bridge in the area of the lower Hudson River known as the Tappan Zee. Here a natural, and possibly self-sustaining population, has recently been identified. A three-year (2015-2017) pilot restoration study showed annual natural recruitment (Lodge et al., 2017). In July 2018, to compensate for loss of oyster habitat from the new bridge construction, NYSDEC worked with the New York State Thruway Authority to restore five acres of oyster habitat at three sites using 881 concrete reef balls and 422 oyster shell gabions. The Billion Oyster Project and New York Harbor School constructed the steel gabion structures and filled them with recycled oyster shells from restaurants. The reef balls and gabions will provide habitat for a variety of estuarine fish and an ideal hard surface where oyster larvae can attach and grow. The first year (2019) of post-restoration monitoring to quantify oyster recruitment, density, growth, and survival, indicates oyster reef development at all three sites (Lodge et al., 2019).

Restoring self-sustaining populations of oysters harbor-wide will require additional pilot projects, monitoring, and research before managers can be confident of success. Many such projects are underway.

Above: Concrete "reef balls" like this are used for habitat restoration. Hudson River Foundation.

Right: Some oysters are naturally reproducing in the Hudson, such as this one found on the west side of Manhattan. The River Project/ Hudson River Park Trust

Estuarine Habitats
Natural and Engineered Shorelines

Did you Know?
More than half of the estuary shoreline is no longer in a natural state.

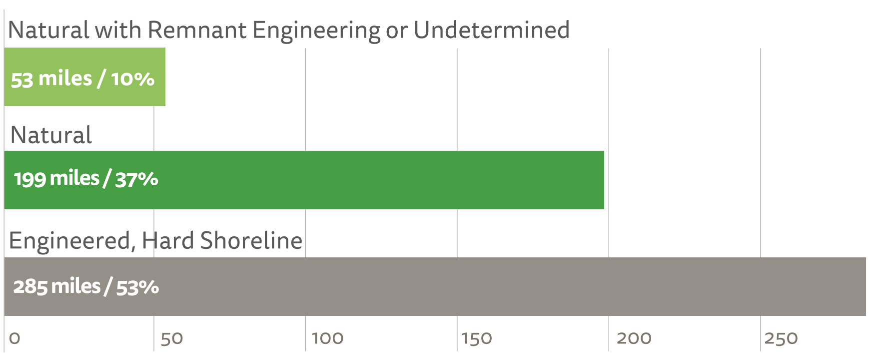
Natural shorelines are those that exist in an unaltered, sometimes dynamic state, without engineering elements constructed to stabilize the shore. These shorelines may include sandy beaches vegetated with intertidal grasses, mudflats, wooded areas, or naturally rocky shorelines often found along the Hudson River. Shorelines that have been restored into "living shorelines" or otherwise naturalized following previous shoreline development are also considered "natural."

As waterfronts were developed and railroads constructed along the banks of the river, much of the shoreline was hardened with riprap (slopes made of boulders) or bulkheads (vertical retaining walls). Further north in the estuary, timber and rock dikes were constructed along the shorelines as part of improving navigation. Near-shore areas are also often dredged for maritime use. The intertidal areas lost by these practices include many critical habitat types: low marsh wetlands only exist in intertidal areas, sandy beaches are critical for nesting and foraging areas for birds and turtles, and mudflats are important for birds, crabs, and invertebrates. Because of their ecological value and relative scarcity in developed portions of the estuary, natural shorelines and associated intertidal areas are critically important habitat.

The Hudson River National Estuarine Research Reserve (HRNERR) inventoried shorelines in 2005. Additionally, the NOAA National Geodetic Shoreline Survey was updated with more recent data from Rutgers University scientists for the lower Hudson and Harbor, including New Jersey. The 2005 HRNERR survey found that roughly 53% of the estuary's shoreline between the Federal Lock at Troy and the Governor Mario M. Cuomo Bridge is currently hardened or engineered, resulting from centuries of navigation, railroad and municipal projects, especially those that took place between 1817 and 1972, before the Clean Water Act restricted the dredging and filling of wetlands and intertidal shorelines. Anecdotally, it is understood that the proportion of hard vs. soft shoreline has been relatively stable since the passage of the Clean Water Act.

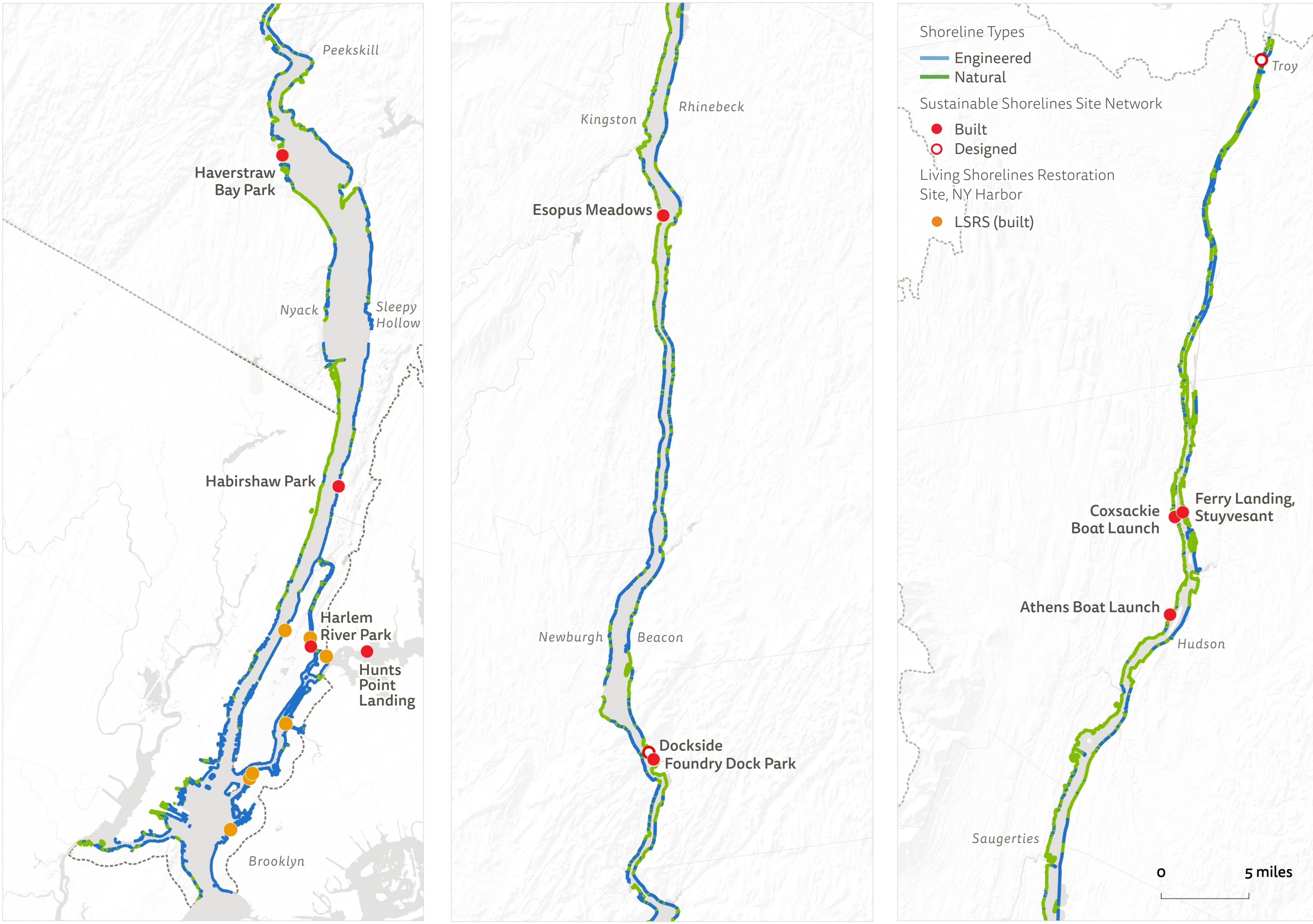
Rock riprap associated with railroad lines, and historic timber and rock crib dikes in the northern estuary are now the dominant types of shoreline. In the lower Hudson and Harbor, bulkheads are the dominant shoreline type, twice as common as wharves or rip rap. Studies of the ecological value of engineered and natural shorelines found that rock riprap, despite being visually unpleasant to some, has similar positive habitat values to the natural rock shorelines of the Hudson, while bulkheads with little physical complexity were found to be less valuable as habitat (Strayer et al., 2012). The baseline measurement established in 2005 will allow future trend analysis.

Shoreline Type by Mile



Data Sources: NYSDEC; HRNERR; NOAA Geodetic Survey; Thomas Grothues, Rutgers University

Location of Natural and Engineered Estuary Shorelines and Shoreline Restoration Sites



Data Sources: HRNERR; NOAA Geodetic Survey; Thomas Grothues, Rutgers University

Estuarine Habitats
Natural and Engineered Shorelines

Sustainable Shorelines Project

Recently, restoration projects have focused on stabilizing eroding shorelines at publicly owned sites where nature-based elements can be combined with engineered structures to protect property while maintaining or enhancing habitat value of the location. The Sustainable Shorelines demonstration sites that have been designed and are currently being implemented include Coxsackie, Cold Spring, and Stuyvesant, NY. State regulations aim to minimize the amount of new shoreline hardening, and NYS guidance encourages nature-based or living shoreline approaches that incorporate use of native vegetation and land-to-water habitat connectivity. While shoreline hardening may be necessary in certain limited circumstances to protect critical infrastructure, the vast majority of estuarine shorelines would benefit from shoreline softening or incorporation of natural and nature-based features. Many such projects have been completed or are underway.

Photos: top: Bulkheads adversely affect habitat but are necessary in some areas. Bottom: Rock rip-rap provides some natural habitat value. NYSDEC

Estuarine Habitats
Submerged Aquatic Vegetation

Long term trend (1997-2018): Deteriorating

Short term trend (2002-2018): Deteriorating

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 freshwater tidal portion of the estuary water celery, (*Vallisneria americana*) is the dominant native SAV species. Eelgrass (*Zostera marina*), the once-dominant species in the brackish section of the estuary, has been largely extirpated due to poor water quality. SAV is sensitive to loss of light, high water temperatures, and the input of excess nutrients and sediment. All of these conditions, as well as toxic sediments, threaten this important habitat.

Analysis

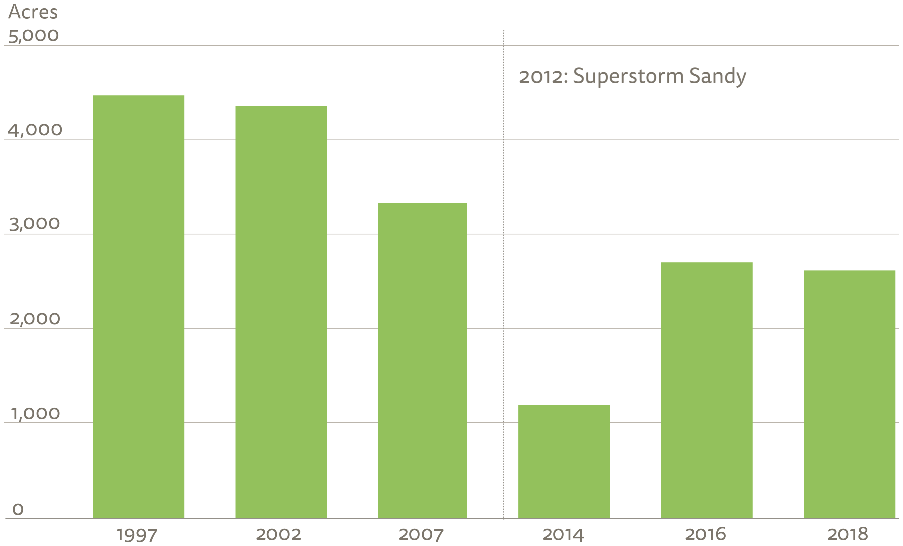
Prior to the late 1990s there was no baseline information on SAV extent or distribution in the tidal freshwater Hudson River or any information on how the extent of SAV is changing with time. SAV habitat was monitored using aerial photography in the Hudson River from Hastings north to the Federal Dam at Troy in 1997, 2002, 2007, 2014, 2016 and 2018. The photographs were interpreted into GIS maps. Additionally, since 2003, citizen scientists have collected SAV cover data by making point observations at specific beds of interest to analyze SAV dynamics occurring between the aerial photography collection years. In 2011, tropical storms Irene and Lee impacted SAV, reducing the cover by approximately 90%. Erosion and sediment deposition from severe flooding are thought to be factors in this loss. Since then, SAV monitoring data has been used to gauge the recovery of SAV to determine if restoration action is required.

Photo: Volunteers will plant this water celery (*Vallisneria americana*) that was raised in the classroom. NYSDEC

Findings

In 1997 there were 4,500 acres of native SAV. Today, Hudson River SAV maps show a decreasing trend in vegetation cover, with the greatest decrease occurring after tropical storms Irene and Lee in 2011. A 56% recovery in SAV habitat was seen in the 2016 inventory. In 2018, SAV may have reached a new state of reduced equilibrium. The cover in the 2016 SAV inventory (2,697.2 acres) is essentially the same as the cover in the 2018 SAV inventory (2,617.3 acres), but still 1,835 acres lower than was mapped in the inaugural survey in 1997, which is likely a reliable baseline for recent years. Volunteers who monitor SAV bed density annually have shown that the density of the remaining SAV beds in 2019 are similar to pre-storm SAV bed conditions.

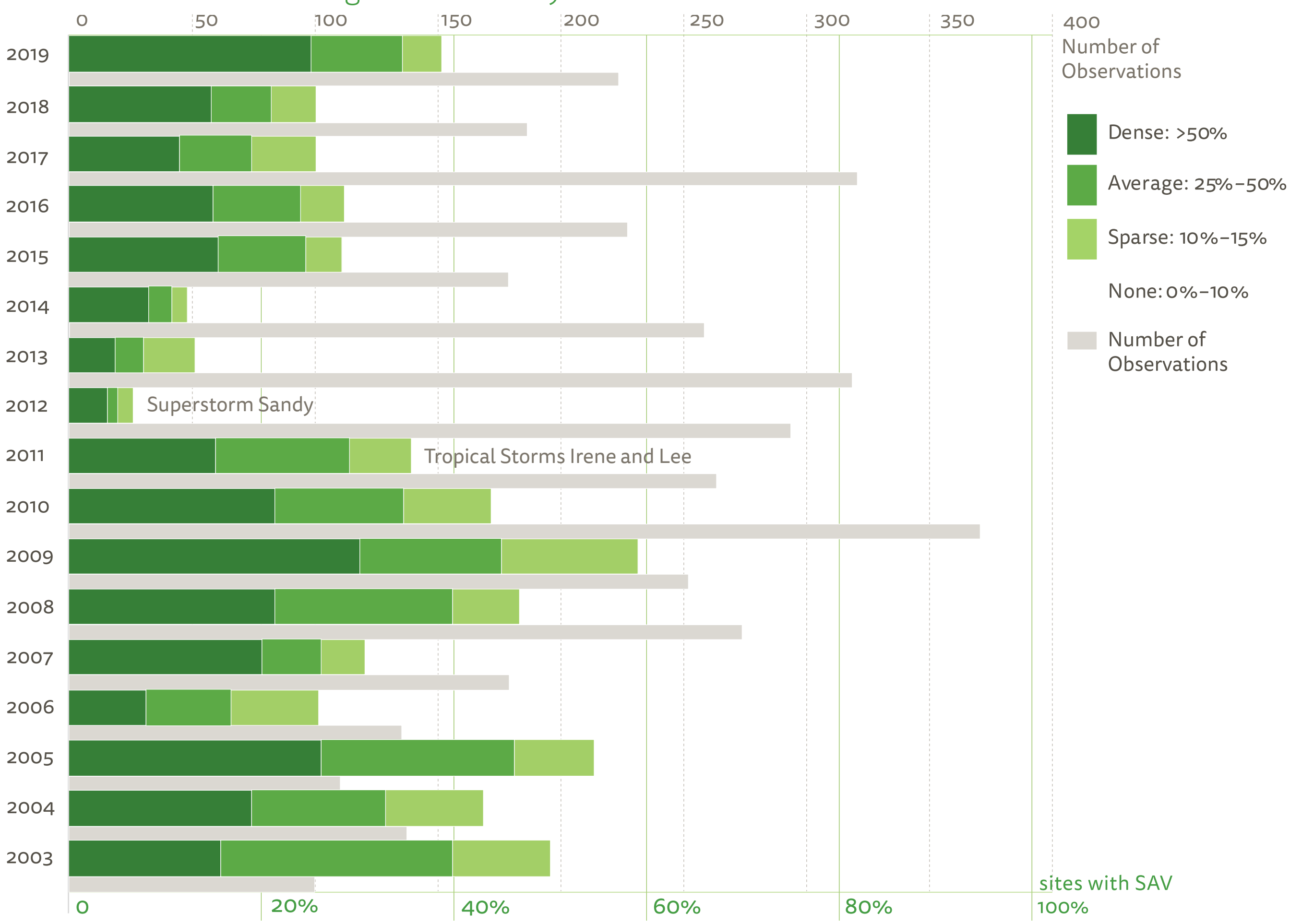
Submerged Aquatic Vegetation, Change Over Time



Data Sources: NYSDEC; HRNERR

Estuarine Habitats
Submerged Aquatic Vegetation

Volunteer Monitoring Data, Submerged Aquatic Vegetation
Points Observations of Vegetation Density



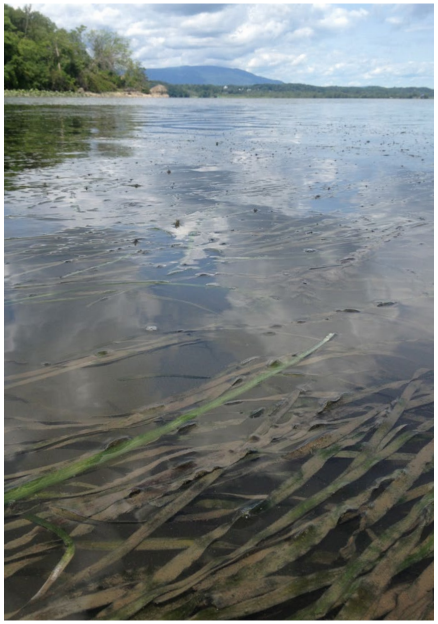


Photo: Floating fronds of water celery (*Vallisneria Americana*). NYSDEC

Graph: Surveys in 2013 and 2012 were conducted after tropical storms Irene and Lee in 2011. The density of vegetation indicates the condition of the SAV beds, with dense vegetation being best.

Data Sources: NYSDEC, HRNERR

Estuarine Habitats
Floating Aquatic Vegetation

Did You Know?
Water chestnut is a non-native, invasive aquatic plant that covers large patches in the River.

The floating rosettes of water chestnut (*Trapa natans*) inhibit light and photosynthesis in the water below, in extreme cases causing low dissolved oxygen conditions. As a result, compared to native SAV, which it has replaced in some areas, its habitat value as a refuge for fish is lower quality. Even so, water chestnut provides some habitat value, especially for juvenile life stages of some fishes, such as alewife *(Alosa pseudoharengus)*, white perch *(Morone anericana)*, and spottail shiner *(Notropis hudsonius)* (Schmidt and Kiviat 1988). The expansion of water chestnut beds into areas previously populated by native SAV seems to be slowing. The 2016 SAV inventory showed a 126% increase in the native SAV, water celery, since the 2014 survey, a rebound from storm- related losses in 2011, whereas water chestnut exhibited a decrease of 43%. However, this may not be a direct causal relationship, but rather, it is indicative of the dynamic nature between the native SAV and water chestnut beds. The cover of water chestnut remained essentially the same between the 2016 SAV inventory (2,116 acres) and the 2018 SAV inventory (2,150 acres), suggesting the dynamic between water chestnut and SAV may be reaching a new state of equilibrium. Additional research is needed to analyze what factors contribute to the viability of native SAV habitat as opposed to a water chestnut bed, and the environmental impacts to the surrounding area.

Photos: Water chestnut rosettes float on the surface in large beds. NYSDEC.

Estuarine Habitats
Tidal Wetlands

Did You Know?
Tidal marshes were not protected until the 1970s.

Among the most productive ecosystems on earth, tidal wetlands are a critical habitat for many of the 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. Historically misunderstood and mistreated, thousands of acres of estuarine wetlands in New York and New Jersey were filled to create new land or were used as garbage dumps for municipal and industrial waste, for example in Beacon, Croton, Haverstraw, Hudson, and Staten Island within New York State.

Large scale construction dredging and maintenance of the Federal Navigation Channel beginning the late 19th century resulted in the significant loss of approximately 4,000 acres of freshwater wetlands and shallows in the upper Hudson Estuary (Catskill to Troy)—about a third of what existed beforehand (Collins and Miller, 2011). The accompanying images illustrate the changes that have occurred in the northern reaches of the estuary. These actions along with filling of shallows throughout the river for transportation and industrial development likely had profound impacts on the availability of spawning, forage, and refuge habitats for fish and wildlife.

