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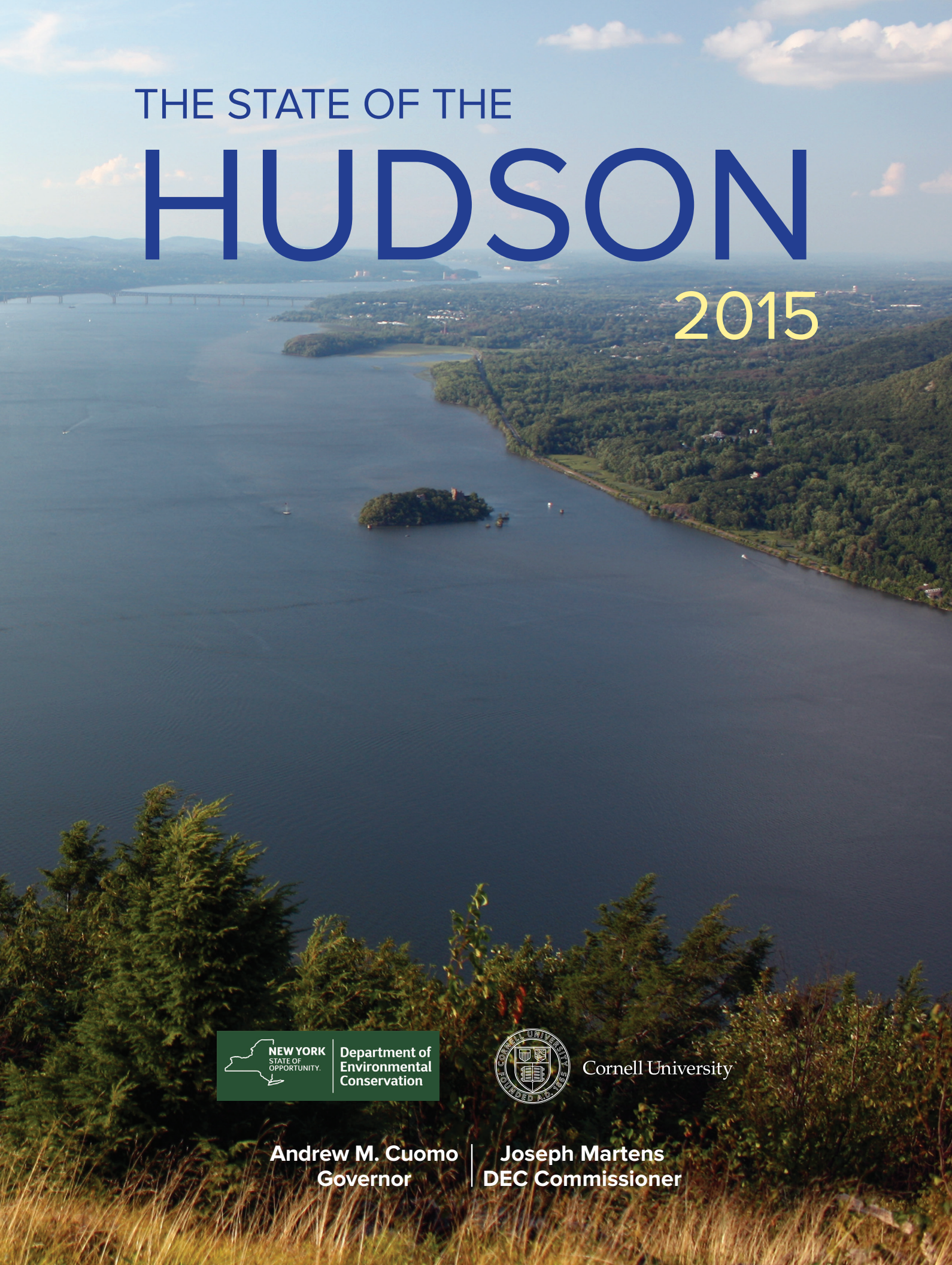
THE STATE OF THE HUDSON 2015



NEW YORK STATE OF OPPORTUNITY. | Department of Environmental Conservation

Cornell University

Andrew M. Cuomo
Governor

Joseph Martens
DEC Commissioner

SOME ESTUARY ESSENTIALS

Clare Dunn and Lana Lau

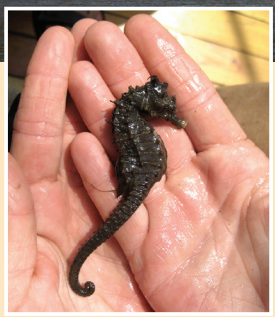
Steve Stanne/DEC

The dam between Green Island and Troy, 153 miles north of the Battery at Manhattan's southern tip, marks the upriver limit of tidal influence on the Hudson. Sunfish, including this pumpkinseed, are common in the fresh water here.

Steve Stanne/DEC

When there is little freshwater runoff from the Hudson's watershed, the salt front may push upriver through Newburgh Bay and past the Beacon-Newburgh Bridge. In droughts, it may reach Poughkeepsie.

Steve Stanne/DEC



Chris Bowser/DEC

Nearer the Atlantic Ocean, the Hudson is almost always salty. Saltwater fish such as the lined seahorse can be found along Manhattan's shores.

THE HUDSON RIVER WATERSHED

A watershed is the area of land from which water drains into a stream, river, lake, or other water body. The Hudson's watershed covers nearly 13,400 square miles, an area equal in size to Massachusetts and Connecticut combined. The Mohawk River is the largest of the Hudson's tributaries — the streams that drain from the watershed into the Hudson.

THE HUDSON RIVER ESTUARY

An estuary is a body of water, partly enclosed by land, in which fresh water running off the land meets salty ocean water. Depending on the volume of runoff from the watershed, the leading edge of diluted seawater, called the salt front, is usually located between the New York/New Jersey state line and Newburgh. As generally described, the Hudson River estuary extends into fresh water beyond Newburgh to Troy, since Atlantic Ocean tides roll up the river to Troy.

"THE TIMES THEY ARE A' CHANGIN'"

According to the State of the Hudson 2009, "The river shaped our past; we now shape its future." While that statement remains true, the situation is more complicated. We do have the power, in the short term and on a local and regional scale, to alter the state of the Hudson for better or worse. However, the scope of human activity over many years and the entire globe has set into motion environmental change over which we have little immediate control. Like the sorcerer's apprentice in the Disney film *Fantasia*, we now find ourselves being buffeted by forces that we cannot command.

Take climate change and invasive species, for example. Even under the most optimistic scenarios for lowering emissions of greenhouse gases, the realities of physics and chemistry ensure that atmospheric concentrations of these gases will remain problematic and promote global warming for decades to come. Likewise, once an invasive species spreads beyond its initial beachhead, there are few practical methods for containing its impacts.

We must reduce emissions and restrict the introduction of non-native species, but at the same time, Hudson Valley communities — natural and human — will have to adapt to ongoing environmental change. In doing so, we must use what powers we do have to alter conditions in ways that improve the state of the Hudson and community resilience in the face of change.

With all the research done on the estuary, one might assume that we thoroughly understand the Hudson ecosystem — all its components and the processes and relationships that knit them together, plus clear metrics for measuring change. Our knowledge is growing, but much remains unknown. Will tidal marshes — a critical estuarine habitat — drown under rising sea levels, or will sediment accumulate to elevate marshes at a pace that matches the rate of sea-level rise? We don't know. Recent years have seen efforts to establish baselines — robust and accurate assessments of conditions at given points in time that become yardsticks for measuring change as years pass.

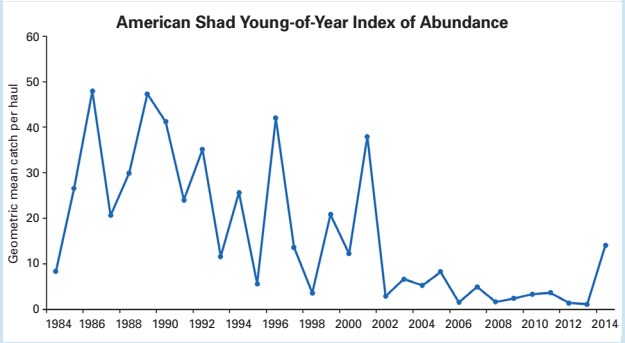
Where long-term data exist, annual variability can make interpretation challenging. Fisheries biologists saw a collapse in the abundance of young American shad in 2002, and the decline continued to 2013. In 2014, their numbers showed an encouraging increase, though they remained very low by historical standards. Was this a single good year? The start of a trend? Over the next decade we should be able to tell. But faced with such variability, the challenge is to come up with a timely, informed response that will benefit the species and take into account people's interests in the fish.