Photos: The 1942 aerial photo at the top shows the river at Coxsackie, Greene County (west shore) and Stuyvesant, Columbia County (east shore). Light areas are freshly deposited dredge materials removed from the navigation channel and deposited in wetlands and shallows. The modern air photo below it shows Bethlehem, Albany County (west shore) and Campbell Island, Rensselaer County (east shore). Red lines indicate the shoreline in 1898, blue lines indicate dikes constructed in the late 19th century, and orange areas are former islands that have been expanded.

Data Sources: top: Columbia County Soil and bottom: Water Conservation District. NYSDEC.

Estuarine Habitats
Tidal Wetlands

Today, there are 7,000 acres of vital fish and wildlife habitat in tidal wetlands between the George Washington Bridge and the head of tide at Troy, not including SAV and water chestnut bed cited elsewhere. Of this amount, there are currently 2,315 acres of wetlands adjacent to the Hudson conserved as natural area by NYSDEC and the NYS Office of Parks Recreation and Historic Preservation (NYSOPRHRP) in 47 parcels (NYSDEC HRNERR GIS data). Restoration of wetlands habitat is in the planning stages or underway, where feasible.

However, the future of tidal wetlands on the Hudson is uncertain. The low elevation of tidal marshes in the estuary makes them one of the first potential casualties of sea-level rise. Tidal marshes can keep up with sea-level rise with a steady supply of sediment, if it is available, to raise their elevation. Tidal marshes can also potentially shift upland with rising sea levels, but they cannot do so when they come up against developed areas or naturally steep topography, which is the case for much of the shoreline.

Researchers are currently studying how much wetland migration is possible into low elevation areas with shallow slopes adjacent to the river. Regional partners have actively researched this issue to help guide protection of critical wetland migration areas by projecting sea-level rise predictions onto high resolution topographic maps of the river and adjacent lands. The results of these efforts have been made available on interactive website tools including the Sea-Level Rise Mapper and Protecting the Pathways found on the Scenic Hudson website (see References / Further Reading).

Photo: Iona Island marsh, a Hudson River tidal wetland. NYSDEC

Estuarine Habitats
Tidal Wetlands

Restoration Success Stories
Gay's Point Tivoli Bays, Stockport Flats and Iona Island

Active restoration of shallow water habitats and tidal wetlands is being explored by several state and federal agencies. The first major effort to restore a shallow side channel was completed in 2018, at Gay's Point in Columbia County. Additional sites for restoration have been identified but determining the feasibility of implementing restoration at these sites can be complex due to private land ownership. Restoration opportunities are primarily confined to sites on public lands. On such sites, wetland restoration is possible, however side channel restoration is quite costly, due to the amount of dredging involved.

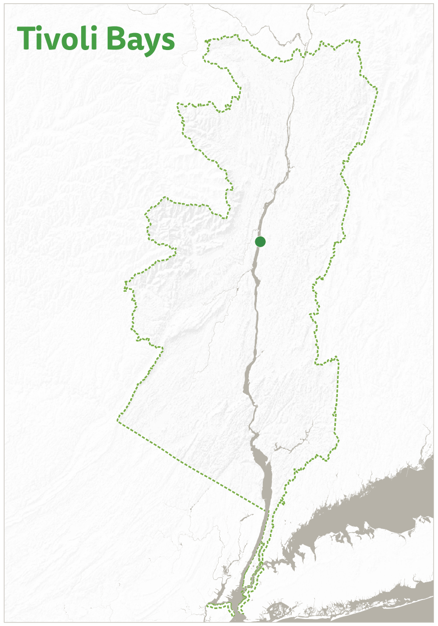
Wetlands are also being managed to control the spread of invasive plant species. Management of Common Reed, *(Phragmites australis)*, in Hudson River marshes has been underway at Tivoli Bays, Stockport Flats and Iona Island HRNERR sites for several years. In Tivoli and Stockport, relatively small initial invasions have been contained and are continually managed to maintain a plant community dominated by native marsh vegetation. It was demonstrated that the invasive plant was expanding at exponential rates, and if left unchecked, would likely spread throughout the marshes, displacing the native vegetation community. By managing and controlling *Phragmites* at these two locations, nearly 1,030 acres of native marsh has been protected or restored. At Iona marsh, approximately 42 acres of marsh that was 100% dominated by *Phragmites* has been successfully restored to a native marsh plant community. Because of the ubiquity of *Phragmites*, most Hudson River marshes will likely always need monitoring, and some may require on-going management and maintenance.

Photo: Gay's Point side channel restoration 2017. NYSDEC.

Estuarine Habitats
Tidal Wetlands Marsh Accretion Monitoring

Did you know?
Scientists are studying the effect of sediment and sea-level rise on marshes.

Tidal marsh monitoring using Surface Elevation Tables (SETs) provides data on the rate of sediment accretion at a scale that can be compared to sea-level rise. Data collection has begun at SETs installed in Piermont Marsh, but 3-5 more years of monitoring will be needed before accretion can be calculated. For comparison, the Palisades Interstate Parks Commission (PIPC) has been collecting SET data at Iona Island Marsh since 2015. PIPC monitoring data show that accretion rates are higher in *Phragmites* marshes (13.5 mm/year) than in areas of active *Phragmites* management (6.3 mm/year) due to the temporary absence of vegetation that traps sediment. These rates are comparable to SET data from Tivoli Bays, where sediment accretion rates near the river edge of the marsh are 10.6 mm/year, rates near the upland shore edge of the marsh are 5.9 mm/year, and rates near water chestnut habitat are 12.4 mm/year. These sediment accretion rates are in the same range as rates calculated in other Tivoli North Bay studies, including 7.0-8.0 mm/year (Sritrairat et al., 2012) and 9.0 mm/year (Yellen et al., in prep.), and are greater than the current rate of sea-level rise at the NOAA Tide Gauge at the Battery (2.85 mm/year). This indicates that these marsh surfaces are currently increasing in elevation at a faster rate than the water elevation is rising.



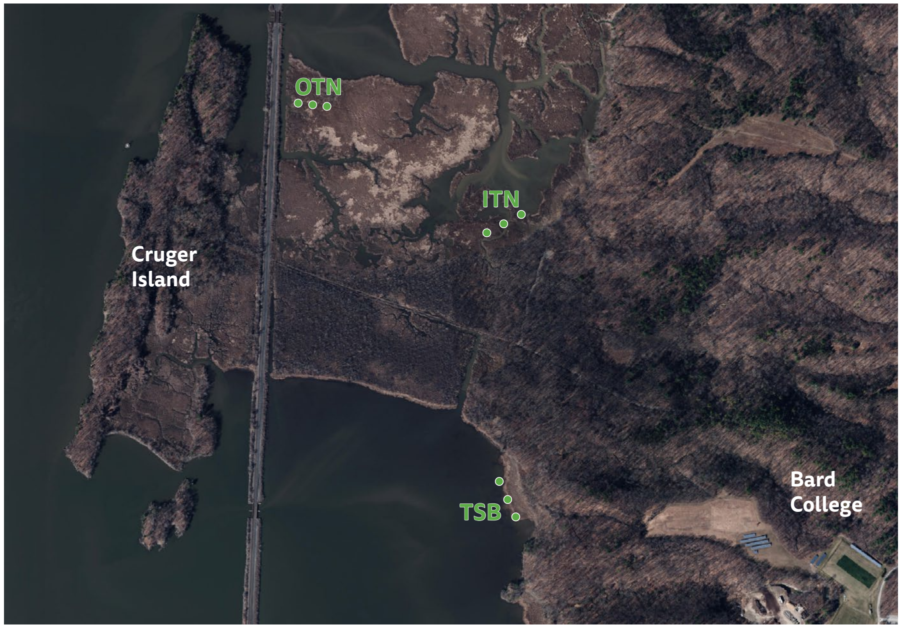


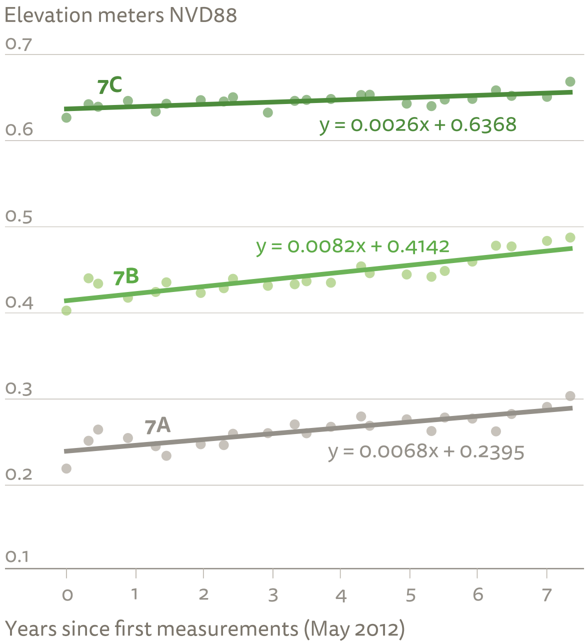
Photo: Surface Elevation Tables (SETs), Outer Tivoli North Bay (OTN), Inner Tivoli North Bay (ITN) and Tivoli South Bay (TSB)

Data Source (photo and map): HRNERR Marsh Accretion Monitoring Program

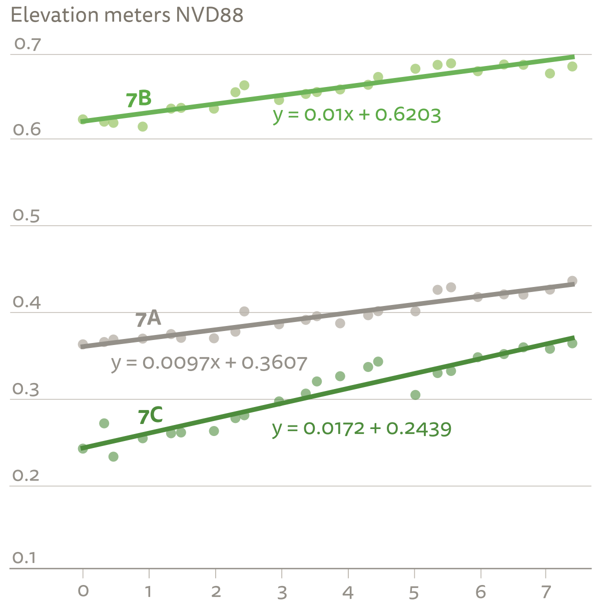
Estuarine Habitats
Tidal Wetlands Marsh Accretion Monitoring

Marsh Accretion Monitoring Surface Elevation Tables (SETs) in Tivoli Bays

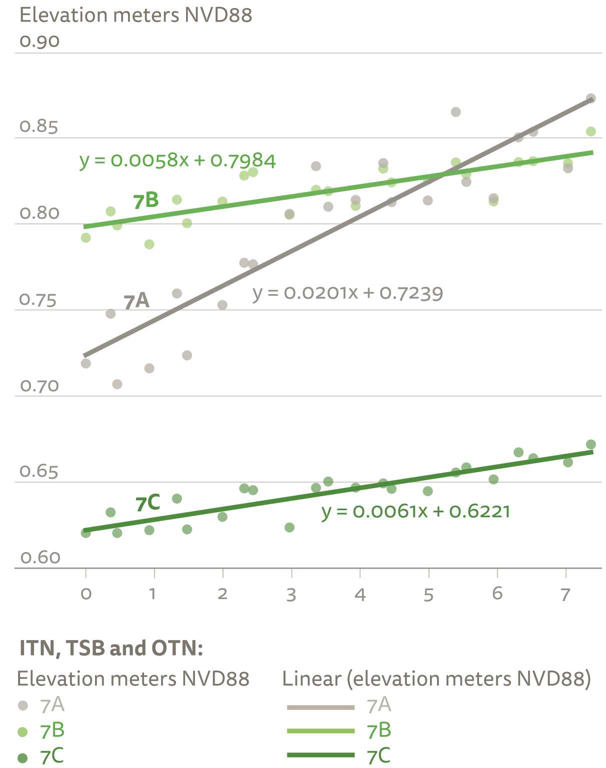
Inner Tivoli North Bay (ITN) Elevation Change



Tivoli South Bay (TSB) Elevation Change



Outer Tivoli North Bay (OTN) Elevation Change



Data Source (graphs): Marsh Accretion Monitoring HRNERR

Watershed Habitats and Ecosystems
Natural Lands

Long term trend (1987-2020): Insufficient Data

Short term trend (2001-2016): Deteriorating

Background

Stretching from New York City north to the Federal dam at Troy, the Hudson River Estuary corridor spans more than 4 million acres. This area, encompassing the ten counties bordering the estuary and five NYC boroughs, comprises only 13.5% of the land area of New York State but provides habitat for nearly 85% of the bird, mammal, reptile, and amphibian species found in the entire state (Penhollow et al., 2006). It is also a desirable place for people to live and visit. Past land-use trends have raised concern about sprawling development patterns and the resulting impacts to the region's natural resources and wildlife. In 2001, the Brookings Institute reported that between 1992 and 1997, urbanized land use in the NYC metropolitan area grew at three times the rate of population growth, and in the Albany Capital District, urban land use grew at six times the rate of population growth (Penhollow et al., 2006). While state-wide population growth has since declined, the populations of Orange, Rockland, and NYC counties were some of the state's fastest growing, according to the 2018 Census Bureau estimates (Empire Center, 2019).

Analysis

To visualize how growth patterns are changing in the region, 2001 and 2016 land cover in the estuary watershed (as defined by HUC 8 boundaries) was analyzed using data from the National Land Cover Database derived from satellite imagery. Summary statistics for the change in forest, wetlands, natural land cover, and impervious surface were calculated. Further spatial analysis to characterize the quality of forest cover applied the University of Connecticut's "Landscape Fragmentation" model, which mapped areas of intact core forest at least 300 ft from a boundary with non-forested areas. A baseline for 2016 was calculated, allowing for future analyses to track changes in forest cover and fragmentation in the watershed.

Photos: The Hudson Valley viewed from the Catskill Forest Preserve (Greene County) and grassland habitat at Mohonk Preserve, Ulster County. Laura Heady and Fran Dunwell

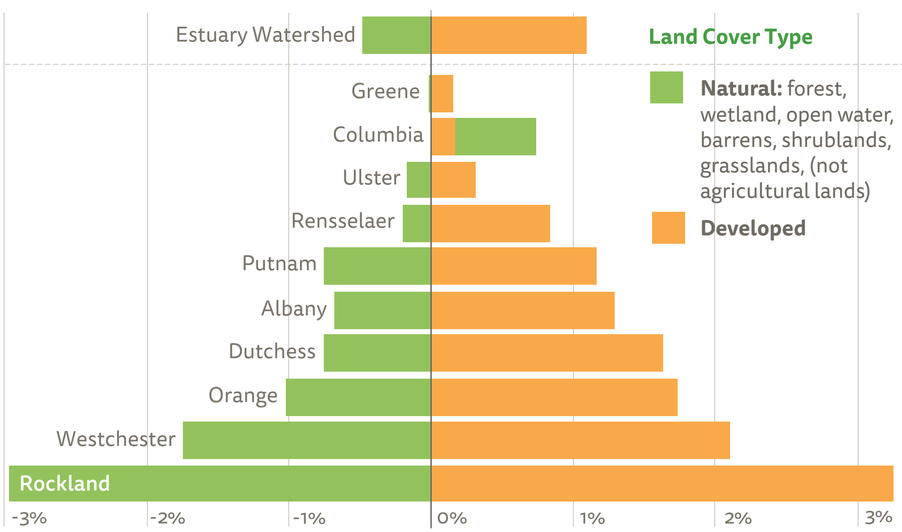
Watershed Habitats and Ecosystems
Natural Lands

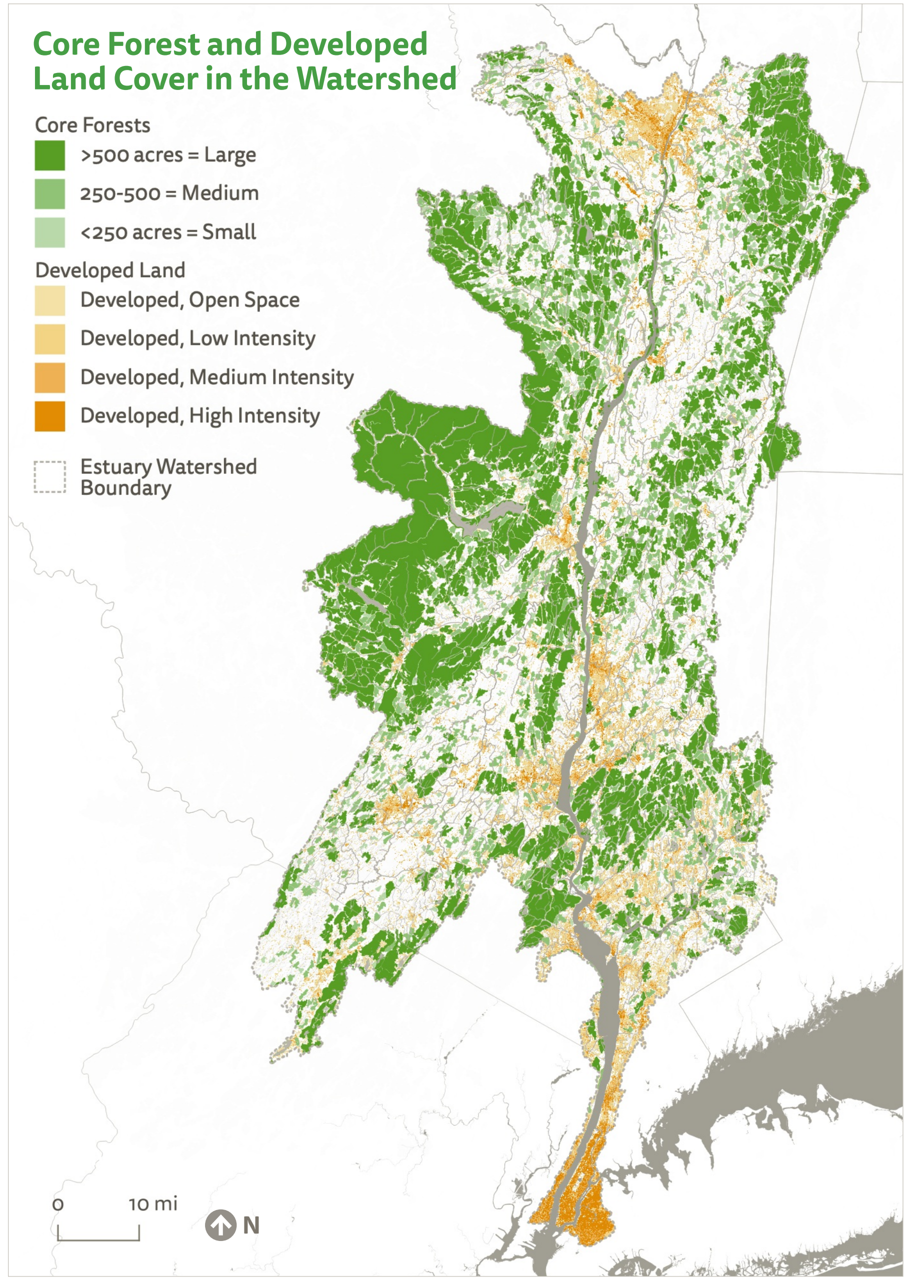
Findings

In 2001, 72% of the estuary watershed was natural land cover, with 67% comprised of forest. In 2016, those values remained similar, with a slight decrease in forest area and slight increase in developed area. Rockland and Westchester counties experienced the most notable increase in developed area and impervious surfaces.

Land cover provides a coarse understanding of where natural and developed areas occur. Further spatial analysis revealed that, while 65.6% of the watershed was forested in 2016, only 34.8% of the area was considered part of a core forest. This metric helps to reveal that development and land-use patterns have influenced the size and shape of natural areas. They are likely impacting habitat quality in the estuary watershed by fragmenting forests and other natural areas. Proactive, informed land-use planning can conserve remaining core habitat that is better able to support healthy plant and animal communities and contribute to climate adaptation, clean air, and clean water.

Changes in Natural Land Cover by County, 2001-2016





Data Sources (map): National Land Cover Database, U.S. Geological Survey (www.mrlc.gov) (2001-2016); New York Natural Heritage Program, DEC, Cornell University (2019). (bar graph) National Land Cover Database, U.S. Geological Survey (www.mrlc.gov) (2001-2016).

Watershed Habitats and Ecosystems
Conservation of Natural Lands

Did you know?
617,000 acres of forests, wetlands, mountains, parks, preserves, and lands surrounding drinking water supplies—have been conserved.

The Hudson River Estuary watershed benefits from the collaborative conservation work of dozens of New York State agencies, land trusts, municipal and county agencies, and other organizations that protect important lands and waters. The watershed's protected natural lands including forests, fields, streams, and estuary shoreline contribute to human well-being by protecting water supplies, building climate resilience, and offering recreational opportunities, which serve as an economic engine. Residents and visitors alike enjoy nature through hiking, birdwatching, hunting, fishing, and boating. Tourist spending in the Hudson Valley reached $5.5 billion in 2017, with recreation as one of the leading drivers (Tourism Economics, 2018).

Currently, 18.4% of the watershed (617,237 acres) is protected. Many partners contribute to this conservation success, with New York State taking the lead on land protection. The NYSDEC and NYSOPRHP protected approximately 60% of this area, and land trusts, non-governmental organizations (NGOs), counties, and municipalities are responsible for 40% of protected lands. Since the start of the Hudson River Estuary Program in 1987, New York State has protected over 118,000 acres in the watershed south of the Troy dam, of which 10% are along the Hudson Estuary, allowing for preservation of the world-famous natural scenery of the river and the valley.

Protected Land in the Watershed Totals 18.4%

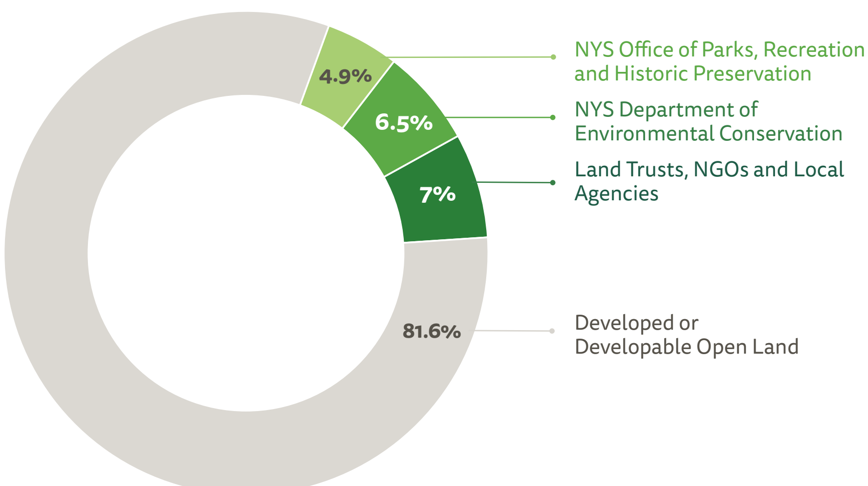


Photo: Harrier Hill Park, Scenic Hudson Land Trust. Emily Gardner, Saratoga Associates

Data Sources (graph): NYSDEC, Cornell University, OPHRP, Scenic Hudson, NYC DEP, NYNHP

Watershed Habitats and Ecosystems
Biologically Significant Natural Lands in the Watershed

To understand progress in land protection, it is important to evaluate the protection status of areas of conservation priority, such as those with greater biodiversity. In 2006, the Hudson River Estuary Program, NYSDEC, and Cornell University published the Hudson River Estuary Wildlife Habitat Conservation Framework (Penhollow et al., 2006). It identified 22 "Significant Biodiversity Areas" (SBAs) with unique topography, geology, hydrology, and plant and animal communities. By knowing the level of protection in each SBA, partners can prioritize conservation efforts. This table shows the amount of land currently conserved in 16 SBAs (for the portions that are in New York State) and the key ecological features of each. Some SBAs in New York City and the lower estuary watershed, like the Narrows, and in high-elevation areas like the Palisades, the Hudson Highlands, and the Catskill Mountains, have high levels of protection. However, half of the SBAs remain 80% unprotected, including areas that were recognized for their particularly high-value wetland, stream, and forest habitats. Conserving the valleys and connecting the habitats between these mountain ranges is increasingly important.

Significant Biodiversity Area	% Protected	Key Ecological Features
Hudson Valley Limestone and Shale Ridges	3.7	cliff and caves
Shawangunk Kill/Grasslands	7.8	stream and riparian habitats, open uplands & barrens
Esopus/Lloyd Wetlands and Ridges	12.6	wetlands
Dutchess County Wetlands	14.0	wetlands
Rosendale Limestone Cave Complex	14.8	cliff and caves
Taconic Mountains	16.0	unfragmented forest and habitat corridors
Neversink River	16.8	stream and riparian habitats
Rensselaer Plateau	16.9	unfragmented forest and habitat corridors
Shawangunk Ridge*	20.2	unfragmented forest and habitat corridors
Albany Pine Bush	34.5	open uplands and barrens
Hudson Highlands*	41.8	unfragmented forest and habitat corridors
Narrows*	50.6	coastal habitats
Palisades*	56.6	cliff and caves
Catskill Mountains*	62.4	unfragmented forest and habitat corridors
Ward Pound Ridge Reservation	98.3	(park/preserve with natural areas in developed context)
Van Cortlandt Park	98.4	(park/preserve with natural areas in developed context)

Photo: Bobolink, a declining species that relies on grassland habitats. USFWS/S. Maslowski

* Data extends beyond political boundaries of the *Framework's* study area, which included the ten counties bordering the estuary from the Troy Dam to the Verrazzano Narrows, and the five NYC boroughs.

Data Sources (chart): NYSDEC, Cornell University, OPRHP, Scenic Hudson, NYCDEP, NYNHP.

Watershed Habitats and Ecosystems
Tributary Streams

Did you know?
There are thousands of habitat disconnections on tributaries of the Hudson.

Over 60 major tributaries flow into the Hudson River Estuary between the Troy dam and the Harbor, providing critical habitat for imperiled migratory fish and the many wildlife species that rely on these streams and surrounding floodplains for feeding, breeding or other aspects of their life cycle. Unfortunately, centuries of human development and industrialization have fragmented these sensitive aquatic ecosystems and created significant artificial in-stream barriers that limit the movement of aquatic organisms.

Dam building began on tributaries of the Hudson as soon as colonial settlement began, initially for grist mills and sawmills, and later for iron mills and textile factories. In the 20th century, some were built or retrofitted to provide hydro-electric power, while many others ceased to provide useful service and became obsolete. Dams block fish from accessing available habitat crucial for spawning, foraging, and nurseries. Many of these dams have outlived their usefulness. They also represent significant flood and public safety hazards and are expensive to maintain. Likewise, where roads cross streams, thousands of culverts are undersized and/or improperly installed, creating fish passage issues as well as local flooding, road failure, and stream bank erosion.

Of particular concern is the impact on native migratory fish such as river herring and American eel which move in and out of the tributaries for different life stages. River herring and American eel have been considered candidate species for potential future protection under the United States Endangered Species Act, making access to tributary habitat in the watershed even more vital. Additionally, studies have shown that the longer the stretch of connected stream habitat, the more resilient those ecosystems will be to climate change.

To increase habitat connectivity in Hudson River tributaries, federal, state, and non-profit organizations are supporting the removal of unwanted dams as well as projects to resize or reshape culverts to reduce flooding and allow fish to pass through.

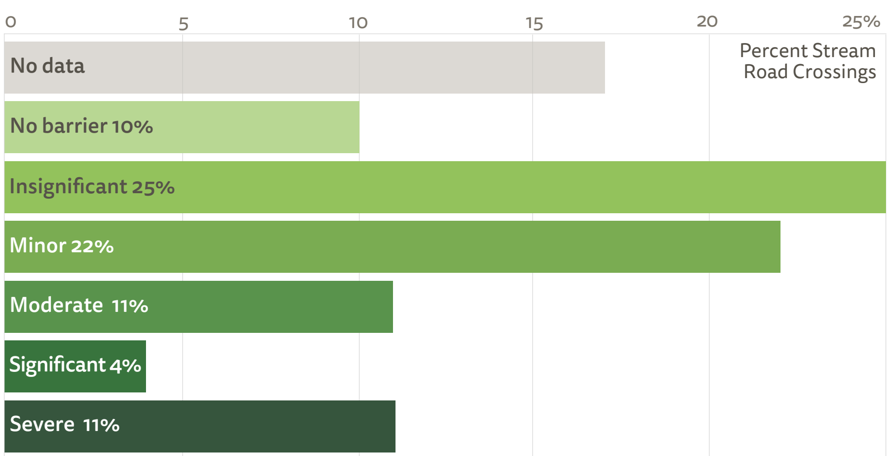
Photo: Dams like this block the migration of herring and restrict the migration of American eel. NYSDEC.

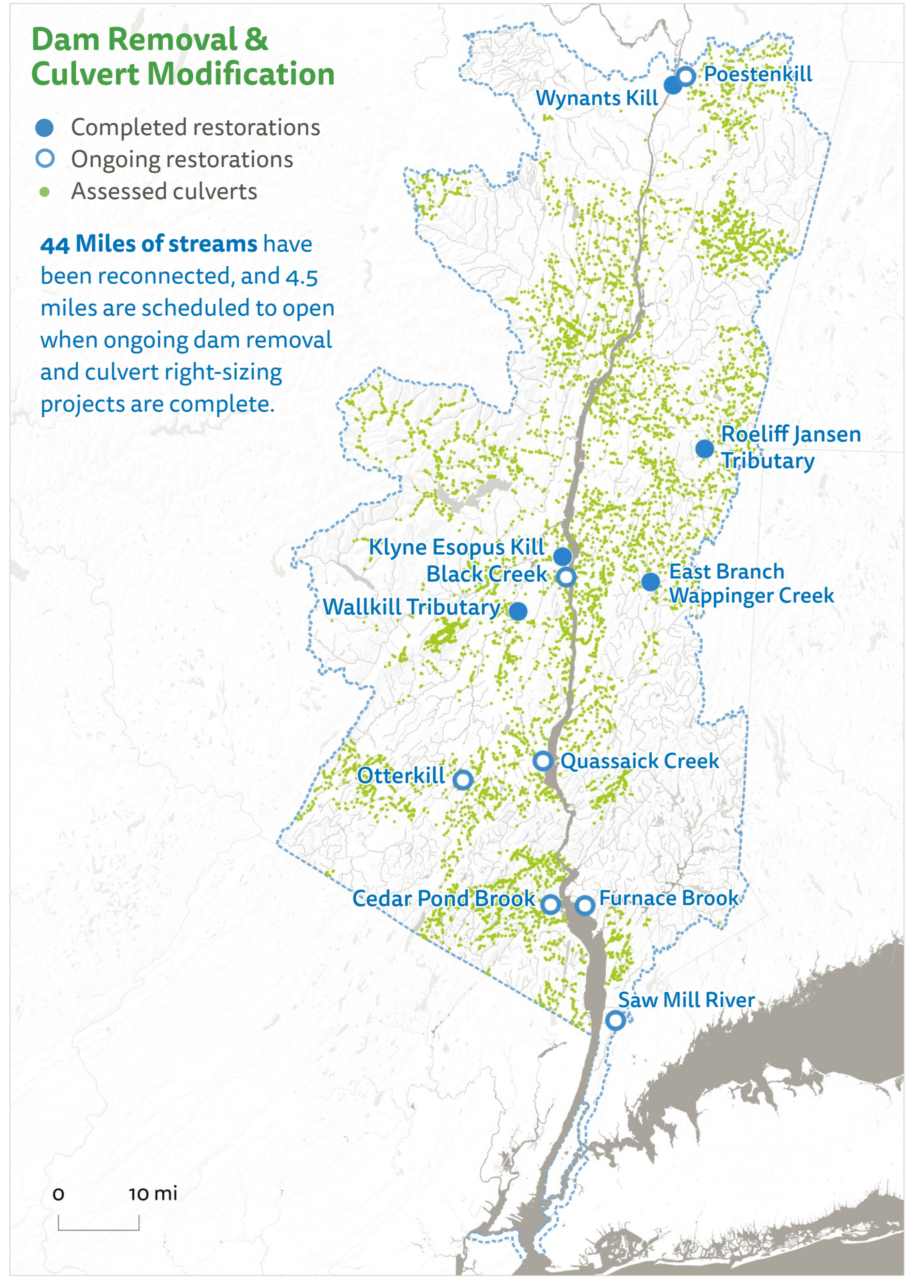
Watershed Habitats and Ecosystems
Tributary Streams

Removing Stream Barriers

A critical first step to successful mitigation of aquatic habitat barriers is to discover their location and assess the severity. In 2013 the NYSDEC began assessing and inventorying road-stream crossings (culverts and bridges) using the protocols of the North Atlantic Aquatic Connectivity Collaborative (NAACC). Culverts were also evaluated for their flow capacity by the Water Resources Institute at Cornell University. As of July 2019, culverts at locations where roads cross streams on tributaries have been assessed in roughly 50% of the Hudson River Estuary Watershed. These results indicate that roughly two-thirds of culverts are not fully passable to aquatic organisms. In 2015, the NYSDEC began the process of identifying all dams, including those that do not appear in the State's official inventory. Preliminary results from 2019 indicate that there are likely more than 3,000 dams in the watershed below the Troy dam within New York State boundaries. Meanwhile, five barriers affecting habitat for migratory species (dams and culverts), were recently mitigated for conservation or flood mitigation purposes, with at least six more planned.

Severity of Culverts as Habitat Barriers where Streams Cross Roads





Data Sources (bar chart and map): NYSDEC and Cornell University, Culvert Prioritization Project.

Watershed Habitats and Ecosystems
Tributary Streams

A Success Story: Dam Removal on Wappingers Creek

For over 50 years, Shapp Pond Dam on the East Branch of Wappinger Creek in Dutchess County, New York served as an obstacle and barrier to the movement of imperiled American eel, a migratory fish, and resident cold-water fishes, such as trout. The dam disrupted natural flow and sediment regimes, creating artificial habitat that favored non-native and invasive species. In 2016, the dam was removed through a partnership between the dam owner, NYS Water Resources Institute at Cornell University, Dutchess County. Soil and Water District and the Hudson River Estuary Program. Removal of the dam reestablished connectivity to over five miles of upstream habitat, while allowing the stream to restore to a free-flowing natural condition through this reach. To document the ecological response and recovery of the stream, fish, macroinvertebrates, and substrate were monitored at locations both up and downstream of the dam location before and after removal. Bioassessment data using macroinvertebrates suggest an improvement within the formerly impounded section from "moderately impacted" to "slightly-impacted" following removal of the dam. The property owner has also noticed new wildlife species at the site.

> ***"I'm so glad that it was a success. The stream is now so beautiful and magical. It keeps shifting and changing. and from my living room window I can see so many creatures enjoying it—turtles, possums, beavers, herons, an otter...and I'm sure many more hidden from my sight."***
> —Hilary Kliros, owner of the Shapp Pond dam commenting on removal of the dam.

Photos: The Shapp Pond dam on Wappinger Creek before and after removal. NYSDEC.

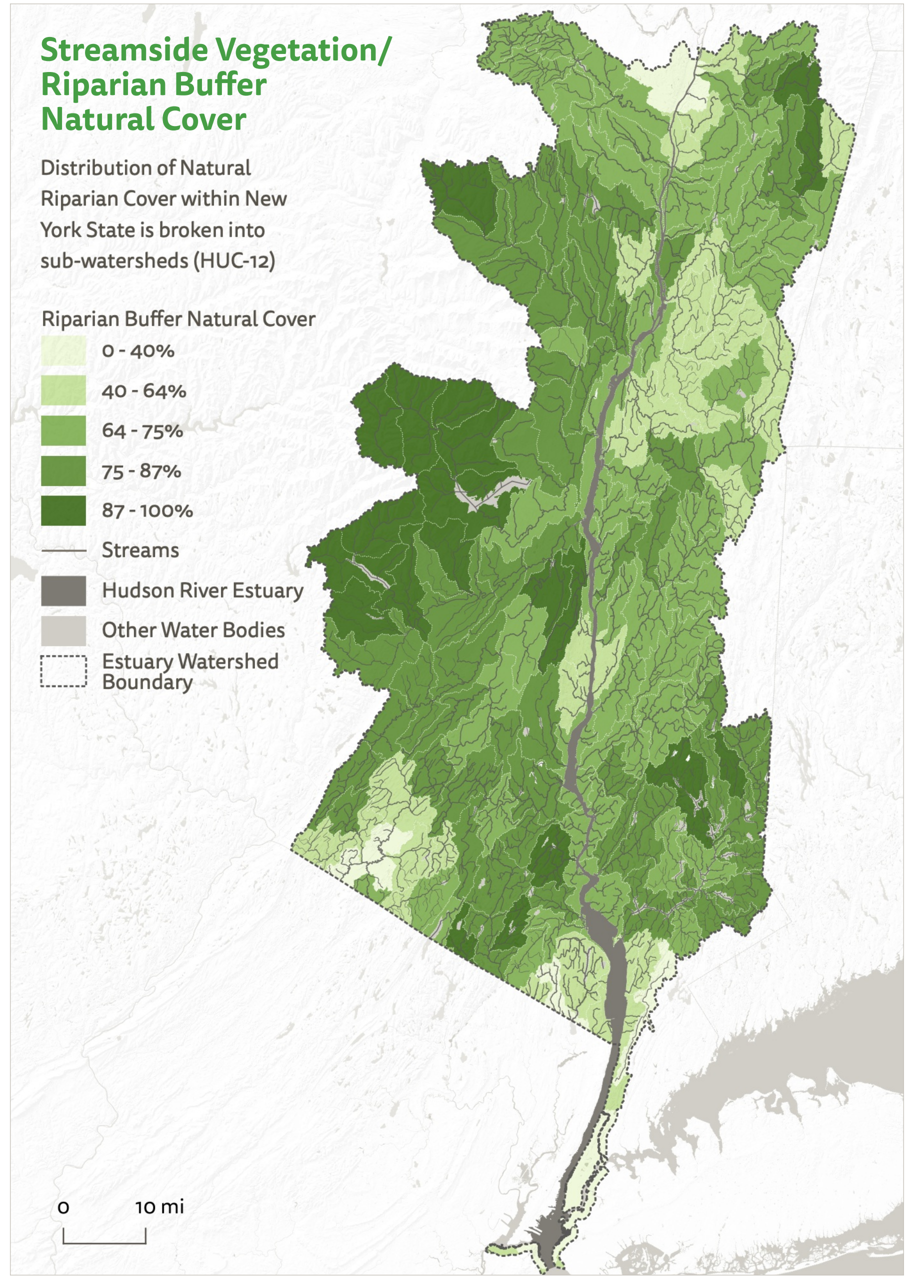
Watershed Habitats and Ecosystems Streamside Vegetation/Riparian Areas

Background

Riparian areas are the lands adjacent to streams and rivers. The forests, shrubs and grasses along rivers and streams, including streambanks and floodplains, maintain water quality by filtering out pollutants, improving nutrient processing, keeping waters cool, providing erosion protection, and providing habitat and food for wildlife. The health and integrity of these vegetated streamside areas is essential to supporting the health and integrity of streams, lakes, rivers and the estuary. Streams lacking such a vegetated edge are more prone to erosion, poor water quality and habitat impacts for fish and wildlife downstream (Meyer et al. 2007).

Analysis

Two methods of analysis were used to assess streamside riparian areas: one incorporates a time series to track overall trends in the extent of riparian vegetation, and the other presents a current look at the condition of riparian areas in the watershed. Changes in land cover over time (2001 – 2016) were used to characterize 150 feet of riparian area next to all major streams in the Hudson River Estuary watershed. Negative changes for stream health included the conversion of natural habitats (forests, grasslands or wetlands) within the sensitive 150 foot buffer area to developed land, barren land, pasture, or cropland. Positive changes included the conversion of these more urban and agricultural uses to forests, wetlands or grasslands. 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. The data in the assessment include ecological health and stress indicators, including land use, water quality, erosion potential and habitat potential. With tools supported by 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 and stream habitats throughout New York State, including the Hudson Estuary watershed.



Data Sources (map): Earth Resources Observation and Science (EROS) Center, National Land Cover Database, US Geological Survey; www.mrlc.gov/ (2001-2016); New York Natural Heritage Program Statewide Riparian Opportunity Assessment.

Watershed Habitats and Ecosystems

Streamside Vegetation/Riparian Areas

Long term trend (1990-2020): Insufficient Data

Short term trend (2001-2016): Deteriorating

Findings

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 61 acres per year. Less than 13 acres per year of riparian areas are revegetating. The most recent data indicate that 19% of the acres within the mapped 150 foot riparian area no longer have natural vegetation. Areas exhibiting the most negative change in riparian area vegetation are in Rockland, Dutchess, and Orange counties. These findings are likely an under-representation of this problem, given that only the largest streams were used in this analysis. Development at the waters' edge and resulting loss of vegetation around smaller and intermittent streams is even more likely to occur, as they have less regulatory protection. Moreover, smaller streams are more vulnerable to the impacts associated with not having a vegetated riparian buffer.

From 2001-2016, acres of natural riparian habitats (forested, grassland, wetland) that changed to:

Developed land	Cultivated Crops	Pasture
696	185	39

From 2001-2016, acres of pasture or crops that changed to:

Forest	Wooded wetlands	Herbaceous wetlands	Grassland	Scrub/shrub
81	7	72	18	7

Photos: Streams with and without stream-side vegetation. Scott Cuppett and NYSDEC

Data Sources (table): Earth Resources Observation and Science (EROS) Center, National Land Cover Database, US Geological Survey (2001-2016); New York Natural Heritage Program Statewide Riparian Opportunity Assessment

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3. Contaminants in the Hudson River Estuary

Due to the presence of contaminants in the Hudson, the NYS Health Department has issued guidance for consumption of fish and crabs. NYSDEC

Contaminants in the Hudson River Estuary
Introduction

As is the case with many large industrialized estuaries in the nation, the Hudson River Estuary has a legacy of toxic contamination due to years of unregulated pollution. These chemicals originated from many industries and related processes including: electric capacitor and transformer manufacturing (polychlorinated biphenyls or PCBs); coal gasification (polycyclic aromatic hydrocarbons or PAHs); herbicide manufacturing and waste incineration (polychlorinated dibenzo-p-dioxins or dioxins); electric power generation (mercury from burning coal), battery manufacturing (cadmium); and pesticide production and application (e.g., DDT, chlordane, and dieldrin) (Skinner and Kane, 2016; Skinner, 2011; Levinton et al., 2006; Baker et al., 2006). The passage of the Clean Water Act in 1972 greatly influenced how industrial waste was disposed. The implementation of this single regulatory authority greatly reduced the chemicals and metals being directly discharged into the Hudson River and its tributaries. Though this prevented further degradation of the estuary, it did nothing to reduce the volume of chemicals and metals that were already deposited in sediments and nearshore soils. In the case of many toxicants, the contamination found its way into the ground water and bioaccumulated (absorbed) in the bodies of fish and benthic organisms. As these contaminants now pass from prey to predator up the food web, they often also biomagnify, leading to high concentrations in predatory fish species, as well as fish-eating birds and mammals, and potentially in people who eat fish and crabs. They are toxic to much of our aquatic life and make much local seafood unsafe to eat. The required dredging of navigation channels and anchorages is greatly impacted by the presence of these toxic chemicals, as well, since there are few beneficial uses for contaminated sediment and the costs of disposal are extremely expensive.