In addition to examining trends, this report looks at how Hudson Valley residents, scientists, institutions, agencies, community leaders, and others are working together to respond to challenges. Only by means of such shared commitment and partnerships will the next State of the Hudson be able to report progress.

BASELINE: Accurately determining the elevation of the river bottom in the Tivoli North Bay marsh will aid in observing how tidal marshes respond to rising sea levels.

Steve Stanne/DEC

TREND: The Hudson's American shad stock has been in decline.



Data from Hudson River Fisheries Unit/DEC

The population peaks of the 1980s are much lower than historic highs. Production of young shad crashed in 2002 and dropped further through 2013. Only time will tell if 2014's uptick signals a new trend.

A young American shad.

Steve Stanne/DEC

IS EXTREME THE NEW NORMAL?

Long-time observers of the estuary claim that — as often as they visit the Hudson — the river is never the same. That said, most people think of the Hudson in terms of averages — "normal" conditions encountered through the seasons. But the five years since the last State of the Hudson report have seen a succession of events that pushed conditions past the norm. Did this run of extreme events come together due to random bad luck, or will such extremes be the new normal?

"A HARD RAIN'S GONNA FALL"

The Mohawk River carries 500,000 tons of sediment to the Hudson each year, on average. After Tropical Storm Irene and the remnants of Tropical Storm Lee deluged the watershed in 2011, it delivered three times that amount — 1.5 million tons — in just eighteen days. Tributaries entering the estuary below the dam at Troy contributed another 1.16 million tons. This load greatly exceeded what the estuary's submerged aquatic vegetation usually deals with; these plant beds virtually disappeared in 2012 and 2013.

Irene and Lee also had a major impact on the defining feature of the estuary — the salt water entering the Hudson from the Atlantic Ocean. The salt front generally ranges from Newburgh Bay upriver (during dry summer weather and prolonged winter cold spells) to the Tappan Zee downriver (during spring runoff and periods of wet weather). Due to massive runoff after the storms, the river ran fresh all the way south to New York Harbor.

TREND: Precipitation is falling in more intense events, causing damaging flooding in the Hudson's tributaries.

Steve Stanne/DEC

Irene's runoff caused severe flooding along the Rondout Creek in Kingston.

THE HUDSON'S UPS AND DOWNS

Barely rising above sea level all the way to the Capital Region, the Hudson estuary is influenced by the rise and fall of ocean tides from New York harbor to Troy. At the southern tip of Manhattan, the average range between high and low tide is about four-and-a-half feet, with the average high tide rising a bit more than two feet above mean sea level there. At Troy, the average range between high and low tides is nearly five feet.

More extreme water levels occur when nor'easters and hurricanes push storm surge into the coast. The highest water level ever recorded at the Battery — more than 11 feet above mean sea level — occurred during Superstorm Sandy in 2012. In addition to the destruction and loss of life in New York City, that storm surge — like the tide — continued up the Hudson, wreaking havoc in low-lying communities. The U.S. Geological Survey's gauge at Poughkeepsie likewise recorded its highest water level ever during Sandy. With sea level rising due to climate change, lesser storms will be capable of pushing water levels to similar heights in the future.

TREND: Surge from coastal storms is a growing threat given rising sea levels and the increasing frequency of intense storms.

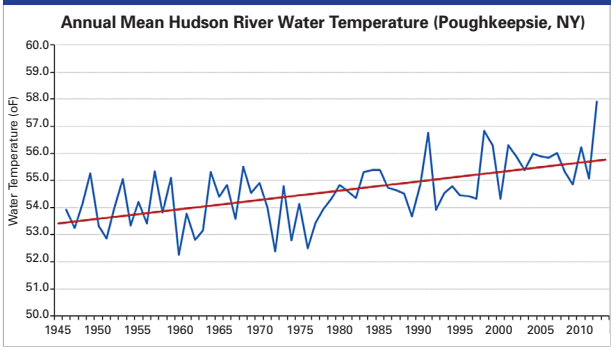
DEC

Sandy's storm surge caused extensive damage in Piermont and other river communities.

A WARMING RIVER

Climate change is also warming the river. At Albany, water temperature records go back to 1972 (with a gap from 1976-1981). 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. A longer record at Poughkeepsie's water treatment plant also shows a clear trend of rising water temperatures.

TREND: The Hudson is becoming warmer.



Data compiled by David Seekell and Mike Pace, Cary Institute of Ecosystem Studies. *Journal of Environmental Monitoring*, 2011.

RIVER INVADERS

Biological events also impact the estuary in major ways. The most well-studied instance is the zebra mussel invasion of the early 1990s. In less than two years. the population of this non- native mollusk went from zero to 500 billion, with dramatic impacts on plankton, native mussels, fish, dissolved oxygen concentrations, and other components of the river ecosystem.

Invasive species continue to arrive in the Hudson Valley. The emerald ash borer, found in Ulster County in 2010, is now present in at least five counties along the estuary; eradication is impossible. This insect has destroyed over 50 million ash trees in the U.S. since being discovered in Michigan in 2002. Most trees die within two to four years of becoming infested. Our ash trees are likely to go the way of the American elm and chestnut; the ecological consequences of their loss are not yet known.

Steve Stanne/DEC

A water chestnut bed at Beacon.

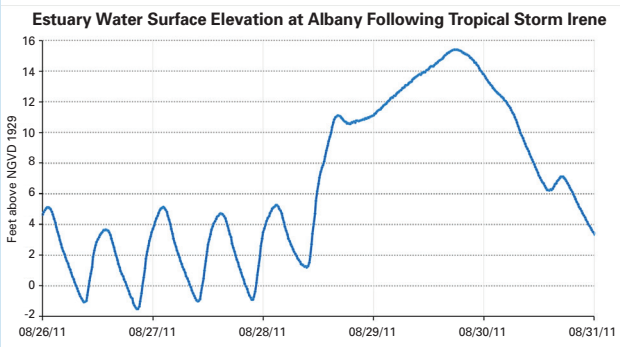
Hydrilla was discovered near the mouth of the Croton River in 2013, joining a list of plant invaders of the Hudson headed by the Eurasian water chestnut. Floating mats of water chestnut can limit dissolved oxygen levels and block sunlight to plants below, displacing native species like water celery. *Hydrilla* has likewise disrupted aquatic habitats around the country; it remains to be seen whether it will do so here.

When confined to a limited area, invaders may be eradicated. In 2008, northern snakeheads were found in an Orange County lake in the Wallkill River basin. This fish grows up to three feet long and feeds voraciously on other fish. To prevent the population from expanding downstream and into the Hudson, DEC applied rotenone, a chemical toxic to fish, in 2008 and again in 2009. Hundreds of snakeheads large and small were killed; none have been found there since.

RESPONDING TO EXTREMES

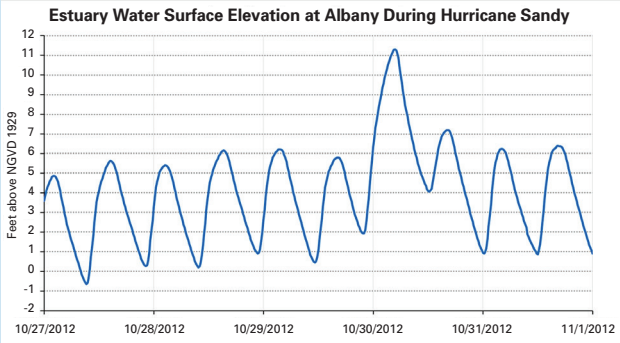
While such counterattacks are of limited use, retreat is not an option. Responding to invasive species, intense storms, and increasing temperatures requires comprehensive approaches that accept the reality of change, attempt to moderate impacts, and formulate long-term plans for adapting to new conditions. For example, in July 2014, the New York State Department of Environmental Conservation (DEC) adopted a regulation prohibiting or regulating the possession, transport, importation, sale, purchase, and introduction of select invasive species, including the examples above. Scheduled to go into effect in March 2015, it aims to slow the introduction of new non-native species and the spread of existing populations.

TWIN FLOODING THREATS: Storm Surge and Runoff



Data from U.S. Geological Survey

While Irene did push storm surge up the Hudson, the flooding associated with the storm came mostly from heavy rains and the resulting runoff. In the Hudson near Albany, this flooding persisted over several days as runoff worked its way down tributaries to the mainstem.



Data from U.S. Geological Survey

Sandy drove a surge of water up the Hudson, combining with high tide to lift water levels more than 11 feet above the baseline datum at Albany. Along the estuary, flooding due to surge from coastal storms is usually relatively brief in duration.

In addition to reviewing the state of the Hudson, the remaining sections of this report describe plans and actions spurred by the extreme events nature has visited on the estuary over the past five years. They underline the potential for conservation of the region's ecosystems, habitats, and biodiversity to promote resilience, economic stability, and quality of life in human communities along the Hudson estuary and in its watershed.

Governor Cuomo has provided the vision to address the challenges of climate change and invasive species, implementing policies that protect the Hudson and preserve its beauty and natural resources.

Governor Andrew M. Cuomo

WATER QUALITY — RUNNING CLEANER?

Water quality in the Hudson Valley will never be as unblemished as it was when the region was a wilderness. Human influence is pervasive. Even brooks far from settlement feel the impacts of climate change, acid precipitation, and mercury falling from the sky. But we don't have to turn the clock back to have a drinkable, swimmable, and fishable Hudson; to protect and restore streams that replenish the estuary and nourish its web of life; or to sustain water resources critical to the health and wellbeing of the region's residents.

Threats to the health of the Hudson and streams in its basin include sewage discharges, urban/stormwater runoff, sediment, and contamination from past industrial activity.

SAFE TO SWIM?

In 2005, TV reports showed boaters and water skiers happily jumping into the Hudson at Albany. Unfortunately, public perception of river health exceeded reality. DEC monitoring showed that water quality failed to meet swimming standards all summer.

Swimming in the Hudson was not foreseen when the Capital Region's sewage plants were constructed decades ago. Thus, they were not required to disinfect their discharges, raising the risk of disease for swimmers. That is changing; the Rensselaer sewer district began disinfection in 2013, and disinfection came on line at two large Albany plants in 2014.

Elsewhere on the Hudson, water quality at official swimming beaches is monitored and generally good, but swimmers leap into the river at many locations that lack lifeguards and water testing. In a Riverkeeper study of bacteria levels at 74 river sites, results overall failed to meet U.S. Environmental Protection Agency (EPA) standards for safe swimming 21% of the time from 2006 to 2010.

Sewage can have impacts beyond limiting swimming, even when treated. In the watershed, sprawl has spurred construction of more wastewater treatment facilities. Though many are small, cumulatively they have major effects. Surveys of Woodbury Creek in Orange County, for example, documented declining water quality from 1987 to 2004. Increased nutrient enrichment fostered an over-abundance of algae, especially downstream of treatment facilities serving new residential developments.

SEWER OVERFLOWS

In older sewage systems, storm drains often connect to sanitary sewer collection pipes. During rainstorms, their combined flow may exceed the capacity of the receiving treatment plant, causing untreated sewage to be diverted directly into the Hudson. Combined sewer overflows (CSOs) are a major pollution problem. Annual CSOs into the Albany Pool total 1.2 billion gallons and into New York City waters, 27 billion gallons.

Communities with CSOs are required to develop long-term control plans, and almost all along the estuary have done so. The Albany Pool plan, announced early in 2014, is expected take 15 years and cost $136 million. In 2012, DEC and New York City signed an agreement to develop ten waterbody-specific long-term control plans plus a citywide plan. This agreement should reduce CSO discharges by approximately 8.4 billion gallons a year.

Modern sewer systems separate sewage and stormwater pipes, eliminating CSOs, but spills still occur. In systems old and new, sanitary sewer overflows (SSOs) may be caused by pipe blockages, human error, aging infrastructure, or extreme wet weather events.

THE SEWAGE POLLUTION RIGHT TO KNOW ACT

In May 2013, the first phase of the Sewage Pollution Right to Know Act went into effect. It requires system operators to notify DEC and the Department of Health within two hours of the discovery of untreated or partially treated SSOs. The public must be informed within four hours.

BASELINE: In the first year of the Sewage Right to Know Act, sewage districts reported 153 spills to the Hudson and streams flowing into the estuary.

Steve Stanne/DEC

Among Sewage Right to Know discharge reports submitted since May 2013, the most common cause of SSOs is heavy rain. Resulting flows strain infrastructure in new and old systems. Pipes break, overflows surge out of manholes, and pumps fail to keep up. As climate change causes precipitation to occur in more intense events, stormwater will be an even greater challenge.

STORMWATER

Stormwater runs off impervious surfaces that prevent water from soaking into the ground — rooftops, streets, and sidewalks — as well as from bare soil and lawns. It plays a big role in CSO discharges; impervious surfaces cover about 72% of New York City's 305 square miles of land, sending substantial volumes of stormwater into sewers.

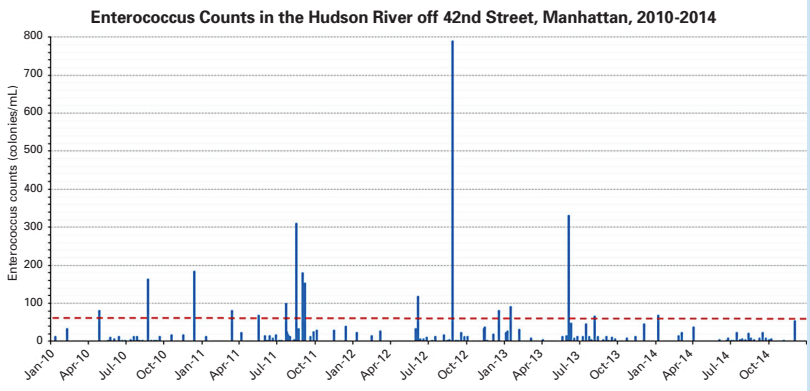
Development expands impervious surfaces. The resulting stormwater flows increase loadings of sediment, nutrients and salt to tributaries, and lead to unstable stream channels, erosion, and degraded habitat. Pollution from a single roof, parking lot, or roadway may seem trivial, but according to the EPA, stormwater runoff is implicated in 50% of water quality impairments nationally.

Cleaning up the stew of contaminants in stormwater where it discharges to a river or sewage plant is expensive and difficult. Control at the source works better; contaminants can be reduced or contained by employing best management practices for storing chemicals and controlling erosion, for example.

Natural communities and infrastructure modeled on them can reduce stormwater flows. On a large scale, solutions include preserving and restoring forests, floodplains, and wetlands, and slowing and reversing the spread of impervious surfaces. On a local scale, green roofs, rain gardens, rain barrels, and other source controls reduce stormwater volume or slow runoff. Green infrastructure can lessen the need for expensive, engineered "gray" infrastructure at the end of the pipes, with secondary benefits including aesthetic improvements, cleaner air, and lower energy costs.

Paul Bastin/Riverkeeper

TREND: On average, bacteria levels in the Hudson meet water quality standards, but sewage overflows cause bacteria counts to spike to problematic levels.



Data from the New York City Department of Environmental Protection.

Angus McIntyre/Riverkeeper

EPA suggests that an enterococcus bacteria count of 60 be used for beach closure notifications. Counts off Manhattan are usually under 60, but spikes occur, especially after rain. DEC has proposed modifying the uses associated with the Hudson's water quality classification here to encompass primary contact recreation including swimming, though other factors may limit such activity. Adopting this change would require effective control of sewage overflows.

HERITAGE CONTAMINANTS – THE PCB CLEANUP

Between 1947 and 1977, General Electric released about 1.3 million pounds of toxic polychlorinated biphenyls (PCBs) into the river from plants in Fort Edward and Hudson Falls. After 1977, PCBs continued to enter the Hudson from subsurface contamination beneath the Hudson Falls plant, adding to the burden of earlier discharges in the river bottom.