Photo: Contaminants such as PCBs move up the food chain from prey to predator. Mauricette Char Potthast

PCBs

Long Term Trend (1986-2015): Improving

Short Term Trend (2000-2015): Not Trending

Background

PCBs (polychlorinated biphenyls) are industrial chemicals that were widely used as flame retardants and electrical insulators because of their ability to withstand high temperatures. They were also used in some paints, caulking materials, fluorescent light ballasts, and carbonless copy paper. In 1977, the EPA banned the production of PCBs because of strong evidence that these chemicals caused increased cancer risks to humans (Fitzgerald et al., 2008) and impaired ecological health (Sutherland et al., 2018; Baker et al 2006; McCarthy and Secord, 2000). PCBs are particularly dangerous organic chemicals because of their persistence and capacity to bioaccumulate and biomagnify. When PCBs enter a water body, they typically bind to organic particles in the water column, which then settle and are incorporated into bottom sediments. Environmental factors, including resuspension of particles that have settled to the bottom, can mobilize PCBs from sediments (Baker et al., 2006).

PCBs are the defining class of contaminants for the Hudson River. PCBs can be found in elevated concentrations in the sediments and biota from Hudson Falls, New York, on the upper Hudson River south, throughout the estuary to New York Harbor (Skinner, 2011; Baker et al., 2006). Though several sources have been identified in the estuary, the largest single source of PCBs was from electrical capacitor and transformer manufacturing at two General Electric (GE) facilities on the upper Hudson River at Fort Edward and Hudson Falls, New York. PCBs were directly discharged into the upper Hudson River between 1947 and 1977 (the year the U.S. EPA banned their use). PCBs continued to enter the river after 1977 through contaminated soils and bedrock seeps. A major release of PCBs occurred in 1991 when a flume gate failed at Hudson Falls, flooding a highly contaminated industrial structure during a high water event and discharging the PCBs that had been building up at the site for decades.

In 1984, the EPA designated the 200-mile stretch of the Hudson River a federal Superfund site, the largest in the nation. In 2002, GE was ordered to conduct environmental dredging of PCB-contaminated sediments in a 40-mile stretch of the upper Hudson River, which took place from 2009 through 2015. This clean-up, at best, only removed 25 percent of the PCBs that GE released to the river, and the effectiveness of the remediation project in reducing PCB burdens to fishes in the estuary has yet to be determined. The EPA estimates that GE released at least 1.3 million pounds of PCBs into the Hudson River and that 344,000 pounds have been removed (USEPA, 2019). PCBs are environmentally persistent, thus, despite the cessation of their use decades ago, they remain in high concentrations in most of the tidal estuary sediments and biota. Loadings of PCBs from the upper Hudson to the lower Hudson River have declined dramatically since their peak in 1973. However, given its scale, the historic legacy of the PCB contamination remains this ecosystem's driving issue.

Photo: General Electric factory at Hudson Falls, one of two north of the estuary on the upper Hudson where PCBs were dumped into the river. NYSDEC

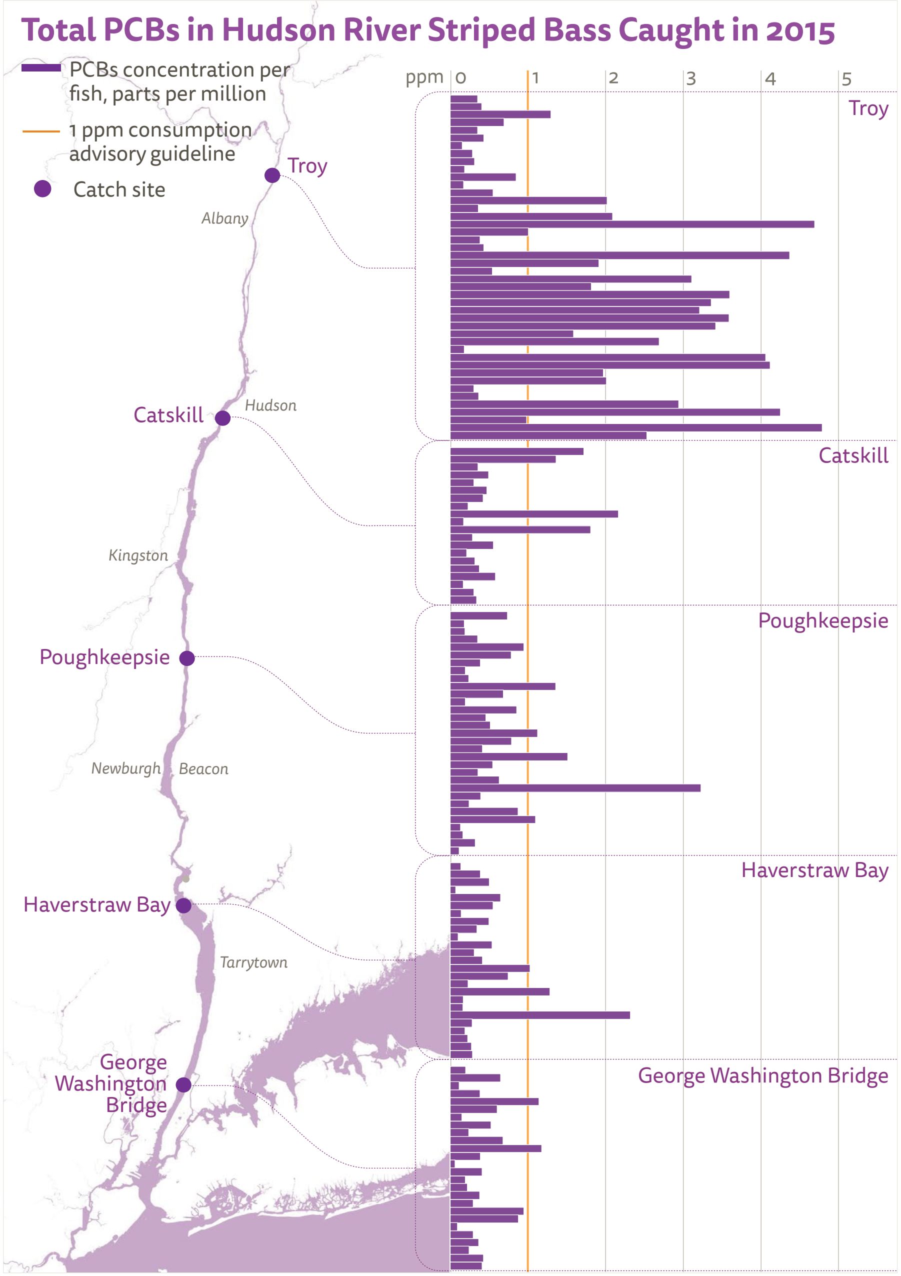
PCBs

Analysis

One way to evaluate the status of PCB contamination in the estuary is to quantify PCB concentrations in fishes. The NYSDEC annually samples fish downstream of the Troy Dam in the lower Hudson. This analysis looked at total PCBs in fish tissue of striped bass *(Morone saxatilis)* because they readily take up PCBs and are one of the most popular species for sport fishing and eating in the Hudson River. This analysis includes a review of the annual averages, as well as an assessment of the contamination level by Hudson River-mile, highlighting the variation in the spatial distribution of the contamination.

Photo: Striped bass. NYSDEC.

Graph: PCB concentrations in standard fillets taken from striped bass caught closer to five locations along the Hudson River Estuary. Each bar is the PCB concentration for each individual fish caught and sampled in 2015. Striped bass caught below the federal dam at Troy were more likely to have PCB concentrations that exceed the New York State Department of Health (NYSDOH) fish consumption advisory guideline of 1.0 ppm than fish caught further downstream, however individual fish exceeding this limit are in every reach of the estuary. For more information see Further Reading.



Data Sources: NYSDEC Division of Fish & Wildlife, Bureau of Ecosystem Health

PCBs

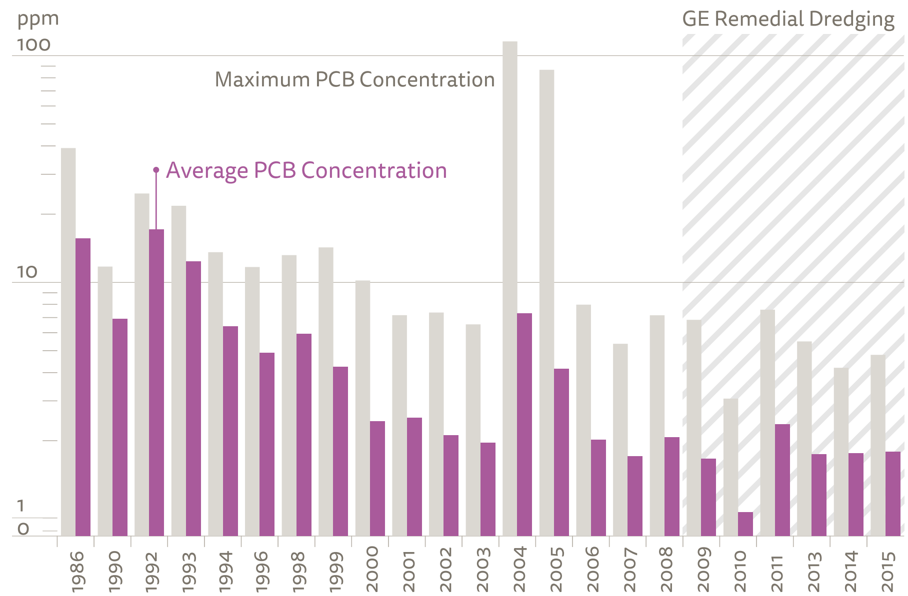
Findings

Though average concentrations of PCBs in striped bass tissues have declined since the 1990s, PCB concentrations have not changed significantly in recent years. The overall effectiveness of dredging sediments from the upper river is not yet known, and NYSDOH fish consumption advisories remain in place. For concentrations above 1.0 ppm, NYSDOH advises 'eat up to one meal per month' for men over 15 and women over 50, and 'don't eat' for women under 50 and children under 15. The EPA estimates that the advisories for consuming Hudson River fishes may need to remain in place for more than 50 years.

Striped bass are migratory fish that may spend portions of their life in the Atlantic Ocean and return to the Hudson River to spawn, or they may migrate locally but remain in the river year-round. The location in the river where striped bass spend the most time has a direct effect on the concentration of PCBs found in their bodies. Sampling results show that fish caught in the upper estuary were more likely to have PCB concentrations above 1.0 ppm and were more likely to have higher concentrations than fish caught down river near Catskill, NYC and points south (Sloan et al., 2005).

The higher concentrations from 1992-1999 were a result of the failure of the Allen Mill flume gate at the Hudson Falls facility, which resulted in a major release of PCBs in 1991 (Sloan et al., 2005). Though average PCB concentrations have dropped, individual fish may still be highly contaminated, as shown by two individual fish sampled in 2004 and 2005. This is likely attributed to the size and/or age of the fish. Remedial dredging to remove PCBs from the upper Hudson took place in 2009-2015. Sampling results after 2015 will be posted to the DEC website when available.

PCB Concentration in Striped Bass, 1986-2015



Graph: Maximum and average PCB concentrations in striped bass from 1986 to 2015.

Dioxins and Furans

Long term trend (1980-2013): Improving

Short term trend (1998-2013): Not trending

Background

Dioxins and furans (polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans) are organic chemicals that biomagnify in food webs and with long-term exposure, cause cancer and impair functioning and development of the reproductive and immune systems. Some fishes and some birds are hypersensitive to impaired early life-stage development from exposure to these chemicals (Fernandez et al., 2004; Fry 1995; Bosveld and Van den Berg, 1994). The most toxic of these chemicals is 2,3,7,8 tetrachloro dibenzo-p-dioxin (TCDD), one of 75 dioxin congeners (forms) which is a byproduct in the production of some herbicides. Most exposure to wildlife and humans to dioxins and furans comes from consumption of contaminated foods. The dominant historical source of dioxins to the lower estuary was the production of Agent Orange, in New Jersey in the 1960s. There are other historic sources of dioxins and furans to the estuary including inputs from waste incineration and other herbicides. While there has been no major in-water cleanup of dioxins, legacy land-based sources around Newark Bay have been remediated over time. Dioxins generally decrease in bioavailability by being buried by and mixed with cleaner sediments that flow down from the tributaries.

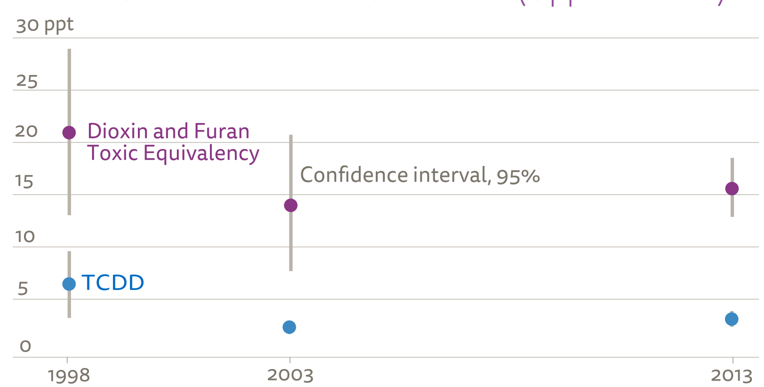
Analysis

The EPA Regional Environmental Monitoring and Assessment Program (REMAP) program tested sediment samples in the lower Hudson River and NY Harbor for dioxins in 1998, 2003 and 2013. The concentrations of the various congeners of dioxins and furans were multiplied by their Toxic Equivalency Factors (TEFs), summed per sampling site, and then the concentrations were averaged for this area of the lower Estuary by year. There were 23 sampling sites used in the average. TEFs are estimates of an individual chemical's toxicity relative to an index chemical. By combining the standardized individual chemical estimates, the values are used to calculate the estimated toxicity of the entire chemical mixture as a single value, referred to as a Toxic Equivalent (TEQ). TCDD, the most toxic dioxin congener, was singled out because it represents a large part of the total dioxin concentration in sediments of the lower estuary. There is no similar long-term sediment dataset for further up the Hudson River, but measurements of dioxins and furans in Atlantic tomcod *(Microgadus tomcod)* livers indicates that dioxin contamination is largely a problem in the lower estuary and particularly in the Newark Bay complex where levels of TCDD were exceedingly high (Fernandez et al., 2004). As such, these data can be considered representative of the dioxin contamination.

Findings

In the mid 1980's, sediment 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). Since 2003, upper Harbor averages of TCDD have fallen and are likely nontoxic in invertebrates. The REMAP data from the past 20 years indicate that dioxin concentrations leveled after an earlier decline. TCDD does not readily biodegrade, so the recent relatively stable concentrations of dioxins in the upper Harbor sediments may indicate that the sediment was being disturbed, preventing burial of the toxic substances, or that contaminated sediments were flowing into the lower Hudson from the more heavily contaminated Newark Bay, NJ. The 2013 REMAP sampling occurred shortly after Superstorm Sandy, which may have re-suspended toxic sediments. The REMAP sampling program has been on hiatus since 2013; however, a new year of sampling is expected in 2021.

Dioxin Concentration in Sediment (Upper Harbor)



Graph: Toxic Equivalency (TEQ) of Dioxin and Furan Concentration and TCDD Dioxin, which represents the most toxic congener, in the upper NY-NJ Harbor sediments. This graph shows the yearly average, and 95% confidence interval of the sampling stations.

Data Sources: EPA Regional Environmental Monitoring and Assessment Program

Cadmium

Long term trend (1979-2005): Improving

Short term trend (2005-2020): Insufficient data

Background

Cadmium, like certain other metals can be toxic to both human and wildlife in high concentrations. The biggest source of cadmium contamination to the estuary was the Marathon Battery Company facility located at Foundry Cove, on the Hudson in Cold Spring, New York. Between 1952 and 1979, the former Marathon Battery Company produced nickel cadmium batteries for military and commercial use (Skinner and Kane, 2016; Levinton et al., 2006). Waste byproducts of the production were discharged directly into the Hudson River via the Cold Spring sewer system and at other times into Foundry Cove wetlands with a significant portion being deposited in sediments. The EPA listed Marathon Battery as a federal Superfund site in 1981. Clean up began in 1994 and ended in 1995. Meanwhile, the NYSDOH determined the levels of cadmium were such that a consumption advisory for Hudson River blue crabs *(Callinectes sapidus)* was necessary. Though the Marathon Battery site was dredged and capped in the 1990s, this advisory remains in place today.

Photo: Blue crab. NYSDEC

Analysis

NYSDEC sampled blue crabs in the Hudson River in both 1979/1981 and 2004. Blue crabs were chosen as a sentinel species for cadmium because they an important Hudson River fishery, are known to bioaccumulate cadmium, and are indicative of the threat cadmium poses to human health. Both male and female blue crabs of an appropriate commercial size were harvested from six sites along the Hudson River and tested for cadmium concentrations in both the hepatopancreas (tomalley) and muscle tissue.

Data Sources: NYSDEC Bureau of Ecosystem Health

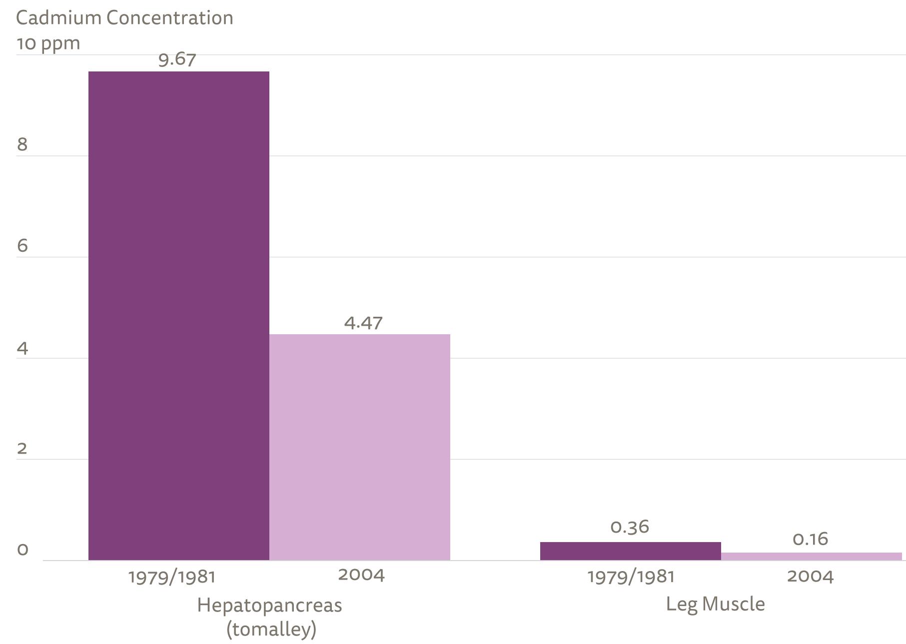
Cadmium

Findings

In 1979-1981, blue crabs collected from Foundry Cove found to contain high concentrations of cadmium in their hepatopancreas (average 9.67 ppm wet weight) and to a lesser degree in muscle tissue (average 0.36 ppm wet weight). In 2004 and 2005, New York resampled blue crabs in and near Foundry Cove and found that cadmium concentrations in muscle tissue and hepatopancreas greatly decreased on average. Though average concentrations were much lower in crabs collected in 2004 and 2005 than those collected in 1979, crabs still exhibited high cadmium concentrations in the hepatopancreas, with 80 percent of the samples exceeding 1.0 ppm, (Levinton et al., 2006; Skinner and Kane, 2016). This 1.0 ppm standard is the NYSDOH 'eat up to one meal per month' consumption advisory guideline for men over 15 and women over 50, and the 'don't eat' consumption advisory guideline for women under 50 and children under 15. This advisory for crab consumption was also deemed necessary by the New York State Department of Health due to PCBs and dioxins.

To determine if the observed reduction in the cadmium concentrations in blue crab muscle and hepatopancreas continues to be an improving trend, an additional year of collection and analysis is scheduled for 2020. Additional sediment monitoring data from EPA's REMAP from the lower Hudson River in New York City, show that cadmium concentrations in sediments are not decreasing significantly but may be low enough since 2008 that they are likely non-toxic (Stinnette et al., 2018).