PCBs became concentrated in fish through the food chain, threatening the wellbeing of people and wildlife that eat contaminated fish. In response, New York State recommended limited consumption of fish caught south of Troy. From Troy to Hudson Falls, nearer the source of the contamination, DEC required anglers to release any fish they captured.

The Hudson's PCBs first made news in 1975: "State Says Some Striped Bass and Salmon Pose a Toxic Peril" was the front-page headline in *The New York Times*. However, it wasn't until 2002 that the EPA settled on a cleanup plan. Years of sampling, feasibility studies, and design work followed before removal began in 2009.

The cleanup will dredge approximately 2.65 million cubic yards of PCB-contaminated sediments from a 40-mile stretch of river between Fort Edward and Troy. At 2014's end, some 2.4 million cubic yards had been removed. Several more years of data collection will be needed to draw conclusions about how the cleanup has affected PCB levels in the estuary's fish.

SEDIMENT

Even when uncontaminated, excess sediment can create problems, muddying the water and blocking sunlight needed by aquatic plants. It smothers shellfish beds as well as gravelly and rocky bottom habitats needed by many aquatic creatures.

The Hudson estuary is typically cloudy with sediment eroded from the watershed and lifted off the bottom by tidal currents. This turbidity can be exacerbated by dredging, boat traffic, and runoff from bare cropland and construction sites. High turbidity may lower concentrations of dissolved oxygen, as less sunlight is available for photosynthesis by aquatic plants.

Sediment deposition has both negative and positive impacts. Accumulating sediment reduces water depth in shipping channels and berths, and must be dredged to enable navigation and docking. In the estuary's shallows, sediment can create a foundation for development of wetland habitats.

TREND: Cleanup of PCBs is proceeding on schedule, with 2.4 million yards of contaminated sediments having been removed from the upper Hudson by the end of 2014.

D.Tromp/DEC

Steve Stanne/DEC

THE HUDSON'S AQUATIC HABITATS

The Hudson's web of life knits together aquatic habitats in light-filled shallows and dark, deep channels, brackish water and fresh water, wide main stem reaches and narrow, winding tributaries. These habitats affect water quality, water supplies, fisheries, recreation, resilience to storms, and our quality of life. Among them, four are especially important to the estuary's health and resiliency.

SHALLOWS AND SUBMERGED PLANTS

In shallow water habitats, the river bottom is below the low tide line but less than six feet down. In fresh and slightly brackish shallows, submerged aquatic vegetation (SAV) may grow. Photosynthesis by SAV produces life-giving oxygen; the plants also contribute to the river's food web. Inhabited by diverse and abundant crustaceans, insects, and other invertebrates, SAV beds offer nursery, feeding, and refuge habitat for fish, birds, and turtles.

Inventories in 1997, 2002 and 2007 each found over 5,000 acres of such plant beds in the estuary (approximately 40% of the available shallow water habitat). Water celery, a native plant, accounted for nearly two-thirds of this acreage. However, after 2011, water celery beds virtually disappeared from the Hudson. Scientists think this was due to flooding and sediment deposition associated with Tropical Storms Irene and Lee.

TREND: Submerged aquatic vegetation surveys from 2003 to 2011 found plants in 43.3% of sites checked, on average. In 2012-2013, plants were found at only 10% of sites checked.

Steve Stanne/DEC

Water celery is predominant in the Hudson's beds of submerged aquatic vegetation. Its near absence in 2012-2013, likely due to impacts of tropical storms, coincided with low counts of young-of-the-year fish, for which these vegetation beds provide important nursery habitat.

HABITATS HALF IN, HALF OUT

More than 6,000 acres of Hudson wetlands flood and drain on rising and falling tides. Intertidal wetlands include mud and sand flats, marshes, and swamps. Once prime sites for garbage dumps, these habitats began receiving protection under the Clean Water Act as awareness of their ecological value grew. These wetlands support a wealth of species, from small fish such as the banded killifish, to predatory birds like the great blue heron.

Mud and sand flats are important feeding areas for wildlife, especially birds. Plants, including some globally rare species, grow on many freshwater tidal flats. Currents, wave action, and high salinity can leave other flats bare. Either way, tidal flats protect adjacent shorelines from erosion by dissipating waves and slowing river currents.

Marshes and swamps occupy more sheltered sites. In the brackish lower estuary, the Piermont and Iona Island marshes contain grass-like, salt-tolerant plants. The diverse plant communities of freshwater tidal marshes north of the Bear Mountain Bridge are often dominated by cattail and spatterdock. Tidal swamps are characterized by shrubs or trees that can tolerate regular flooding.

Steve Stanne/DEC

Spatterdock commonly grows on tidal flats in freshwater.

NATURAL SHORELINES

Vegetated natural shorelines resist erosion, reduce wave energy, and support fish, invertebrates, birds and amphibians. Wrack (natural debris) that washes up on beaches provides sustenance to many creatures. Riverbanks with a gradual slope facilitate migration between land and water. Vertical shores, particularly seawalls and bulkheads, support fewer plants and animals.

From Troy to the Tappan Zee Bridge, 58% of the Hudson's shoreline is "natural," ranging from steep rock faces to gentle mud slopes. The rest has been altered with revetment, bulkhead, cribbing, and riprap during construction of railroads, industrial sites, docks, and erosion control structures. Comparisons of modern and historic maps suggest that 71 miles of shoreline were eliminated during channelization of the upper estuary.

Ellen Edmonson/DEC

TRIBUTARY STREAMS

The Hudson's tributaries deliver water, nutrients, and sediment to the estuary while providing habitats for wildlife and for resident and migratory fish. Swimming into the estuary from the ocean, most alewives continue into tributaries to spawn. Hatched in the mid-Atlantic Ocean, American eels enter tributaries as tiny, transparent glass eels. There, they grow to adulthood, some staying over 20 years before swimming back out to sea to spawn.

Cody Yeakel

Like dams, some culverts are also barriers to fish.

Dams and culverts now block access to much of the tributary habitat once used by herring and eels. This is likely one of the factors contributing to steep declines in their populations. When feasible, dam removal is preferred over facilitating fish passage with fish ladders, which don't always work. Dam removal may improve in-stream habitats, sediment and nutrient transport processes, and water quality. Water temperatures are typically higher and oxygen levels lower in ponds above dams. These impoundments also trap sediment, disrupting the supply to shallows and wetlands downstream.

CLIMATE CHANGE IMPACTS

As the estuary rises with sea level, wetlands and flats now flooded and drained by tides may find themselves under water continuously. If rising water levels are balanced by sediment deposition on the river bottom, then marshes may survive in place. Alternatively, as higher water floods wetlands and adjacent low-lying shores, marshes may shift shoreward to stay in the intertidal zone. However, this will only be possible where the bordering terrain and land use allow.

If sedimentation fails to keep pace with rising sea level, then increasing water depth will reduce light penetration, limiting the growth of submerged plants. In addition, increasingly severe storms and flooding may physically damage or uproot plants and mobilize sediments to further reduce light penetration or smother SAV beds.

Rising sea level and flooding threaten both natural shorelines and human communities. Commonly proposed engineering remedies sometimes protect property in ways that severely degrade habitat. The best solutions are those that reduce flooding and erosion while protecting or enhancing habitat.

EXOTIC AND INVASIVE SPECIES

Exotic and invasive species have dramatically altered estuary habitats. Research in the freshwater Hudson suggests that about seven new species arrive per decade, one of which is likely to have serious ecological impacts. Among recent arrivals, *Hydrilla* might be that one. Discovered in 2013 in the tidal Croton River, this plant is known to displace native water celery in other ecosystems.

Where feasible and ecologically justified, controlling exotics can be an important part of habitat restoration. An invasive variety of *Phragmites*, the common reed, has displaced native cattail in some marshes. At Iona Island, its exponential expansion coincided with significant declines in nesting marsh birds. A project to control ten acres of *Phragmites* began in 2008; follow-up surveys show that cattail is returning, and along with it, birds such as marsh wren and Virginia rail. In addition, Iona's population of salt marsh asters, an endangered plant, has grown from a handful to the largest in the state.

A FRAMEWORK FOR HABITAT RESTORATION

DEC's Hudson River Estuary Habitat Restoration Plan, released in 2014, lays out five actions to improve the ecosystem's health and resiliency.

- Preserve existing estuary habitats and adjacent uplands where wetlands may become established as sea level rises.
- Restore side channels, vegetated shallows, backwaters and other habitats altered by dredging and other human activity.
- Implement fish passage, dam removal, and culvert right-sizing projects in Hudson tributaries.
- Promote use of ecologically enhanced shoreline stabilization methods of protecting property, infrastructure, and other assets.
- Implement programs to control and prevent introduction of invasive species.

Differences in natural landscapes and development along the river call for diverse restoration strategies. For example, wetland and SAV restoration is a priority in the upper estuary, where these habitats — once very extensive — were lost when the navigation channel was deepened.

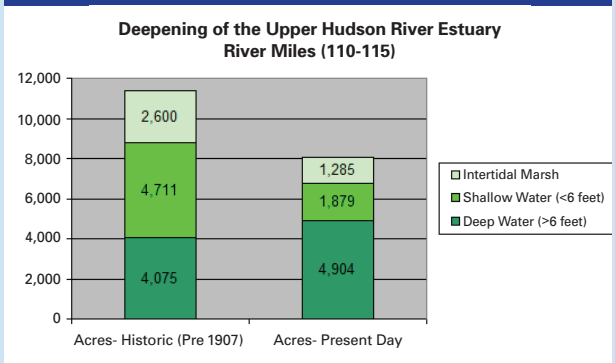
Projects to fulfill Restoration Plan goals are underway. An example is the Hudson River Sustainable Shorelines Project, which is developing stabilization techniques that preserve natural benefits while meeting engineering needs. Its cooperative engagement of stakeholders and decision-makers to build consensus offers a template for habitat restoration along the estuary.

BASELINE: From Troy to the Tappan Zee Bridge, 58% of the Hudson's shoreline is in a natural state; the rest has been altered with revetment, bulkhead, cribbing, and riprap.

Steve Stanne/DEC

Steve Stanne/DEC

BASELINE: From Catskill north to Troy, there are at present 1,285 acres of intertidal marsh and 1,879 acres of shallow water habitat, compared to 2,600 and 4,711 acres respectively before the channel was deepened early in the 20th century.



Dan Miller/DEC

This portion of the river, which offers important spawning, foraging, and refuge habitat, was converted from a river dominated by shallow and intertidal areas to one that is dominated by deep water. The total river acreage decreased as shallows became land — filled in with sediment from the channel.

THAT RIVER'S ALIVE!

At last count, 221 species of fish had been recorded in the Hudson and its watershed. Of New York State's breeding birds, 87% occur here, as do 85% of the state's amphibians, 73% of its reptiles, and 92% of its mammals. The river's menagerie includes plenty of crustaceans, mollusks, insects, and other invertebrates too.

"THIS RIVER IS RICH IN FISHES"

Adriaen Van der Donck's 17th-century observation, quoted above, holds true today, though this abundance can be hard to see, hidden by shimmering waves and muddy water. Modern technology has helped to pierce this veil, adding to data from ongoing fisheries surveys. Scientists tag fish with sonic transmitters and track them through the estuary, gathering information critical to conserving our fish stocks.

After living in the estuary briefly as youngsters, the Hudson's signature species — Atlantic sturgeon, striped bass, and American shad — go to sea and range along the Atlantic coast. As adults, they return for only a few weeks or months each year to reproduce. Thus they are not just "our" fish — their management requires coast-wide perspective and cooperation.

Atlantic sturgeon

Atlantic sturgeon spawn in fresh water from May through July. Young fish may remain here up to seven years before heading to sea, where their travels take them in and out of rivers from Canada to Georgia. Males return to spawn as early as age 10. Females return closer to age 20. Sturgeon will spawn many times, as their lifespan can exceed 60 years.

Young sturgeon became scarce from the late 1980s through the mid-1990s as spawning adults were overfished for caviar and meat. New York's fishery closed in 1996; in 1998, Atlantic coastal states jointly enacted a 40-year moratorium. In 2012, the Atlantic sturgeon was given endangered species status.

Steve Stanne/DEC

On-going studies indicate that the moratorium is working. Sturgeon born when the fishery closed are returning to spawn; more young fish are showing up in surveys. The moratorium will provide protection until these offspring launch a third generation some 20 years from now.

American shad and river herring

Numbers of adult American shad started to decline in the 1990s due to overfishing. Ocean fishing for shad ended in 2005, and the 2009 Hudson River Shad Recovery Plan closed all Hudson shad fishing starting in 2010. Nonetheless, annual monitoring continues to document depressed stocks of what had long been the Hudson's most valuable commercial fish.

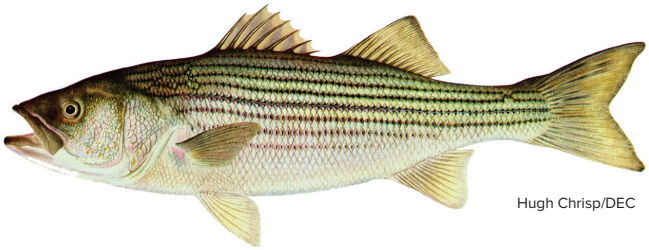
The Recovery Plan also includes studies of spawning locations, shad behavior in the estuary, and losses due to predation and ocean bycatch. Other roadblocks to recovery have appeared, notably loss of SAV beds – prime nursery habitat for young shad – after Irene and Lee hit in 2011.

Stocks of migratory river herring (alewife and blueback herring), closely related to shad, were declared depleted in a 2012 coast-wide assessment. In 2013, this resulted in harvest restrictions in New York, where herring are mainly taken for use as bait.

Striped bass

Striped bass drive the most popular fishery in the estuary. Anglers pursue stripers all the way to the Troy dam during the fish's spring spawning run.

Annual monitoring has revealed below-average production of young striped bass in recent years. Fishing mortality has increased here and along the coast. Under interstate management, tighter fishing regulations are being developed for all coastal stocks.



Hugh Chrisp/DEC

OYSTERS

On New York City streets where hot dogs and falafel are offered today, vendors once hawked local oysters. Early in the twentieth century, pollution, siltation, and overharvesting ended the estuary's oyster fishery.

Attempts are now underway to restore oyster beds in New York harbor and the lower Hudson. While these waters are still too polluted to allow oyster consumption, the reefs could have important ecological benefits. Oysters filter the water; restoration of large reefs could result in a cleaner estuary. Reef habitat could also enhance the diversity of bottom-dwelling animals.

In 2010, experimental oyster reefs were placed in the estuary. Designed to mimic natural beds, they also enabled monitoring of oyster growth and ecological functioning. The project demonstrated recruitment and growth of wild oysters on the beds, benefits from their filtering activity, and increased biodiversity compared to that found at the sites prior to reef placement.

In 2013, wild oysters were found as construction of the new Tappan Zee Bridge began. They may be genetically adapted for survival in the changeable salinities of the lower Hudson. Oysters and historic reef materials from the construction zone will be stockpiled for subsequent reestablishment.

Roberta Miller/Fisheries and Oceans Canada

TREND: After bald eagles began breeding along the Hudson again in modern times, the number of nests along the river increased from one in 1997 to 24 in 2013.

Terry Hardy

BIRDS

Highly visible, birds are ready indicators of environmental change — perhaps none more than raptors, which suffered from indiscriminate pesticide use in the mid-twentieth century. Bald eagles are now commonly seen here. Young peregrine falcons again launch into the air from traditional cliff aeries, and now from nests on river bridges too. Ospreys have begun to breed along the estuary in recent years.

Around New York harbor, herons, egrets, and ibises have become star attractions; ecotours take nature lovers out to see the rookeries. A 2013 survey found 26% fewer nests than in 2010. However, the total number of nests remained within the range observed since the early 1990s.

INVASIVES

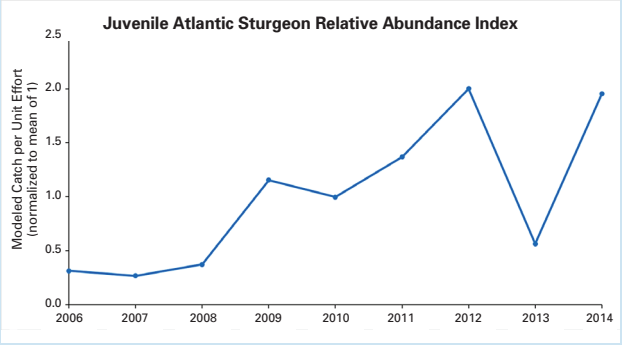
Of the invasive species starring in Hudson River ecological dramas in recent decades, none is more infamous than the zebra mussel. Its population explosion from 1991 to 1992 reduced plankton populations 50 to 90 percent, disrupting food webs. Dissolved oxygen levels dropped measurably. Native pearly mussels, unable to compete, declined in number.