Average Cadmium Concentrations in Blue Crab Tissues
Foundry Cove, NY 1981, 2004



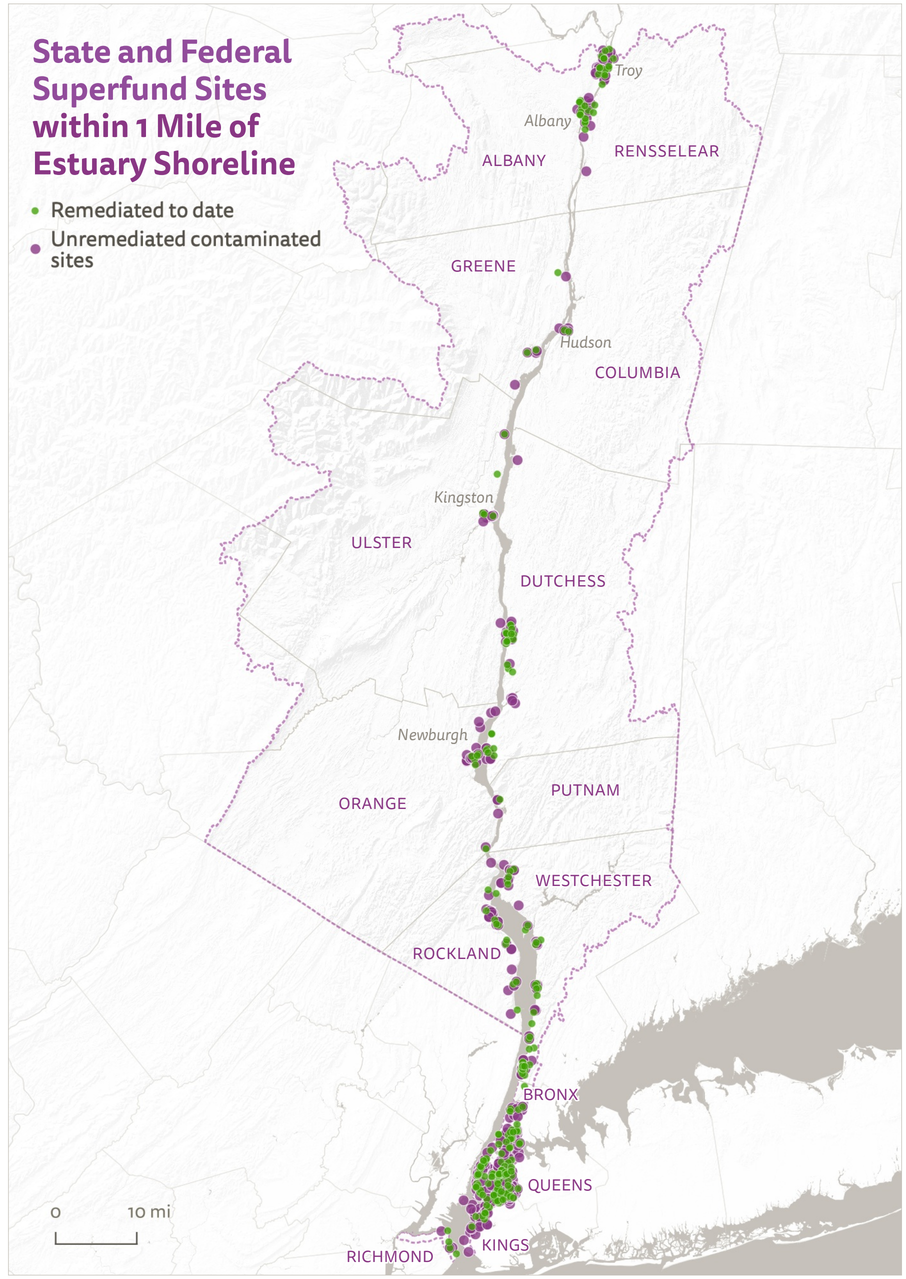
Graph: Average wet weight cadmium concentrations measured in the hepatopancreas and muscle of Hudson River blue crabs collected in Foundry Cove, New York. The 1979/1981 data represent the contamination in blue crabs before the Superfund cleanup of the cadmium pollution was completed in 1995.

Data Source: Skinner and Kane 2016, Levinton et al. 2006

Contamination Along the Estuary

Did You Know?
Hundreds of contaminated sites along the estuary are being cleaned up.

A comprehensive, estuary-wide assessment of industrial contaminants has not been undertaken within New York State. However, over 600 contaminated sites within one mile of the estuary shoreline have been identified through state and federal Superfund programs. To date, over 270 sites have been remediated (cleaned up) via these programs, and remediation is either underway or planned at the rest. Each site that has reduced local sediment chemical contamination provides a health benefit to fish and wildlife resources and reduces health risks to communities living near them. Based on the number of sites that have been remediated, it is likely that sediment conditions have improved.



State and Federal Superfund Sites within 1 Mile of Estuary Shoreline

Data Sources: NYSDEC Division of Environmental Remediation & Division of Fish and Wildlife, Bureau of Ecosystem Health

Contamination Clean-ups Along the Estuary

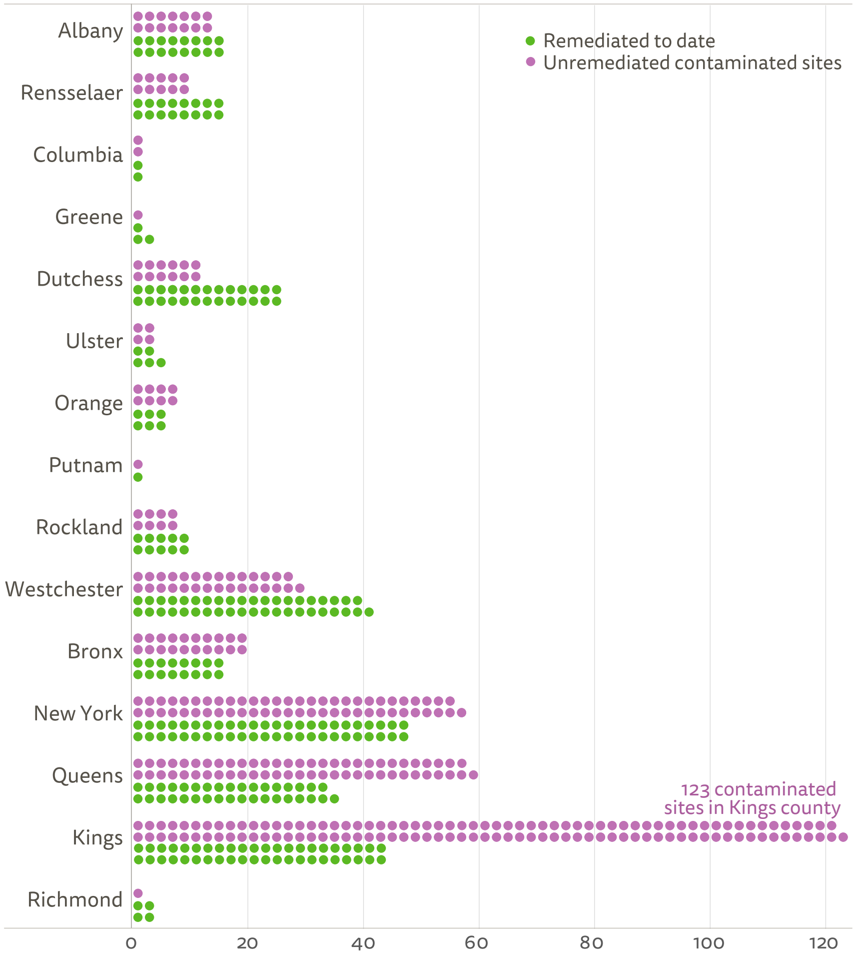
Clean-Up Success Story: Coal Tar

One example of a remediated state Superfund site on the estuary is the former Central Hudson Gas and Electric Manufactured Gas Plant in Newburgh, New York. Before remediation, tar sheens were frequently observed on the river in front of the site with both polyaromatic hydrocarbons (PAHs) and coal tar contaminating the sediments. PAHs are contaminants created as a byproduct of burning wood, waste incineration and vehicle emissions. They also occur naturally in petroleum and coal. Coal tar contains a mixture of toxins including benzene, toluene, ethylbenzene, xylenes and several PAHs.

Remediation included upland soil removal, installation of a barrier wall, a coal tar collection system, river sediment dredging, and capping with clean materials. The clean-up removed the volatile and semi-volatile compounds in the sediments and has collected 7,500 gallons of coal tar from the ground water to date. Since remediation, coal tar is no longer released to the estuary. A similar project began in 2020 along the Poughkeepsie shoreline.

Photo: Coal tar residue removed from the Hudson. NYSDEC

State and Federal Superfund Remediation Sites within 1 Mile of Estuary Shoreline by County



Data Sources: NYSDEC Division of Environmental Remediation & Division of Fish and Wildlife, Bureau of Ecosystem Health

DDT

Long term trend (1990-2019): Improving

Short term trend (2000-2019): Improving

Background

DDT (dichlor-diphenyl-trichloroethane) was initially used by the U.S. military during World War II for public health to control malaria, typhus, bubonic plague and lice spread by insects. In the U.S. it was also used as an insecticide in the 1940s to control insects in crop and livestock production, around homes and gardens and to regulate the spread of invasive insects. The negative effects of using DDT became widely known after publication of Rachel Carson's book Silent Spring in 1962. The book revealed the negative environmental impact of DDT upon wildlife including bald eagles *(Haliaeetus leucocephalus)*. According to the National Pesticide Information Center, DDT has been identified as slightly to moderately acutely toxic to mammals (including humans), and biomagnifies through the food web, making predators the most vulnerable to the accumulation of this chemical in their fatty tissue (NPIC, 1999).

The adverse effects of DDT vary in different species. In birds of prey, DDT causes eggshell thinning, resulting in eggs that break or do not hatch (WHO, 1989). By the mid-1960s, DDT extirpated the Hudson River watershed's bald eagle and peregrine falcon *(Falco peregrinus)* populations. DDT use was banned by the EPA in 1972 due to its negative environmental impacts and concerns over it being a "probable" human carcinogen (USEPA, 2017). In 1976, the Bald Eagle Restoration Project was founded, and eagle nestlings collected in Alaska were released in New York to re-establish a population (Town, 2015). Though these birds were not released in the lower Hudson watershed, they eventually made their way here. In 1990, for the first time in decades, bald eagles nested along the Hudson River Estuary. They successfully produced two young. Similarly, peregrine falcons were reintroduced to several areas of the state in 1974, and in 1988, the first new eyrie (peregrine nest) was established along the Hudson River Estuary on the Tappan Zee Bridge.

Analysis

Every year the NYSDEC and its volunteers survey the entire Hudson Valley for bald eagle and peregrine falcon nests. Because bald eagles often come back to the same area annually, the counting of bald eagle pairs is done, not by counting individual nests, but "territories." A territory is the area a single pair of bald eagles occupies and may consist of multiple nests. Often, bald eagles will build a new nest in the same territory if the previous year's nest failed or a better nest tree is found. A territory is considered occupied if a pair of eagles are found adding sticks to a nest, perching at a nest, incubating eggs, or raising young. Falcons are known to use the same nest sites year after year.

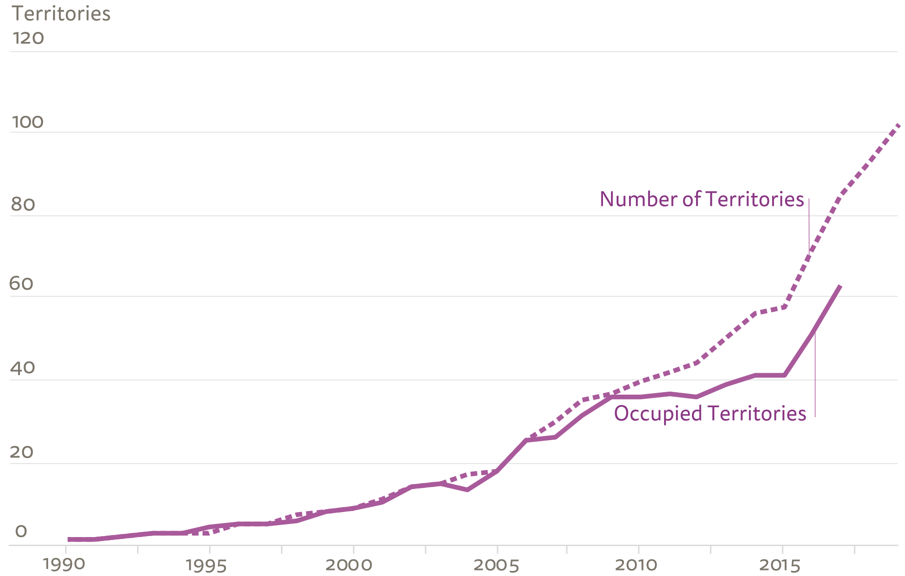
Photo: Bald eagle with chick. John Badura

DDT

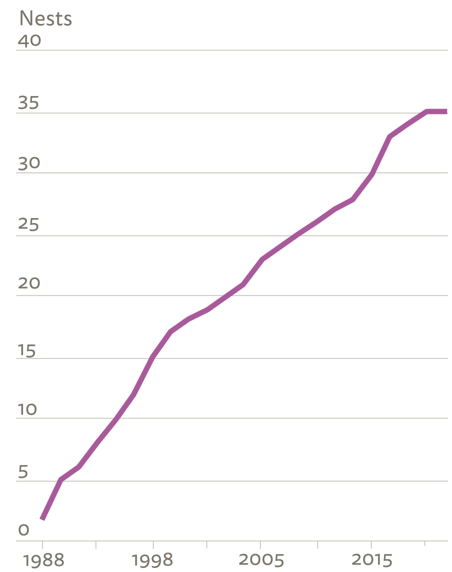
Findings

The health of raptor populations is dependent on a number of variables including habitat and prey availability. While toxic contamination may still be affecting Hudson watershed raptors species, populations are likely no longer impaired by DDT. The ban on DDT, coupled with the reintroduction efforts and a robust raptor management strategy, resulted in population increases of both bald eagles and peregrine falcons. There are now over 100 eagle territories, as described above. Peregrine falcons now nest in 35 eyries in the watershed—on cliffs, high-rise buildings, and on every Hudson River bridge south of Troy to the Verrazzano Narrows.

Bald Eagle Territories in the Estuary Watershed, 1990-2018



Number of Peregrine Falcon Nests in the Estuary Watershed, 1988-2019



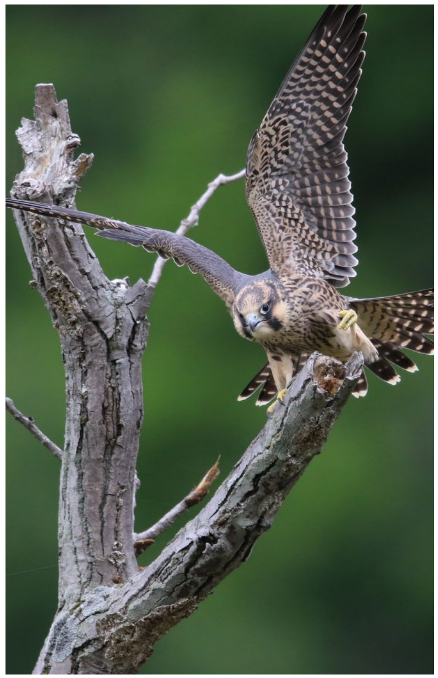


Photo: Fledgling peregrine falcon. Steve Stanne.

Data Sources: NYSDEC bald eagle and peregrine falcon nesting surveys

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4. Public Access for People of All Ages and All Abilities

Kayaking at Kingston Point Beach.
Nancy Beard

Public Access and Stewardship
Introduction

Access to the Hudson River Estuary improves the quality of life for millions of residents and visitors. Shoreline parks and other similar access points offer the opportunity for shoreline fishing, enjoying nature, relaxation, and feeling inspired by the water and spectacular landscapes. Other types of access offer the opportunity to get on or in the water for boating, fishing and other forms of recreation, including a small number of public beaches for swimming. Access to the water is known to improve physical activity levels and public health (Gies, 2006). It is also essential for fostering a connection with and stewardship of the Hudson River. As water quality continues to improve, the demand for access to the river and estuary has also increased.

Since the inception of the two Estuary Programs 30 years ago, the amount and quality of public access along the Hudson River Estuary has been vastly improved. In 2005, the Hudson River Estuary Program set a goal of establishing one new or improved access point per community. This has largely been achieved. The Program's focus has shifted to improving access for people of all ages and abilities, assisting site managers to maintain existing sites, and addressing the resiliency of access sites to flooding and rising sea levels. Public and private marinas are also an important source of access to the river. In 1991, NYS established a Greenway Trail for walking and, in 1992, a companion Greenway Water Trail for canoeing and kayaking, with access sites designated at least every ten miles along the river.

In most instances, throughout this chapter, the term 'access' will refer to a publicly owned or managed site where the general public can interface with the shore and waters of the river. The terms 'accessible' and 'accessibility' will most often refer to features for people with disabilities that comply with the Americans with Disabilities Act (ADA). In New York, state and local agencies, non-profit organizations and developers have invested heavily in improved access to waterways since the 1980s. Increasingly, these sites are being improved to provide a range of opportunities for people of all abilities, including people with disabilities. Visitors to facilities along the Hudson can enjoy fishing, boating, canoeing, kayaking, picnicking, and wildlife observation.

Photo: Steve Stanne.

Public Access to Hudson River Estuary Shorelines

Long term trend (1987-2019): Improving

Short term trend (2000-2019): Improving

Background

In recent years, the Hudson River Estuary's waterfront has seen a remarkable transformation.Better water quality, the trend toward redevelopment of remediated, industrial sites for parks and housing, and an increased public desire for outdoor activity close to home has led to the creation of new parks, shoreline trails, and other public spaces along the river. These spaces provide both proximity to the water as well as the opportunity for educational and stewardship programs.Most public access occurs on 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.

Analysis

The amount of public access (shoreline miles) along the Hudson River Estuary has been collected by the Hudson River Estuary Program and NY-NJ HEP. This involved mapping parks and other public access sites where public ownership or a public easement guarantees access. North of the Governor Mario M. Cuomo Bridge, publicly managed waterfront spaces were mapped by the NYSDEC using a variety of databases (see Further Reading for information on DEC's comprehensive, web-accessible databases). South of that bridge, public access data from a comprehensive NY-NJ HEP/US Forest Service study was used (Boicourt et al., 2016). The locations of publicly owned or managed shoreline from both sources were compiled into a single map and database, and linear miles were compared to the total Hudson River Estuary shoreline. The amount of public shoreline in the lower estuary may be slightly overrepresented in this analysis, both because the data is more comprehensive and the shoreline is more irregular in the harbor, due to the numerous piers and other shoreline structures. A NYSDEC data base of funded projects by year allowed additional analysis of change over time. A comparison of historic and present-day accessibility at NYS sites on the river side of the railroad tracks north of New York City measured progress in overcoming the particular challenge of access across the tracks (The Hudson River Access Forum, 1989).

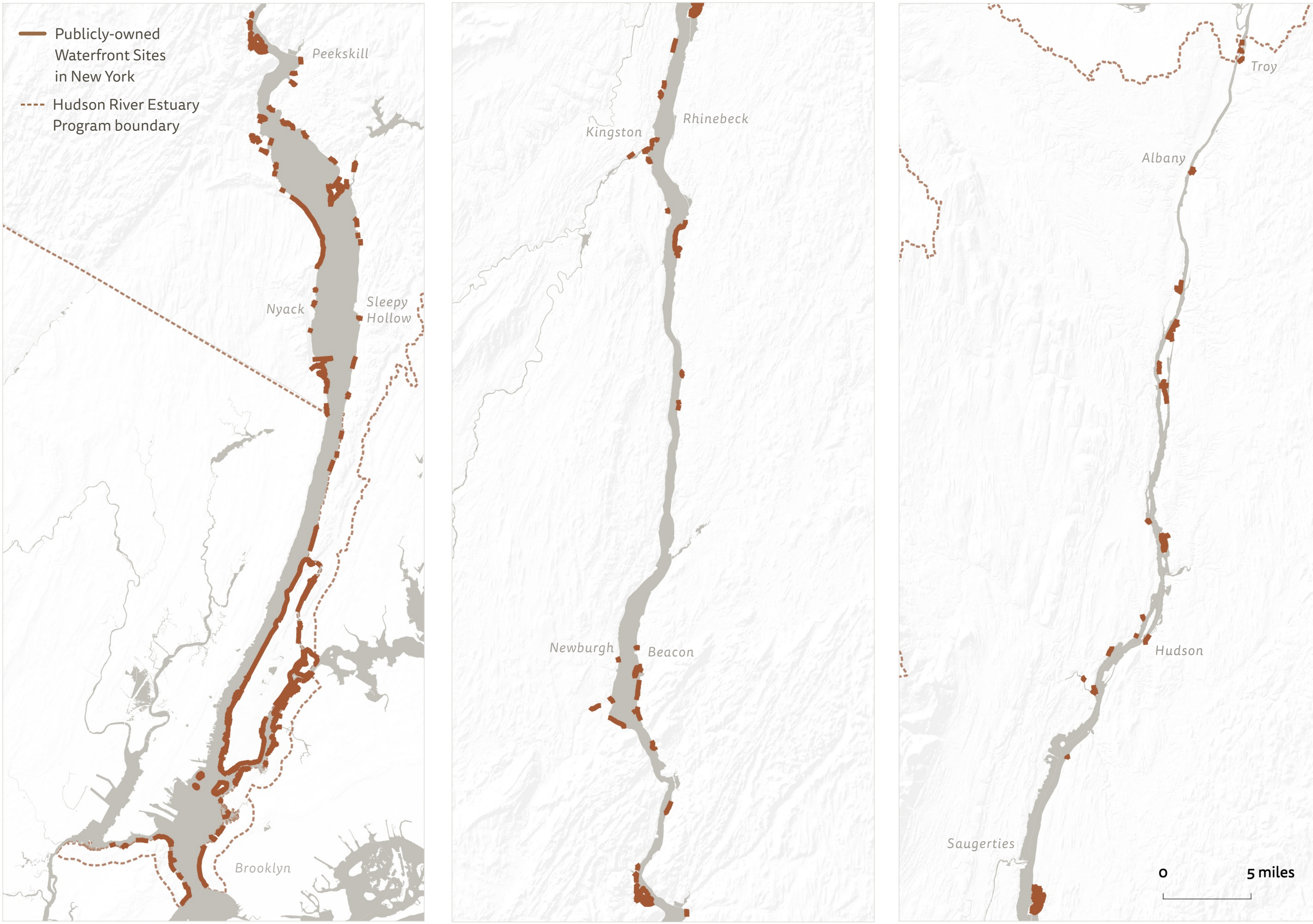
There is no standard that constitutes adequate access to this public resource. Analysis is limited to reporting absolute numbers and the number of access projects. The quality of waterfront access points is also not assessed in this report, but it has a significant effect on how much a site is actually used by the public. Nearby transportation or parking, ADA accessible public restrooms, sidewalks and picnic tables, shelter from the elements such as a gazebo or pole barn, on-site storage of equipment for stewardship and educational programs, and adequate signage are necessary for a quality and equitable experience.