However, recent research has written a second act. While still abundant, zebra mussels are not living as long now. Younger and smaller, their capacity to filter river water is lessened, and some of the changes seen earlier are being undone. Native mussel populations are rebounding. Numbers of other small invertebrates have returned almost to pre-invasion levels. The causes of zebra mussel mortality are unclear, though predation by blue crabs may be part of the story.

New York Sea Grant

While the zebra mussel may be the most dramatic invader of the Hudson ecosystem, it is not the only one. Mitten crab and Oriental weatherfish are just two of the non-native species recently found here. More are waiting in the wings. Once established, invasives are extremely difficult to eradicate. A better solution is to keep alien species out of the Hudson in the first place.

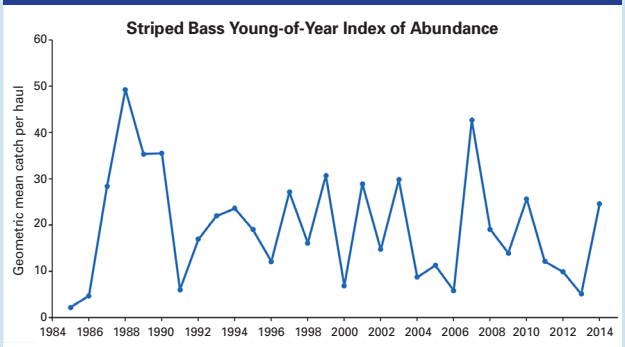
TREND: Catches of juvenile Atlantic sturgeon have been increasing in recent years.



Hudson River Fisheries Unit/DEC

Though there is variability from year to year, fisheries surveys show an upward trend in numbers of young Atlantic sturgeon in the Hudson thanks to the 1996 closure of the sturgeon fishery.

TREND: While 2014 was a good year for production of young striped bass in the Hudson, the overall trend in recent years has been downward.



Hudson River Fisheries Unit/DEC

While survey results vary from year to year, the data suggest that overfishing of adult striped bass may be reducing their spawning success.

Peregrine falcon

CONSERVING NATURE IN THE WATERSHED LANDSCAPE

Spotted salamander

The Hudson Valley boasts remarkable biological diversity. Comprising only 13.5% of New York's land area, it hosts 25 of the state's 31 vegetation cover types and 86% of its bird, mammal, reptile, and amphibian species. Roughly 40% of New York's animals in greatest need of conservation occur here – one of the highest densities of such species in the state.

Biodiversity encompasses more than flora and fauna. The term includes habitats and the web of interactions by which species adapt to or modify their physical environments. Similarly, the valley's human residents benefit from its unique habitats and the ecological processes they maintain.

HEALTHY ECOSYSTEMS BENEFIT PEOPLE

Conserving biodiversity is a proven, cost-effective way to sustain the vitality of human communities as well as the estuary's health. Biologically diverse habitats and ecosystems prevent the spread of diseases and pests and provide pollinators and rich soils for growing food. Wetlands absorb floodwaters. Natural vegetation stabilizes soils and limits erosion.

Nature can often provide these services at lower cost than built systems. Wetlands and forests are natural filters that can minimize the need for filtration infrastructure in water supply systems. And maintaining ecosystem health lessens the likelihood of disruptions of these essential services due to climate change.

Laura Heady/DEC

Tropical Storm Irene provided a telling example. Flooding occurred from the Hudson Highlands through the Catskills and eastern Adirondacks into Vermont's Green Mountains. In Rutland, Vermont, Otter Creek wreaked havoc as its flow peaked at 15,700 cubic feet of water per second (cfs). Thirty miles downstream in Middlebury, peak flow was only 6,180 cfs. What happened in between? Floodwater spread into a large wetland area on the creek's floodplain, was stored there, and slowly drained over two weeks, preventing severe damage in Middlebury. Similar attenuation of flooding occurred on some small tributaries of the Moodna Creek in New York's Orange County.

Engineers are imitating natural processes when restoring and maintaining ecological assets. In Dutchess County, water quality in Wappinger Lake is deteriorating due to sedimentation and nutrient enrichment. While the problems stem from cumulative inputs upstream, the Village of Wappingers Falls decided to pilot an artificial wetland system to treat stormwater from part of the lake's watershed within the village boundaries. Completed in 2013, the system uses engineered wetlands on a two-acre site to reduce flooding impacts, remove nutrients, and filter out over 85% of the sediment from a 110-acre drainage area.

ECOSYSTEMS IN FLUX

The Hudson Valley's ecosystems face many challenges — climate change, invasive species, rapid urbanization, and sprawl. Conserving biodiversity and bolstering ecosystem resilience — the ability to respond effectively to change — first requires an inventory of the region's natural communities and then an analysis of changes and trends driving them.

In an example of work designed to assess the integrity of the valley's ecosystems, Cornell researchers collected population and distribution data for nearly 50 species of frogs, toads, woodland salamanders, and marsh birds at hundreds of sites across the Hudson Valley between 2009 and 2012. This baseline information is essential to future studies of trends in the status of these creatures.

Long-term data sets do exist for forests, allowing trend analysis. Forest cover here peaked in the latter half of the 20th century; today it extends over roughly 75% of the watershed. Forests were becoming more fragmented even when forest cover was increasing. In Rensselaer County for example, the average size of forested areas shrank as overall forest acreage expanded from 1958-2010.

In recent years, counties bordering the estuary north of New York City have lost woodland. Their core forest acreage — a reserve of forest biodiversity and integrity — is dwindling faster than forest overall. Core forest fragmentation can cause loss of forest-breeding songbirds and woodland salamanders, diminish water quality, and increase forest susceptibility to the impacts of invasive species and climate change.

LINKING HABITATS

Sprawling development and habitat fragmentation are likely to complicate adaptation to climate change. As temperatures rise, some plants and animals will need to move north or to higher elevations. In addition, fragmented landscapes threaten the valley's distinctive character by promoting the spread of invasive and overabundant plants and animals.

To meet this challenge, we must keep natural areas connected across the landscape. Forest and wetland loss and fragmentation limits opportunities to maintain connectivity, as do barriers in streams. Without routes for migration and dispersal, many wildlife species that require a complex of habitats for survival may decline.

CONSERVING BIODIVERSITY: AN ECOSYSTEM APPROACH

While charismatic wildlife grab public attention, the core task of conserving biodiversity is maintaining habitats and ecosystems in which these species live. Habitats created by development in the Hudson Valley do support wildlife; white-tailed deer, raccoons, and coyotes live there. But conserving biodiversity requires safeguarding other unique and valuable habitats to preserve ecosystem integrity and their benefits to people.

Intact core forest is critical to the survival of many creatures — bobcat and black bear, woodland warblers and forest thrushes, for instance. Clean, cool headwater streams in such forests are vital habitat for trout as well as amphibians such as spring and two-lined salamanders. Forests aid human communities by absorbing rainfall, filtering pollutants, and slowing runoff that might otherwise cause flooding.

Well-functioning wetlands are essential to the health of natural and human communities, yet few ecosystems have been as misunderstood and undervalued. New York has lost nearly half of its original freshwater wetlands over time. In the Hudson Valley, nearly 3,000 acres disappeared between the 1980s and 1990s, endangering wetland species such as bog turtle, Blanding's turtle, and northern cricket frog. Human communities also suffered from wetlands' diminished capacity to regulate water flow, control shoreline erosion, and improve water quality.

Stream corridors link habitats, while streamside trees can moderate water temperature, reduce erosion and sedimentation, and create critical fish habitat. Their fallen leaves fuel aquatic food webs. The proximity of aquatic and terrestrial habitats here promotes biodiversity, as do rich, moist soils well suited to ferns, orchids, and other unique plants. Protection of such habitats is a priority; creation of the Black Creek State Forest in 2011 is an example. DEC and local land trusts added 600 acres to an eight-mile corridor of public and private conservation lands along this Ulster County stream, with benefits for water resources, flood control and recreation.