Findings

Of the 570 miles of undulating shoreline bordering the Hudson River Estuary in New York State, about 140 miles of the waterfront are available to the public at parks, designated fishing access sites, nature preserves, or other lands. This includes approximately 25% of the total shoreline length. Within New York State, the Hudson River Estuary Program has supported over 125 projects since 1987. NYSDEC is just one of many agencies and organization supporting enhanced estuary access. The other 75% of the estuary's shoreline has limited or no public access at this time. In many cases, this is because of maritime, industrial, transportation, or private ownership that limits safe access to the water. In particular, 135 miles of railway line along the eastern shore of the Hudson River from the Bronx to the Troy Dam, make access a challenge, due to the limited number of safe crossings across the tracks to the shore. Even so, a 1989 report identified 43 opportunities to establish or enhance public access on peninsulas of land on the river side of the railroad tracks, and implementation has occurred at 33 of them (The Hudson River Access Forum, 1989).

Photo: The railroad creates an obstacle to river access. Steve Stanne.

Publicly-Owned Waterfront Sites in New York



Data Sources (maps): NYSDEC, Hudson Valley Natural Resource Mapper; See Boicourt et al., 2016.

Access for Water-Based Activities

Long term trend (1989-2019): Improving

Short term trend (2000-2019): Improving

Background

The number of and types of access sites where one can safely recreate on or in the water is an indicator of the public's ability to safely boat, fish, and in some cases, swim in the water. Such access is limited due to land use, land ownership, water quality shoreline and river geography, a lack of facilities, and management considerations, such as the availability of lifeguards.

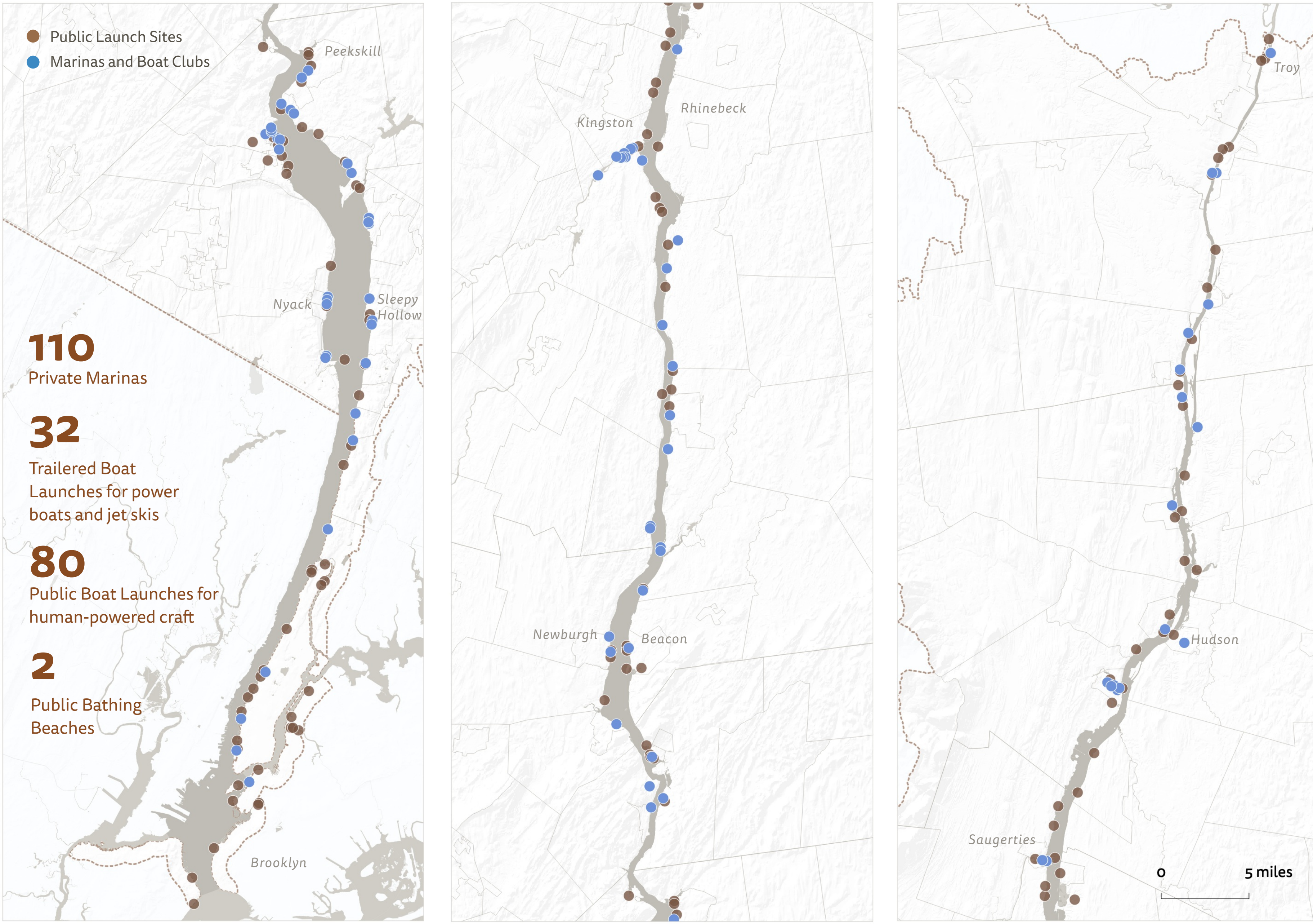
Each type of in-water access has specific requirements. Access for safe swimming is very limited; there are few beaches suitable for swimming on the Hudson, and in recent years, the limited availability of lifeguards has become an issue. Kayaks and other human-powered boats have different requirements to allow access to the water's edge from a sloping shore, low dock or specially designed dock. Access for motorboats requires space and slopes that can accommodate cars hauling trailers, as well as large parking areas. Access that enables stewardship and educational programs in or on the water is enhanced by natural, sloping shorelines which enable a wide variety of activities, such as the unique experience of seining. The estuary is home to a number of nonprofit sailing and research vessels that celebrate the river's heritage and provide education programs. For any local community to welcome these larger vessels, the access point must provide a dock with utilities and adequate water depth.

Analysis

Both NYSDEC and NY-NJ HEP inventory access points such as boat launches, marinas, and swimming beaches. Other agencies and organizations monitoring the available access include: the NYSOPRHP, NYSDOS, Hudson Valley Greenway, NYC Parks, and NYC Water Trail Association, and the Hudson River Boat and Yacht Club Association.

Photos: Kayak access at Downtown Boat-house Pier 26 in New York City, motorboat access in Newburgh, and canoe access at Tivoli Bays. NYSDEC.

Public and Private Access Sites



Data Sources: NY-NJ HEP, NYSDEC Hudson River Estuary Program

Access for Water-Based Activities

Findings

In 1997, there were 15 boat launches for human-powered craft along the estuary from Yonkers north to the Troy dam. Today, there are more than 80 such launch sites, many of which are designated Hudson Valley Greenway Water Trail sites. Estuary access grants continually provide funding to municipalities and qualifying not-for-profits to make improvements to their access sites and develop new sites where feasible throughout the entire estuary.

Public trailered boat launches also increased since the 1990s with investments by state and local government. In 1988, there were 14 publicly-owned boating facilities and 53 private or commercially owned ones, primarily oriented towards motorized craft (NYSDEC, 1998). There are now 32 public trailered boat launches along the Hudson River Estuary in New York State. A complex of private boat clubs and commercial marinas also serve recreational boaters along the entire stretch of the river, providing essential docking, fueling and pump out stations for boaters who enjoy the river locally or utilize the estuary as a travel corridor on their way to more distant destinations. There are only two bathing beaches that are open to the public as of 2020: Kingston Point Beach in the City of Kingston, and Croton Point Park in Westchester County. Many sites are now improving their accessibility for people of all abilities.

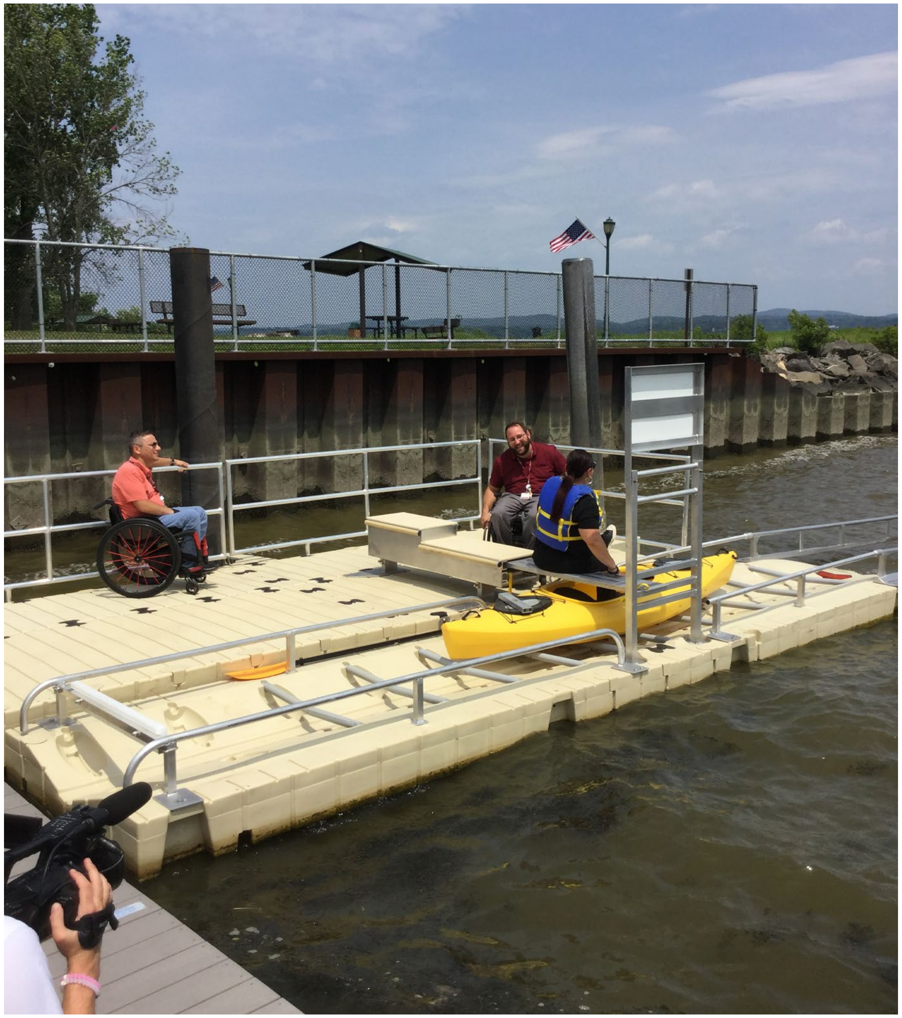
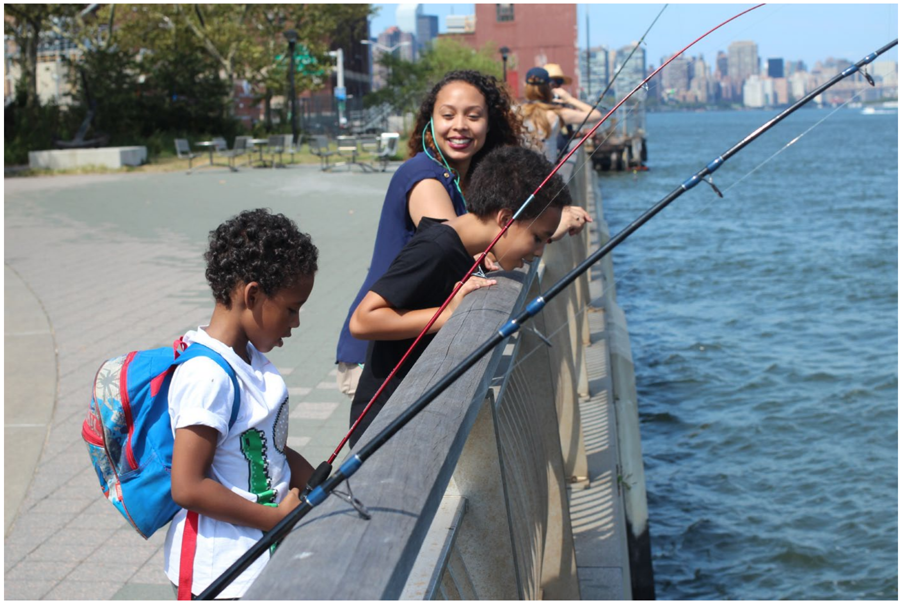


Photo: In July 2019, Rockland County upgraded their docks at Haverstraw Bay County Park to make them ADA compliant and to provide an accessible kayak launch that will serve a diverse user group, including the Adaptive Sports Program of the Helen Hayes Rehabilitation Hospital, located just minutes away from the park. This specially designed dock allows wheelchair users to get into and out of a kayak. NYSDEC

Access for Water-Based Activities

Did you Know?
One of the most popular activities undertaken on the Hudson is fishing.

Whether from a boat or from the shore, the Hudson is renowned for its diversity of fishing opportunities, from the striped bass run in the spring, to crabbing for blue crabs, to angling for black bass and other resident species throughout the fishing season. Fishing occurs almost anywhere an avid angler can find a spot to drop a line in the water. While there is no inventory of informal fishing access sites, there are many ways to find a place to fish. Docks and piers at numerous public access sites along the estuary are catalogued in NYSDEC's Hudson Valley Natural Resource Mapper. NYSDEC has also produced the "I Fish NY: NYC Fishing Map" highlighting over 35 fishing sites and describing their features and amenities (NYSDEC, 2019). See Further Reading for links to these resources online.



Photos: Shorefishing, New York City. Matthew Combs, Lower East Side Ecology Center.
Fishing boats, Bethlehem, NY. NYSDEC.

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5. Community Engagement

Poughkeepsie students remove invasive species before planting submerged aquatic vegetation they grew in their classroom. NYSDEC

Community Engagement
Introduction

People of all ages throughout the Hudson Valley have had a positive effect on their local waterways and the estuary watershed through a wide range of actions. Teachers and students study the estuary in their classroom and in the field. They study the river firsthand. People also volunteer to clean up the shoreline and monitor the river. Community residents are involved formally and informally in decisions about lands and waters throughout the watershed. They contribute their local knowledge and leadership to conservation planning efforts in municipalities large and small. Community engagement empowers people to have an impact on the places where they live.

Photos: left: Trees for Tribs volunteers at work. NYSDEC; right: Volunteers pick up trash at the Riverkeeper Sweep. Riverkeeper.

Stewardship Participation

Long Term Trend (1990-2020): Insufficient Data

Short Term Trend (2000-2020): Improving

Background

Stewardship activities have a variety of purposes, such as developing awareness and an appreciation of natural resources, restoring habitats, and collecting biological and environmental data. A variety of organized stewardship activities exist throughout the watershed, ranging from one-day events to ongoing programs that encourage a sustained commitment to conservation. Community participation in river stewardship began in the 1970s through projects such as the Hudson River Sloop Clearwater's People's Pipewatch, which provided citizen eyes and ears to improve enforcement of the Clean Water Act. In those years, dozens of small environmental groups also formed at the community level to address local concerns, though data on participation in stewardship was not regularly collected at that time. Organized citizen participation in stewardship has significantly increased over the last two decades. Major annual volunteer programs that are still underway and growing are described below. They include the Hudson River Estuary Program's Day in the Life of the Hudson and Harbor, which started in 2003, Trees for Tribs (2007), the American Eel Migration Research Project (2008), and the Amphibian Migrations and Road Crossings Project (2009). Annual stewardship events hosted by other organizations have also grown and evolved over the last two decades.

Photo: This spotted salamander was counted by a volunteer during the spring migration of amphibians from their forest habitat to breed in woodland ponds. Laura Heady

Analysis

Stewardship activity in the watershed was analyzed using seven representative annual events and ongoing volunteer programs. The largest and most consistent annual events were selected for this analysis:

- City of Water Day, a harbor-focused event organized by the Waterfront Alliance and NY-NJ Harbor & Estuary Program (NY-NJ HEP);
- Riverkeeper's River Sweep, a one-day regional event which takes place throughout the watershed;
- The SUBMERGE festival on Manhattan's west side shoreline, organized by the Hudson River Park Trust; and
- A Day in the Life of the Hudson and Harbor, a one-day shoreline event from the harbor up the tidal Hudson to the Mohawk, organized by the Hudson River Estuary Program, the Hudson River National Estuarine Research Reserve, and the Lamont-Doherty Earth Observatory.

In addition to these annual events, three ongoing volunteer programs created by the Hudson River Estuary Program were analyzed. Trees for Tribs encourages property owners to apply for assistance in planting trees and shrubs along streambanks, the start of a long-term strategy for ensuring healthy streams. The Amphibian Migrations and Road Crossings Project engages volunteers to find and document locations where salamanders and frogs cross roadways on their annual migrations from forests to woodland pools for breeding. Throughout the watershed, volunteers help characterize these late winter and early spring migrations by recording weather conditions, species and car traffic. They help mitigate the effects of habitat fragmentation by assisting amphibians safely across roads. The Eel Project in partnership with the Hudson River National Estuarine Research Reserve, stems from a fisheries management need to better understand the migrations of juvenile American eels from the ocean near Bermuda where they hatch to Hudson River tributaries each spring. Volunteers, from high school students to retirees, use special nets to catch and count tiny two-inch "glass eels," then release the fish upstream of dams and other barriers to aid them in their natural migration. All of these projects include different levels of engagement, and all take place at multiple sites throughout the estuary watershed.

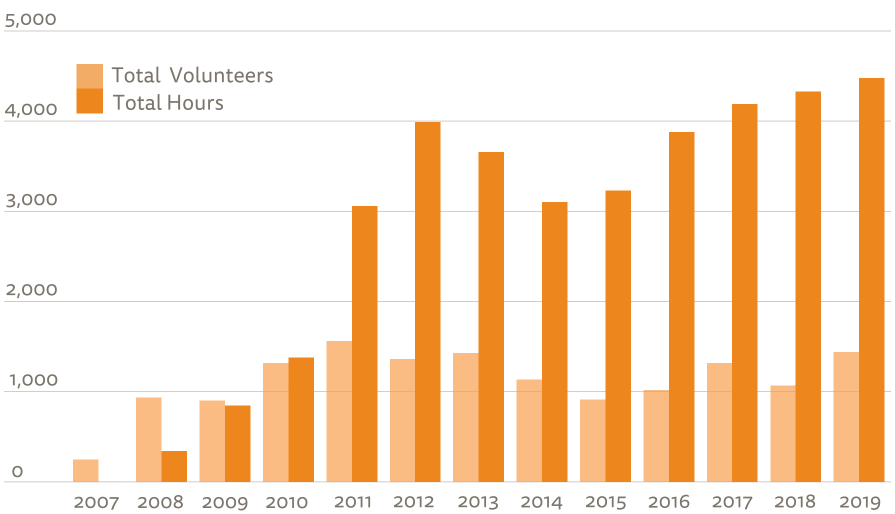
Stewardship Participation

Findings

The total number of community members participating in stewardship events has grown dramatically since 2003, as has the number of hours they contribute. For example, the number of volunteers in the three Hudson River Estuary Program stewardship activities we studied (below) grew steadily from a few dozen in 2007 to over 1,500 in 2019, contributing over 4,000 hours of time. Participation in one-day events offered by four organizations showed that more than 200 sites hosted over 50,000 people in 2019, compared to about 340 participants in 2003. Volunteers are also becoming more engaged and deepening their experiences as schools make some of these events a regular part of their curriculum. The overall increase in stewardship

Combined participation in three programs offered by the Hudson River Estuary Program

(Trees for Tribs, the American Eel Migration Research Project, and the Amphibian Migrations and Road Crossings Project)



Participation in One-Day Stewardship Events offered by Partner Agencies and Organizations

	A Day in the Life of the Hudson & Harbor		City of Water Day	Riverkeeper Sweep		Submerge
Year	Sites	Participants	Participants	Sites	Participants	Participants
2003	14	341				
2004	16	1,175				
2005	26	695—rain				
2006	34	1,329				
2007	49	2,500				
2008	53	2,800	7,200			
2009	61	3,000	11,000			
2010	54	3,336	13,000			
2011	59	3,487	25,000			
2012	67	3,765	26,000	30	450	
2013	60	3,271	26,000	70	1,400	
2014	54	3,220	25,000	82	1,900	4,500
2015	80	5,121	25,000	102	2,000	cancelled
2016	81	5,297	26,000	109	2,200	7,000
2017	90	5,502	35,000	102	1,790	6,500
2018	89	6,328	35,500	120	2,300	8,500
2019	93	5,263	35,000	122	2,405	7,500

Data Sources: NY-NJ HEP, NYSDEC Hudson River Estuary Program, Hudson River Park Trust, Riverkeeper

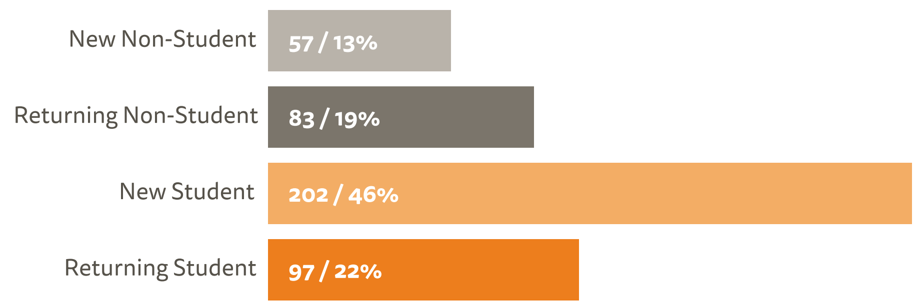
Stewardship Participation

participation likely indicates greater public interest in the river and watershed as well as the increased capacity of governmental and non-profit entities to offer programs to engage the public. Of course, data from these programs and events do not capture all the people and organizations engaged in stewardship activities; organizations such as the Billion Oyster Project and dozens of individual park conservancies engage thousands of other volunteers on an annual basis.

A recent analysis of Hudson River eel monitoring volunteers from 2008 through 2018 found that more than two thirds of adult volunteers participated for more than one year, and about a third were new volunteers each year. This indicates a healthy mix of experienced volunteers who help train a regular stream of new recruits to the project. Students are an important group to engage as their participation can lead to a lifetime of river stewardship, although they have more turnover as volunteers, to be expected as students advance to new grades. However, the teachers and schools who monitored each site tended to be consistent. Eel project volunteers have had a significant ecosystem impact as well. Over one million eels were caught and counted between 2008 and 2020. The program regularly involves up to a thousand volunteers each year.

New vs. Returning Volunteers 2008-2019

Annual American Eel Research Project



Photos: Glass eel monitoring occurs in springtime on tributary streams. NYSDEC

Data Source (graph): NYSDEC

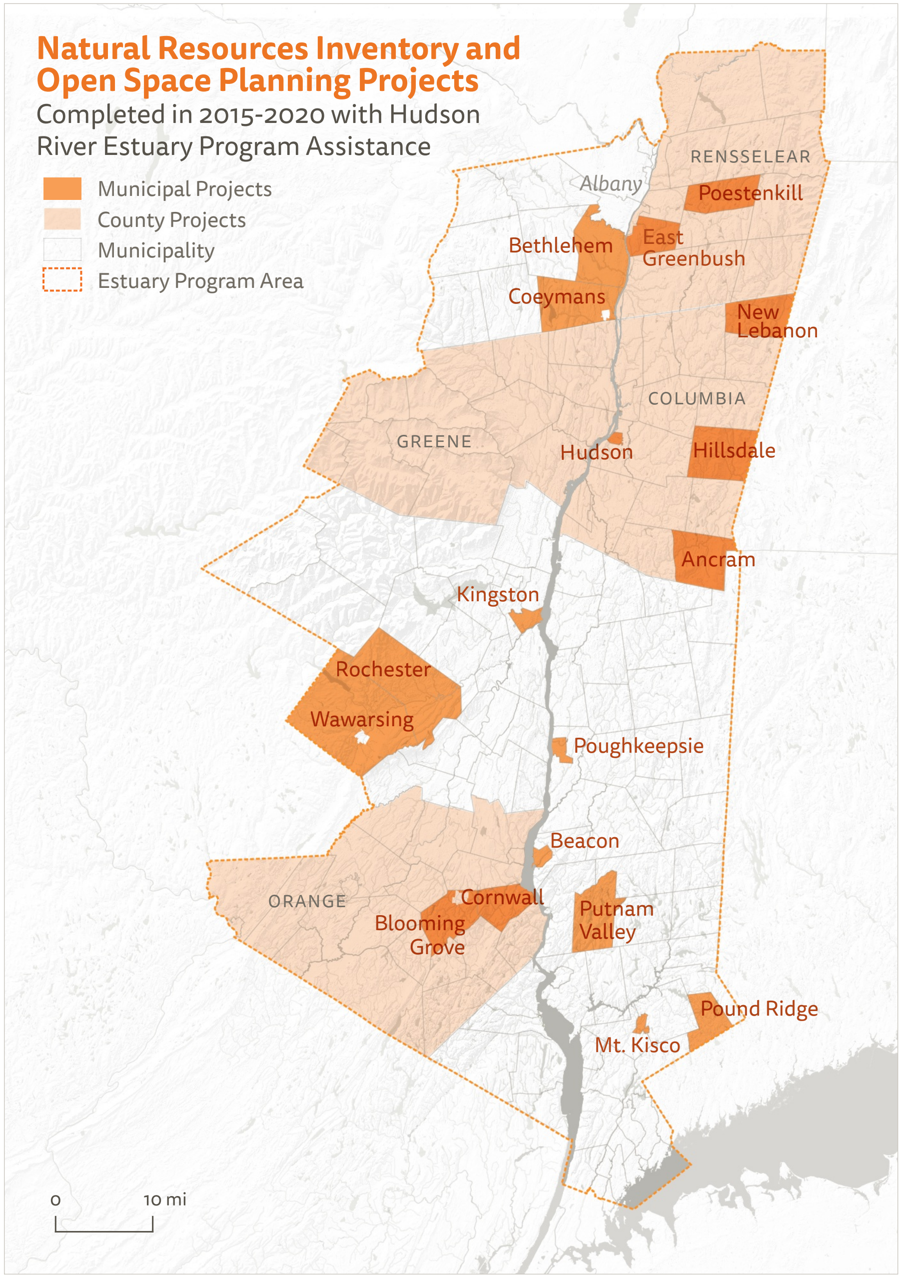
Local Conservation Planning

Did you Know? Between 2015 and 2019, nearly 6,500 decision-makers from 106 municipalities and 58 conservation groups received planning assistance from the Hudson River Estuary Program.

The responsibility for conservation and planning within the estuary watershed often falls to the volunteer members of planning and zoning boards, conservation advisory councils, and other committees in more than 250 municipalities. A high level of participation by such members in training and technical assistance offered by the Hudson River Estuary Program indicates a deep commitment to long-term environmental stewardship and an increasing demand for natural resource information to support planning and decision-making (Allred et al., 2015).

This participation leads to planning outcomes that help to conserve lands, water resources, and biodiversity in the estuary watershed (Allred et al., 2015), and assist in preparing for climate change. Since publication of the guidebook *Creating a Natural Resources Inventory* (NRI; Haeckel and Heady, 2014), 18 municipalities and 4 counties completed NRI, open space inventory, and open space planning projects with technical assistance and/or funding from the Hudson River Estuary Program. Another nine municipal NRIs are underway. Participating municipalities represent a range of rural to urban communities, and many are utilizing their NRI to inform subsequent open space planning and conservation policy actions.

Photo: Municipal officials and volunteers participate in a conservation and land-use training program sponsored by the Hudson River Estuary Program. NYSDEC



Data Sources (map): NYSDEC, Hudson River Estuary Program

Community Science

Historic trend: See text below

- Long Term Trend (1990-2020): Insufficient Data
- Short Term Trend (2000-2020): Insufficient Data

Background

Community 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 estuary. Also known as citizen science, community 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 the watershed. Community science programs improve management and maintenance of shared water resources by building active constituencies.With sufficient capacity or technical assistance, community science programs can even develop and meet quality assurance standards for their data to contribute to understanding and tracking water quality.

Expanding and improving the quality of community science programs in the estuary directly raises awareness about the need to protect and restore shared waterways. Such 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 community science programs include placement and monitoring of oyster reef habitats, mapping of submerged aquatic vegetation, and collection and analysis of the amount and sources of floating trash and marine debris. The number of successful, long-term community science programs is an indicator of the public's willingness to participate in scientific research and conservation of the estuary as well as the growing capacity of agencies and non-profits to support such community engagement and use the resulting information.

Analysis

A 2019 survey of members of educational and stewardship organizations in the Hudson River Valley between Yonkers and Albany identified 27 organizations that conduct community science and data collection. This survey data was combined with findings from a nearly identical 2018 survey distributed by the Citizens Advisory Committee of NY-NJ HEP for organizations operating in the estuary south of Yonkers. The surveys asked groups about the diversity of environmental 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.

Photo: Students at the NY Harbor School on Governors Island study oysters and record their data for the Billion Oyster Project's participation in the Day in the Life of the Hudson and Harbor. NYSDEC.

Community Science

Findings

The survey results show that 44 organizations throughout the estuary were conducting community science programming and data collection for a variety of purposes, with most monitoring multiple parameters. Water quality was the topic of greatest participation with 68% of organizations monitoring some aspect, primarily bacteria. The next most common parameters being measured were biodiversity, fish catches, and litter or other floatable debris. Over half (66%) of the organizations surveyed stated that they work with individual volunteers in their community science and data collection programs. In addition, many programs collaborated with colleges and universities (61%), non-profit organizations (61%), K-12 schools (55%), and government agencies (52%). The majority of organizations were using some sort of formal protocol—36% were using protocols established by the NYSDEC, and 30% were following university protocols. In terms of sharing their data, 61% of respondents did so on a publicly accessible website, while 41% sent their data to a government agency, primarily the NYSDEC. In addition, 23% of organizations supplied downloadable spreadsheets of their data that can be used for further analysis. Organizations responded that the greatest needs for their community science programs are funding, staff, and volunteers.

Community Science Topics and Number of Engaged Partners

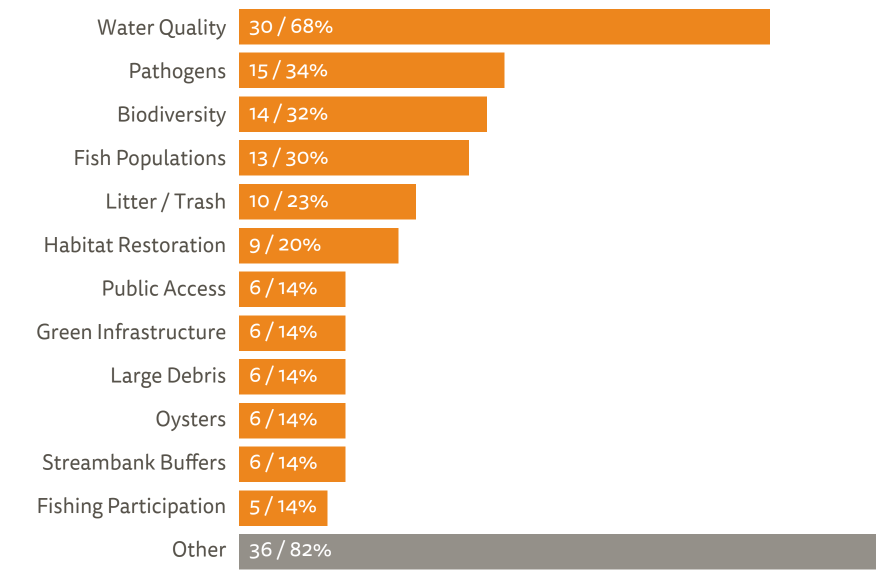


Photo: Installing an eel net on Quassaick Creek, Newburgh.

Data Sources (graph): NY-NJ HEP, NYSDEC

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Further Reading

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Hudson River Estuary Program Community Science: American Eel Research.**www.dec.ny.gov/lands/49580.html**

Hudson River Estuary Program Conservation and Land Use **www.dec.ny.gov/lands/5094.html**

NYSDEC. Amphibian Migrations and Road Crossings Project. **www.dec.ny.gov/lands/51925.html**

NYSDEC. Conserving Land in Your Community: Critical Environmental Areas. Video: **https://youtu.be/PrB-oCvRNJM**

6. Climate Change

Extreme precipitation events are occurring more frequently, such as Tropical Storm Irene, which flooded the waterfront up and down the Hudson, including here in Poughkeepsie, at Waryas Park. Steve Stanne.

Climate Change
Introduction

Climate change is caused by the accumulation of excess carbon dioxide and other greenhouse gases in the atmosphere resulting from human activity, including the burning of fossil fuels for transportation and energy generation. Solar radiation warms the Earth, which, in turn, radiates heat to the atmosphere when it is cool, relative to the Earth. The excess greenhouse gases trap some of this heat in the lower atmosphere that warms the air and water beyond normal levels. This causes other changes, including sea-level rise and variatioins in the hydrologic cycle. Climate change is affecting the Hudson River Estuary on a local level. Sea level is rising, water and air temperatures are increasing, extreme precipitation is occurring more frequently, punctuated by interim periods of drought, and wildlife distribution and migration patterns are changing (IPCC, 2014; Horton et al., 2014; Reidmiller et al., 2018; NYSDEC, 2015; Rosenzweig et al, 2011; Pirani and Boicourt, 2018; Yozzo, 2018).

Sea-level rise and flooding are likely to affect the estuary's tidal marshes and shallows. It remains to be seen whether they might survive in place or migrate into newly flooded shallows. The flooding associated with intense storms like Hurricane Irene and Tropical Storm Lee can carry huge volumes of sediment into the Hudson, where it hinders the growth of submerged aquatic vegetation (Hamberg et al., 2016). Hurricane Irene and Tropical Storm Lee had acute but shorter-term direct impacts on fish. Populations living in near-shore waters declined, while runoff swept young migratory fish further seaward than normal in late summer, a shift correlated with reduced growth rates. Sea-level rise and frequent flooding is impacting the provision of public access to the estuary, requiring park managers to contend with a variety of challenges from damaged infrastructure to increased erosion.

Reducing greenhouse gas emissions and adapting to climate change requires actions at all levels of government, as well as personal and institutional decision-making. The NYSDEC Climate Smart Communities Program and the Hudson River Estuary Program are encouraging local actions to address these issues locally and statewide (see Community Engagement Chapter).

Photo: Sediment flowing from the Mohawk River into the Hudson at Cohoes Falls after Tropical Storm Irene. USGS

Resetting Natural Clocks

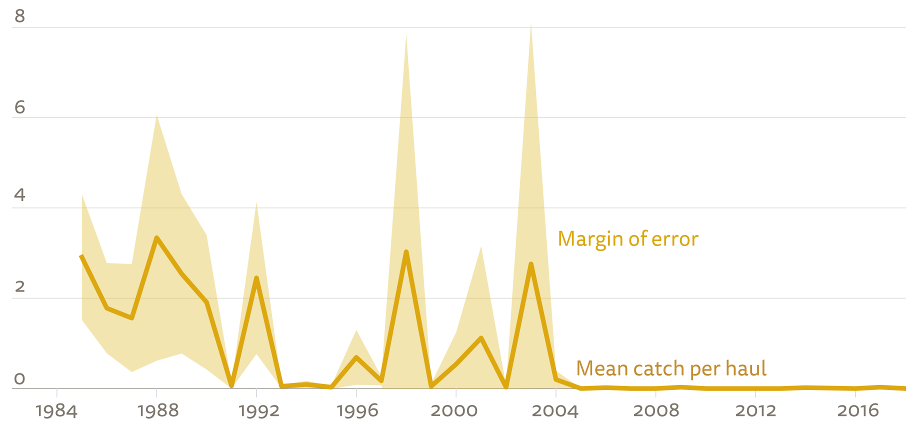
Did You Know?
Our warming climate has altered the timing of events keyed to seasonal change.

Bloom dates of many plants are 4 to 8 days earlier than in the early 1970s . At the Mohonk Preserve in Ulster County, where detailed records go back to the 1930s, some woodland flowers are now blooming earlier in spring—bloodroot 14 days earlier, and Hepatica, 20 days earlier. Amphibians are emerging from winter dormancy earlier—wood frog by 14 days, Jefferson's salamander, by 23 days. The arrival of summer resident birds shows the same trend: the eastern towhee returns 10 days earlier, the ruby-throated hummingbird, seven days earlier (Mohonk Preserve, Daniel Smiley Research Center, long-term phenology records).

Increasing water temperature is likely influencing the spawning behavior of anadromous species of the estuary. Using historic Hudson River water temperatures from 1950 to 2012, the onset of spawning for American shad and striped bass was estimated to have occurred 6 to 7 days earlier in the 2000s when compared to the 1950s (Nack et al., 2019). Warmer waters and shorter winters may be beneficial to some species such as the blue crab. For example, in the Chesapeake Bay, the overwintering survival of blue crab is predicted to increase by at least 20% by the year 2100 compared to current conditions, and the northern range of blue crab also appears to be increasing in relation to warmer water temperatures, affecting the Hudson as well (Johnson, 2015; Glandon et al., 2019 ; Daniels et al., 2005). In concert with rising water temperatures, the rainbow smelt has disappeared from the estuary, and Atlantic tomcod numbers are declining. While correlation is not causation, both are fish of more northerly waters, reaching the southern limit of their range in the Hudson. Their early life stages are known to require cool temperatures for survival (Daniels et al., 2005).

Species that are most at-risk from climate change in the watershed include vernal-pool-breeding amphibians, alpine/boreal breeding bird species that are at the southern edge of their range in the Hudson Valley and nest at high elevations in the Catskills, Bicknell's thrush, blackpoll warbler, and yellow-bellied flycatcher, and brook trout in the cold water reaches of tributary streams (Brooks, 2009; Audubon, 2020).

Atlantic Tomcod—Young-of-Year
Brackish Tidal Index Abundance



Graph: YOY Atlantic tomcod *(Microgadus tomcod)*, a brackish resident estuarine species, have severely decreased in abundance and have only been collected sporadically in recent years. The Hudson River is close to its southern range, and the changing climate may be causing a decline in abundance relative to catches observed in the mid to late 1980s. **Photos:** Tomcod, Ruby-throated hummingbird. NYSDEC & USFWS Steve Maslowski

Data Source (graph): NYSDEC Juvenile Anadromous Surveys, annual arithmetic mean of all hauls or net sets.

Sea-Level Rise

Long Term Trend (1900-2019): Deteriorating

Short Term Trend (2000-2019): Deteriorating

Background

Sea level is rising due to the expansion of ocean water as it warms as well as the melting of glacial ice on land, both influenced by global warming. There is growing concern that large ice sheets covering Greenland and Antarctica may be melting faster than previously thought. If so, the rate of sea-level rise could increase. Sea-level rise affects people by increasing the size of the shore area affected by tidal and storm surges. Additionally, sea-level rise in the Hudson River Estuary affects marsh habitats that support the whole ecosystem. As sea level continues to rise, Hudson Estuary marshes will need room to expand landwards or could risk inundation and destruction (Tabak et al., 2016). The types of marsh seen along the Hudson could also shift, as high marsh habitats transition to low marshes in response to rising waters (Tabak et al., 2016). The extent of this transition will depend on the amount of sediment deposition on existing marsh land that might offset rising water levels. This sediment deposition is known as accretion. Higher levels of accretion could improve the ability of existing wetlands to adapt to sea-level rise. Sea-level rise will also affect submerged aquatic vegetation (SAV) beds, which thrive in specific water depths. SAV provide crucial habitat for fish and supply oxygen to the water (see Habitat & Ecological Heath chapter).