THE LOCAL ROLE IN CONSERVING BIODIVERSITY

Conserving the region's diverse ecosystems and their benefits for people requires partnerships among stakeholders and decision-makers. Given New York's home rule tradition, success depends on community involvement — working through local governments and private landowners to encourage sound initiatives grounded in science.

Many communities have identified and inventoried critical habitats and important natural resources, prioritizing those with high conservation value. These inventories and priorities inform comprehensive plan updates, open space acquisitions, and project reviews.

As a result, communities are employing new planning approaches. In Red Hook (Dutchess County), linkages among forests, wetlands, and streams have been carefully mapped. Planners and stakeholders strategized ways of improving land-use decision-making to preserve these linkages as the community grows. Recognizing that natural systems cross town boundaries, counties are providing "big picture" guidance. Dutchess County's Centers and Greenspaces initiative integrates regional land use, transportation, and ecological planning to prevent residential sprawl.

Such approaches encourage a broader view of the ecological landscape that facilitates watershed planning, inter-municipal agreements, and regional initiatives. Whether on a local or regional scale, considering biodiversity early in the planning process contributes to long-term protection of our natural heritage and the benefits it bestows on our communities.

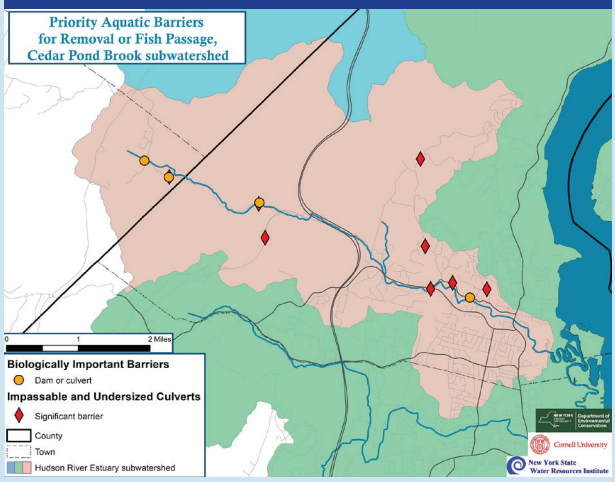
TREND: From 1996-2010, there was a small but consistent loss of forest cover in all ten counties bordering the estuary north of New York City.

County	% Forest 1996	% Forest 2010	% Change Overall	% Change in Core Forest
Albany	61.78	60.90	-1.43	-2.39
Columbia	58.19	57.91	-0.48	-1.20
Dutchess	59.74	58.83	-1.53	-2.61
Greene	84.38	84.01	-0.44	-0.93
Orange	64.05	62.98	-1.67	-2.49
Putnam	76.04	75.36	-0.90	-1.50
Rensselaer	63.45	62.82	-1.00	-2.33
Rockland	57.15	54.63	-4.40	-5.97
Ulster	83.23	82.84	-0.47	-0.81
Westchester	48.58	47.46	-2.32	-3.66

Coastal Change Analysis Program/National Oceanic and Atmospheric Administration

The integrity of forest habitat depends on the amount of core forest present. Far from a forest edge, core forest offers protection from disturbance. Every Hudson Valley county has seen more core forest loss than total forest loss, which may be linked to reduced habitat integrity and water quality.

BASELINE: Barriers on Hudson River tributaries are a problem for fish and people. Of over 1,000 culverts that have so far been assessed in the watershed, about 14% are both impassable to fish and too small to pass the high flows associated with increasingly intense rainfall.



Andrew Meyer/DEC

Cedar Pond Brook flows to the Hudson in Rockland County. In its watershed, 8 of 62 culverts assessed have been prioritized as being impassable to fish and undersized in relation to expected high flow events. Upgrading such culverts offers a two-for-one deal, facilitating fish passage and capacity to handle floods.

TREND: When asked about their community's willingness to conserve natural areas and wildlife, roughly half of a group of local planners and conservation advisory committee members said that, over the last five years, their communities have increased or greatly increased their willingness to conserve.

Laura Heady/DEC

THE CHALLENGE OF CLIMATE CHANGE

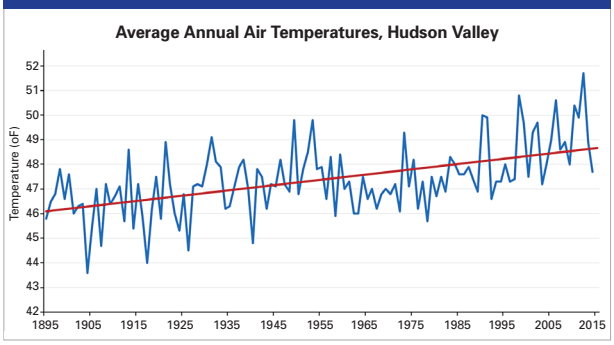
Tropical Storms Irene and Lee in 2011. Superstorm Sandy in 2012. The frigid, snowy winter of 2013-2014. While it is tempting to blame individual events on climate change — or lack of it — direct cause and effect cannot be established for specific events. What can be said is that the trend toward more extreme weather fits with the predictions of climate scientists, and that long-term data display abundant evidence of a warming Hudson Valley.

HOW HAS THE CLIMATE CHANGED IN OUR REGION?

As the sun warms Earth, our planet radiates heat. Certain gases, called greenhouse gases (GHGs), trap some of this heat in the lower atmosphere. Human activities that release GHGs, like burning fossil fuels, are elevating their concentrations and warming Earth. This global warming is affecting climate — long-term weather patterns — around the world and in the Hudson Valley.

New York State's average annual temperature has gone up nearly 2°F in 30 years. Winter average temperatures have warmed even faster — 5°F in 30 years. In the Hudson Valley, every year but one since 2000 has been hotter than the average established over the base period from 1901-2000. The year 2012 was the warmest on record here.

TREND: Average annual temperatures in the Hudson Valley are rising.

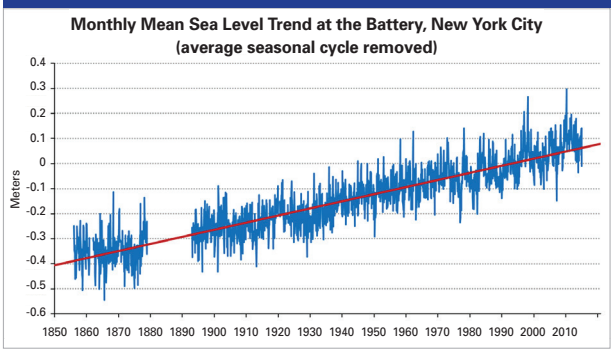


Data from National Climatic Data Center, National Oceanic and Atmospheric Administration

The warming trend can also be seen in the Hudson River itself. At Poughkeepsie, the river's annual average water temperature has increased by more than 2°F since the late 1940s. While two degrees may not seem like much, the impact on ecosystems and people can be substantial.

Statewide and here in the Hudson Valley, average rainfall is increasing, exceeding the 1901-2000 base period average in all but two years since 2000. 2011 was the wettest year on record. And of all regions in the U.S., the Northeast has experienced the greatest recent increase — 74% between 1958 and 2010 — in extreme precipitation events that deliver more than an inch in 24 hours.

TREND: At the Battery at the southern tip of Manhattan, mean sea level has been rising 2.83 millimeters — 0.11 inch — per year on average.



National Oceanic and Atmospheric Administration

SEA LEVEL IN AN ARM OF THE SEA

Sea level is rising due to global warming. This impacts the Hudson estuary — a long arm of the sea. Sea level in New York harbor, 15 inches higher now than it was in 1850, is expected to go up another 11-21 inches by 2050. At Troy, water levels will likely rise 9-19 inches by mid-century.

Sea level is rising due to expansion of ocean water as it warms, and melting of glacial ice on land. There is growing concern that the huge ice sheets covering Greenland and Antartica may be melting faster than previously thought. If true, then sea level could go higher than predicted, up to six feet by century's end.

TREND: According to the Northeast Regional Climate Center, the frequency of two-inch rainfall events in New York has increased since the 1950s, and storms once considered a 1 in 100 year event have become more frequent.

Steve Stanne/DEC

Engineers must take into account the prospects for intense precipitation events when planning structures to withstand high flows.