Analysis

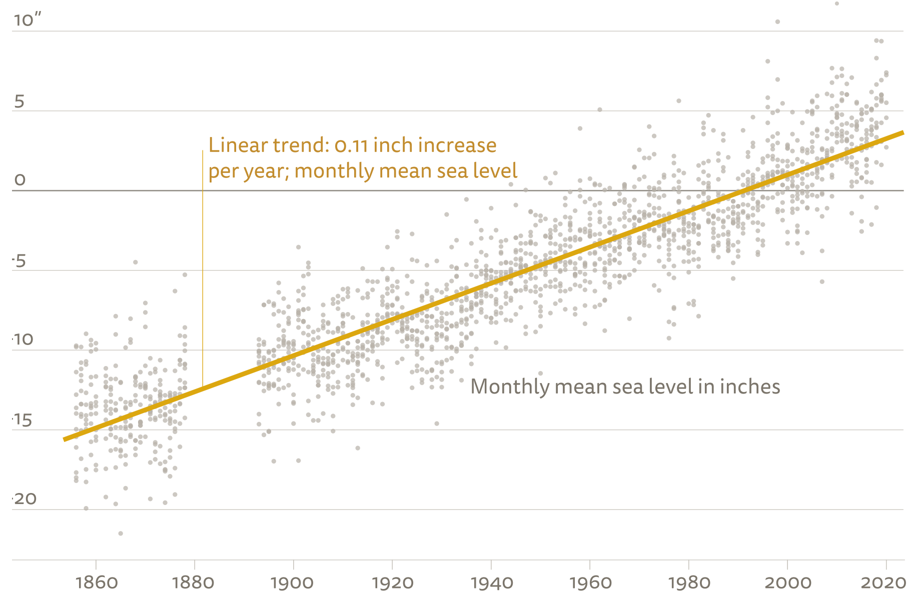
Sea level data were collected from the NOAA gauge at the Battery on the southern tip of Manhattan, which has been continuously tracking sea level since 1850.

Photo: Even on sunny days, extreme high tides are flooding waterfront areas. NYSDEC

Findings

At the Battery in New York Harbor, sea level rose, on average, 0.11 inches per year (NOAA Tides and Currents, 2020). Sea level along New York's coastline has risen over one foot since 1900 (Rosenzweig et al., 2014). Furthermore, the rate of rise appears to be increasing, averaging 0.28 inches per year between 2000 and 2014 (Tabak et al., 2016). There is growing concern that the large ice sheets covering Greenland and Antarctica may be melting faster than previously thought. If true, sea levels could rise higher than predicted-between 6 and 9 feet by century's end (NYC Panel on Climate Change, 2019). The Mid-Hudson Region will likely see a rise of 14 to 27 inches in the Hudson River by 2050, and 30 inches under the most extreme scenario (Rosenzweig et al., 2014).

Relative Sea level Trend, The Battery, Lower Manhattan, NY



Data Source: NOAA, Tides and Currents, the Battery sea-level gauge, New York City

Air Temperature

Long Term Trend (1970-2019): Deteriorating

Short Term Trend (2000-2019): Deteriorating

Background

A trend of rising air temperatures affects the Hudson Valley's ecosystems and communities in a number of ways. For instance, extreme heat waves negatively impact people (Rosenzweig et al., 2014). Particularly in urban areas, a worsening of the urban heat island effect is dangerous for vulnerable populations including children, the elderly, and those without access to air conditioning or cooling centers (USEPA, 2020). Rising temperatures also affect the ecosystem by stressing native plants and animals, which creates conditions favorable to invasive species (Rosenzweig et al., 2014; Dukes and Mooney, 1999).

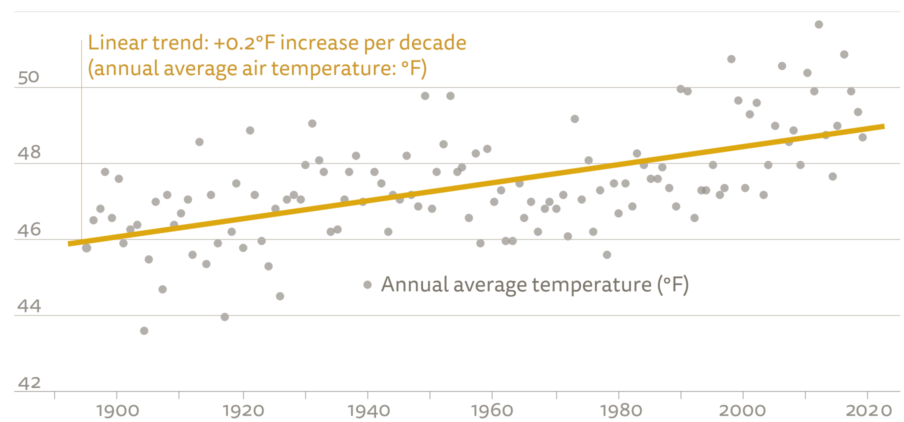
Analysis

Long-term trends were identified by researchers for the New York State Energy Research and Development Authority ClimAID report created in 2011 and updated in 2014 (Rosenzweig et al., 2014). These trends were established using meteorological data from 22 NYS observing stations distributed across all state climate regions. Additional corroboration of these trends in the Hudson Valley is provided by NOAA National Centers for Environmental Information (NOAA NCEI), which provides data to the year 2019. For the Hudson Valley, annual average temperature was calculated from 1895 to 2019 and winter average temperature from 1970 to 2019.

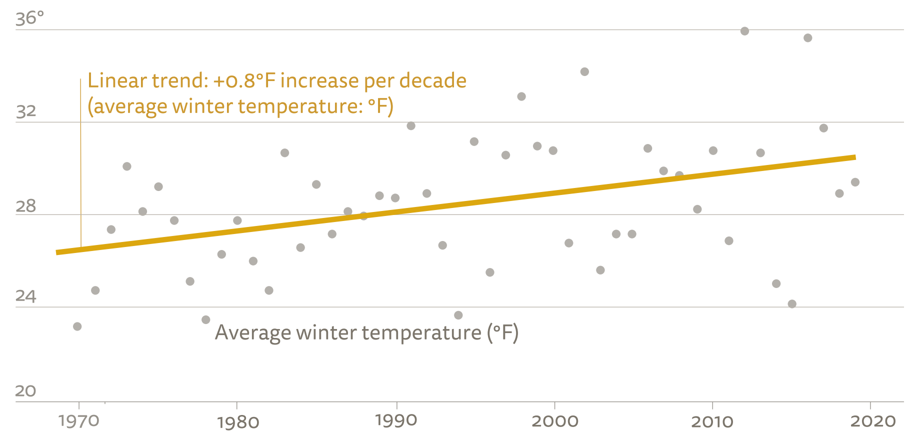
Findings

New York State's average annual temperature increased 0.25°F per decade since 1901 (Rosenzweig et al., 2014). Winter average temperatures warmed even faster over the same time frame, especially between 1970 and 2008, when they increased 1.14°F per decade (Rosenzweig et al., 2011). Recent data from NOAA NCEI for the Hudson Valley confirms this continuing trend in the Hudson watershed showing 0.2°F average warming per decade since 1895 and 0.8°F of winter warming per decade between 1970 and 2019 (NOAA NCEI, 2020). Since 2000, every year in the Hudson Valley was hotter than the annual average temperature from 1901-2000. The year 2012 was the warmest on record in New York State and the Hudson Valley (NOAA NCEI, 2020).

Annual Average Temperature 1895-2019, (Hudson Valley, NY)



Average Winter Temperature, December-March 1970-2019, (Hudson Valley, NY)



Data Source: NOAA National Center for Environmental Information, 2020 Hudson Valley divisional time series data.

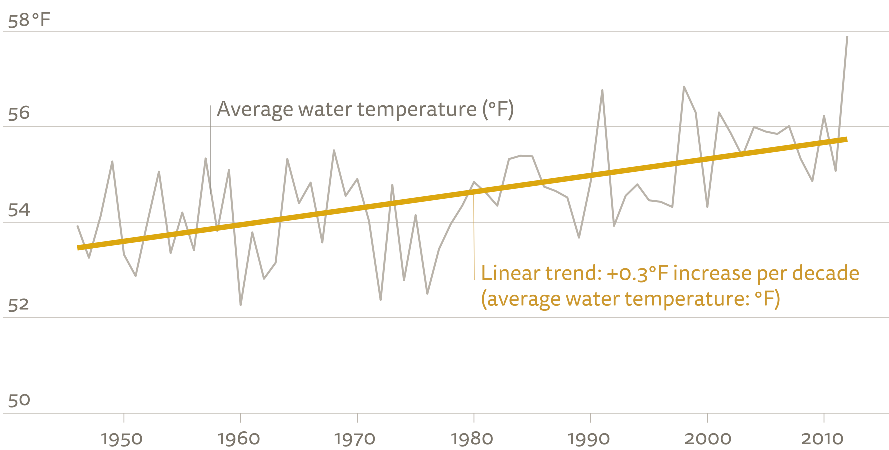
Water Temperature

Long Term Trend (1940-2012): Deteriorating
Short Term Trend (2000-2020): Deteriorating

Background

Worldwide, the upper ocean surface has warmed by 0.2°F every decade since the 1970s (IPCC, 2014). Water temperature is a key indicator of ecosystem condition, influencing a variety of other indicators, including dissolved oxygen, acidity, and specific conductance (salinity), as well as many biological life cycles. Even small increases in water temperatures can affect the growth, behavior, and species distribution of aquatic animals. For example, the estuary has likely lost rainbow smelt as a resident species due to warming waters pushing the fish's range north. Species from the mid-Atlantic such as blue crab are migrating northward to the Hudson River Estuary in response to warming temperatures (Daniels et al., 2005). The metabolic activity of many organisms, such as fish and macroinvertebrates (e.g., aquatic insects, snails, and amphipods), is dictated by water temperature, ultimately influencing reproductive timing and the rate of growth (Yozzo, 2018). Warmer temperatures are also a problem for smaller tributaries and embayments that are not well-flushed or are more sensitive to summer heat waves.

Hudson River Water Temperature (Poughkeepsie, NY)



Analysis

Results from United States Geological Survey (USGS) gages at Poughkeepsie and Albany were examined to find maximum temperatures. Long-term trends were observed in a study of data obtained from the Poughkeepsie water treatment plant, which has collected data since 1946 (Seekell and Pace, 2011). HRECOS continuous water temperature data were not used for this analysis because tracking only started in 2008; however, this will become a key data source for tracking climate-driven changes in water temperature as the time series lengthens.

Findings

Similar to other waters throughout the world, the Hudson is warming, consistent with the effects of climate change. At Poughkeepsie, the river's annual average water temperature has increased by more than 2°F between 1940 and 2011 (Seekell and Pace, 2011). At Albany, water temperature records go back to 1972 (with a gap from 1976 to 1981). Prior to October 2007, the highest temperature on record was 83.3°F, observed in the summers of 2002, 2005, and 2007. Higher temperatures have been observed since. In July 2011, the river reached a temperature of 84.9° F. Since this record high, the highest temperature observed at Albany was 84.6°F in July 2018 (USGS Port of Albany gage, 1972-2020).

Illustration: Rainbow smelt. NYSDEC

Data Source: Seekell and Pace, 2011

Precipitation

Long Term Trend (1940-2019): Deteriorating

Short Term Trend (2000-2019): Not Trending

Background

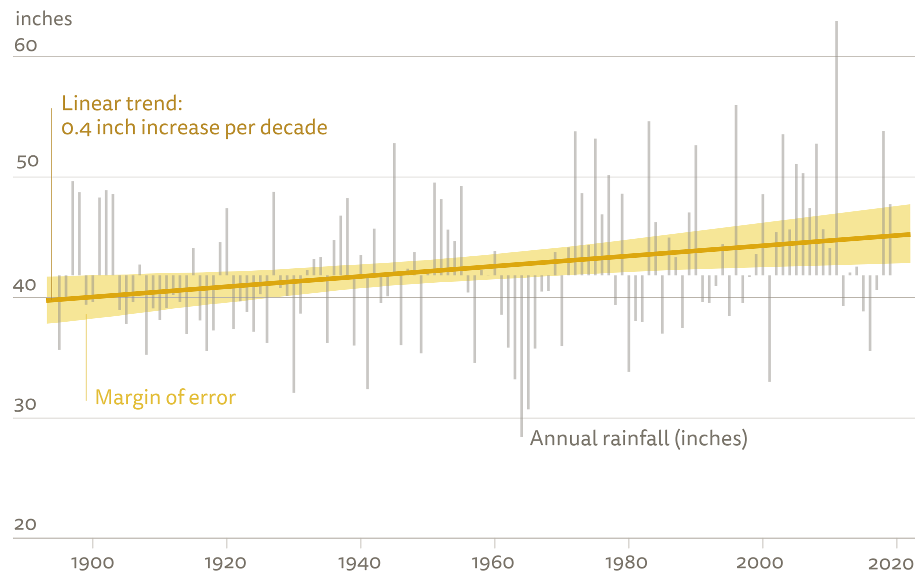
Annual average precipitation is increasing in the Northeast US (Horton et al., 2014). Additionally, precipitation patterns are changing. Extreme precipitation events are occurring more frequently, punctuated by interim periods of drought (IPCC, 2014; Horton et al., 2014). This emerging pattern poses many challenges for people and ecosystems. For people, drinking water supplies may be impacted by longer periods of drought (Rosenzweig et al., 2014). Waste-water infrastructure such as combined sewer overflows could be overloaded by intense rainfall (Rosenzweig et al., 2014). Additionally, extreme rainfall will cause severe flooding and storm water problems in many areas in the Hudson River Estuary watershed and will further impact communities by worsening the effects of erosion (Rosenzweig et al., 2014). For ecosystems, extreme precipitation is likely to cause increased stream flows and higher sediment loads (Stryker et al., 2018). Periodic drought affects a host of water dependent species.

Photo: Periods of drought can dry up streams and affect water supplies. NYSDEC.

Analysis

Annual precipitation data were collected from the NOAA National Centers for Environmental Information for the Hudson Valley Division. Annual average precipitation was calculated for the period of 1895-2019. Additionally, extreme-precipitation event data were collected from NOAA Northeast Regional Climate Center using the SC ACIS (Applied Climate Information System) Tool. These data show the number of days per year when rainfall exceeded 1 inch in a 24-hour period between 1939 and 2019 for Albany International Airport.

Annual Average Precipitation 1895 - 2019 (Hudson Valley)



Precipitation

In the Hudson Valley, average rainfall is increasing over the long term. Average annual precipitation increased 0.43 inches per decade between 1895 and 2019 (NOAA NCEI, 2020). This trend is consistent with observations from the 2017 National Climate Assessment for the Northeast US. In that report, researchers observed a precipitation increase in the Northeast of 0.4 inches per decade between 1895 and 2011 for a total of 5 inches more rain annually in 2011 than in 1900 (Horton et al., 2014). The wettest year on record in the Hudson Valley was 2011, with 75 inches of precipitation, including 5-10 inches of precipitation delivered by Tropical Storm Irene (NOAA NCEI, 2020; USGS, 2020).

The number of extreme rainfall events in the Hudson Valley may be increasing as well. An extreme event is defined as one in which rainfall exceeded 1 inch in a 24-hour period. Data taken from the Albany International Airport show an average of 8 extreme rainfall events per year over the past 30-year period between 1989 and 2019 (NOAA SC ACIS, 2020). This is compared to an average of 6 extreme rainfall events per year over the period from 1939 to 1980. This upward trend in extreme precipitation is consistent with findings from the 4th National Climate Assessment (NCA4) that show an increase in annual rainfall delivered through extreme rainfall events between 1958 and 2015 (Reidmiller et al., 2018).

Number of Days with Rainfall greater than 1 inch, 1939-2019
(Albany International Airport)

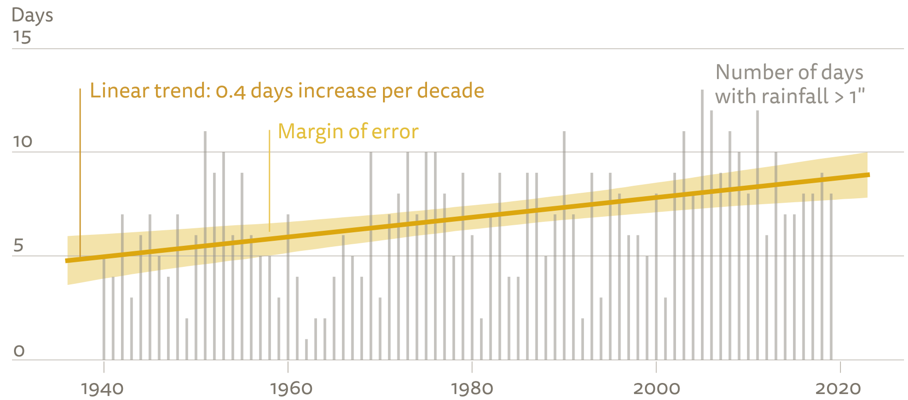


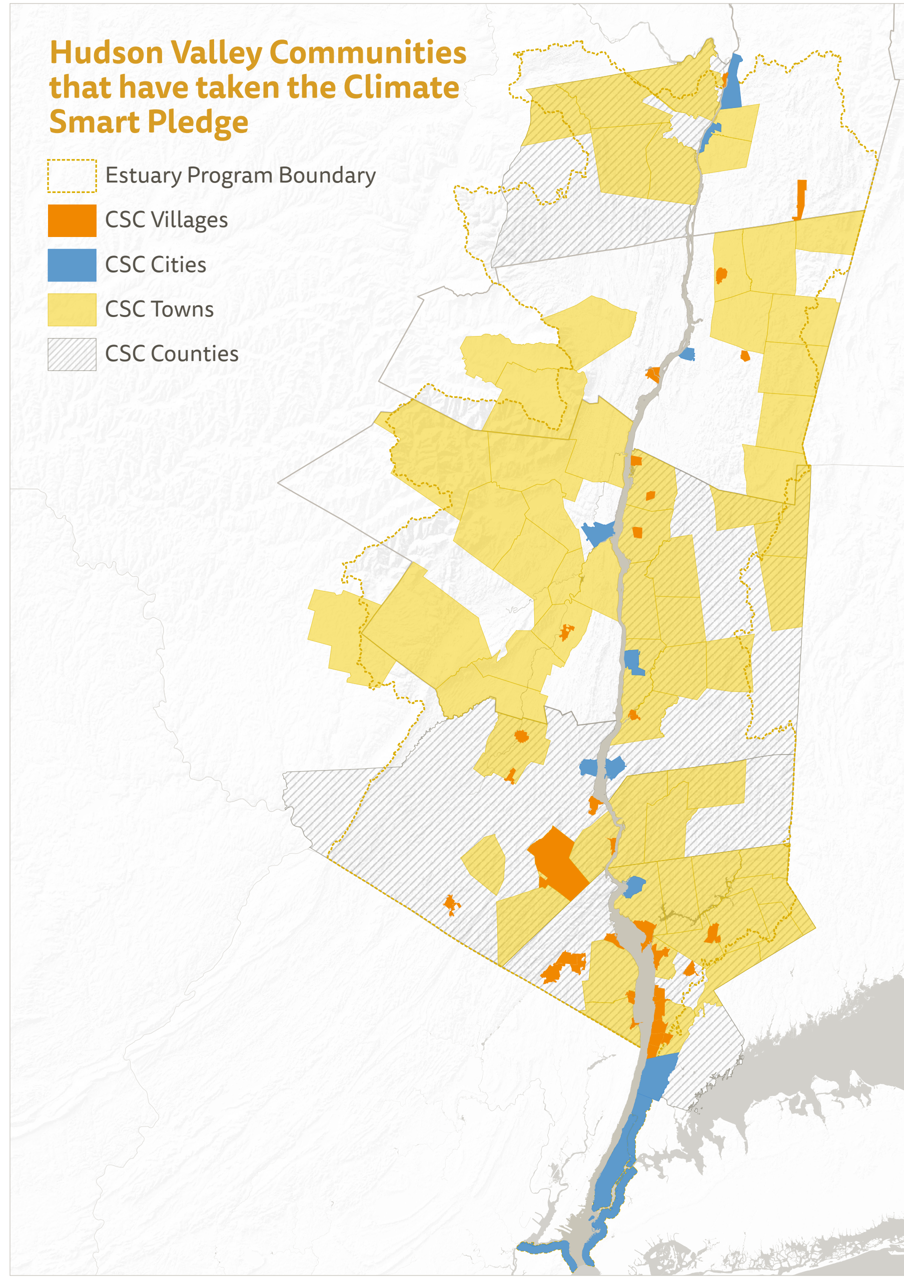
Photo: Extreme rainfall causes extensive street flooding. NYSDEC

Data Source: NOAA Northeast Regional Climate Center. (2020). SC ACIS Version 2 Tool. Accessed at: http://scacis.rcc-acis.org/

Tackling Climate Change

Did You Know?
107 communities in the Hudson Valley are taking action for climate resilience.

Within the estuary watershed, 107 municipalities have signed up to be Climate Smart Communities (CSC), which is 44% of the watershed's total municipalities. In addition, 6 counties have taken the CSC pledge (60%), well above the statewide total of 19%. This New York State program helps local governments take action to reduce greenhouse gas emissions and adapt to a changing climate. The program offers free technical assistance and grants. These communities are taking steps to ensure a more resilient society that keeps pace with a changing ecosystem for decades to come. With Hudson River Estuary Program assistance, they are conducting vulnerability assessments, developing visions for the future of their waterfront, and adopting plans to address flooding and sea-level rise over time. Since 2015, city leaders from seven waterfront sites in Ossining, Kingston, Piermont, Hudson, and Catskill have partnered with a unique public-academic partnership with Cornell University called Climate-adaptive Design (CaD). Graduate students work with municipal stakeholders to design innovative concepts for future waterfronts that enhance both quality of life and climate resilience (see References/Further Reading).



Data Source: https://climatesmart.ny.gov/actions-certification/participating-communities

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