Flooding in Poughkeepsie during Tropical Storm Irene.

Steve Stanne/DEC

Steve Maslowski/U.S. Fish and Wildlife Service

Ruby-throated hummingbird.

RESETTING NATURAL CLOCKS

Our warming climate has altered the timing of events keyed to seasonal change. Statewide, bloom dates of many plants are 4-8 days ahead of where they were 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.

Dave Moore/U.S. Forest Service

Bloodroot

IMPACTS ON HUDSON VALLEY COMMUNITIES

The extreme storms of recent years bear out predictions of more intense disturbances. The downpours associated with Irene and Lee showed what might happen as this trend increases the risk of severe flooding. Sandy's impacts here had less to do with rainfall than with its size and high winds, which drove a massive storm surge into New York harbor and the Hudson estuary. Water levels went up dramatically, with catastrophic results. Steadily rising sea level will endow surge from lesser storms with the capacity to cause similar damage in the future.

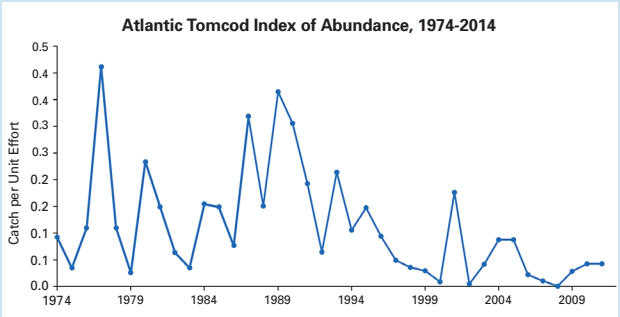
Shorter, warmer winters and longer, hotter summers will affect local farmers and winter recreation, and may increase the prevalence of some diseases as populations of their insect hosts shift northward. More numerous heat waves will boost the incidence of pollution-related asthma and heat exhaustion, especially in urban areas.

CLIMATE CHANGE AND THE ESTUARY ECOSYSTEM

As discussed in the aquatic habitats section, sea-level rise and flooding are likely to impact 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 Irene and Lee can carry huge volumes of sediment into the Hudson, where it hinders the growth of submerged aquatic vegetation.

Irene and 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.

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.



Data from Long River Utilities Survey

Robert Adams/DEC

Atlantic tomcod.

RESPONDING TO CLIMATE CHANGE

The severity of climate change to come will depend on energy choices made over the next decade. Cutting GHG emissions is essential. Using more renewable energy sources — solar and wind power instead of fossil fuels — will help. Improving energy efficiency in buildings and transportation will reduce demand for energy. Conserving forests can also help lower atmospheric levels of carbon dioxide, the major GHG, because trees absorb this gas during photosynthesis.

Even under the most optimistic scenarios for cutting emissions, GHG concentrations will remain problematic for decades if not centuries. Accordingly, communities are adapting to climate change, taking charge of their future.

Within the estuary corridor, local and state governments are moving to build resilience – their ability to manage climate risks, respond productively as the climate changes, and recover quickly from extreme events. Examples in recent years are Waterfront Flooding Task Force initiatives in Piermont, Stony Point, Kingston, and Catskill. In each locality, concerned citizens have determined what is vulnerable, developed a vision for resilience, and submitted recommendations to residents and governing boards. At the state level, the New York Rising Community Reconstruction Program provides rebuilding and revitalization assistance to communities severely damaged by Sandy, Irene, and Lee.

In 2010, New York State initiated a Climate Smart Communities Program, through which communities pledge to minimize the risks of climate change and earn state certification of their accomplishments. Certification requires communities to reduce GHG emissions and adapt to predicted and actual climatic changes. By late 2014, 144 New York counties, cities, towns, and villages had earned certification as Climate Smart communities — 60 of them in counties bordering the Hudson estuary. The program emphasizes the key government roles of leading, educating, and setting an example in confronting the challenges of climate change.

STEWARDSHIP: AN UPWARD TREND

Adding to the usual cast of scientists in academic settings, resource managers in government, and advocates in not-for profit organizations, growing numbers of individuals — students, kayakers, amateur naturalists, planning board members, and more — are joining efforts to build understanding of the estuary, track environmental trends, and address ecological concerns.

A growing number of citizen science projects, many organized by DEC's Hudson River Estuary Program and its partners, recruit volunteers to study the natural world and record and share their findings. Well-designed citizen science projects provide personal satisfaction and valuable data as participants engage with nature and become better environmental stewards.

THE FIRST CITIZEN SCIENCE PROJECT

As the conservation movement evolved in the late 1800s, Frank Chapman — an ornithologist active in the nascent National Audubon Society — proposed a new tradition to replace the Christmastime "side hunt." Instead of joining teams (sides) to go afield in a competition to kill as many creatures as they could, participants would count birds.

On December 25, 1900, 27 birders conducted Christmas bird counts in 25 locations. Over 100 years later, annual participation exceeds 70,000 observers in more than 2,300 places, 17 of them in counties along the estuary. The world's longest running citizen science effort, the Christmas Count has become a source of critical data on bird population trends and a highly anticipated and enjoyable tradition for birders.

Mike Pogue

Common mergansers are frequently seen on Hudson in winter.

HOW MANY AMPHIBIANS?

Frogs, toads, and salamanders are sensitive indicators of environmental change. They are not able to move across the landscape as quickly or freely as most birds, and many have very specific habitat requirements.

The North American Amphibian Monitoring Program, begun in 1997, surveys frog and toad populations using the unique calls of each species. Adopting its methods, the Estuary Program and Cornell University have engaged volunteers since 2008 to develop an index of frog and toad distribution and abundance in the Hudson Valley; the information also goes into a national database.

In 2009, the Estuary Program and Cornell began the Amphibian Migrations and Road Crossings Project to monitor amphibians that depend on woodland pool habitat. On rainy spring nights, volunteers search for migrating salamanders, frogs, and toads on local roads. Their observations help researchers locate critical habitat and road crossings where mortality is high, and inform local plans to conserve biodiversity. Over the years, we can also learn whether the timing of spring migrations may be shifting due to climate change.

UNRAVELLING THE MYSTERIES OF EELS

The American eel is among the Hudson's most familiar fishes, but much of its life history remains a mystery. Its populations are shrinking over much of the fish's range. Strategies to address this decline require baseline information. The Hudson River Eel Project involves teams of scientists, students, and community members in collecting young eels as the fish enter tributaries each spring. They count, weigh, and release the eels; at season's end, the data are compiled and submitted to state and federal biologists to inform management decisions. Since 2008, the project has expanded from 3 sites to 12; over 500 volunteers now participate in the project annually. More than 250,000 eels have been counted since the project began.

TREND: Citizen science participation in the eel migration study increased from 120 volunteers in 2008 to 516 in 2014.

Steve Stanne/DEC

Chris Bowser/DEC

American eels enter the Hudson and its tributaries as tiny glass eels.

PADDLING FOR SCIENCE

In partnership with the Estuary Program and the Hudson River National Estuarine Research Reserve, the Cary Institute of Ecosystem Studies has recruited volunteer teams of kayakers and canoeists to collect data on the estuary's submerged aquatic vegetation [SAV]. Their observations track year-to-year changes in extent of the plants, and has been especially valuable following Tropical Storms Irene and Lee, when the volunteers first detected dramatic loss of SAV.

Participants in the SAV study receive training in the necessary protocols and are encouraged to attend a season-ending session in which researchers discuss the year's results. Such training is a part of all these projects, as it is essential to ensure data quality. The season's end gatherings offer opportunities for scientists

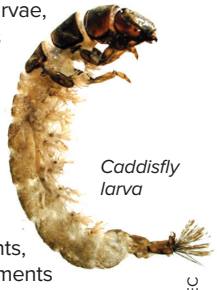
TREND: Observation points checked by volunteer paddlers tracking the presence of submerged aquatic vegetation in the Hudson increased from 100 in 2003 to over 300 in 2013.

Bob Green

to communicate understandings gained from their work and for participants to share a sense of accomplishment and build camaraderie.

ASSESSING WATER QUALITY

Water Assessments by Volunteer Evaluators (WAVE) is a citizen-based water quality monitoring program developed by DEC. Volunteers collect and identify insect larvae, small crustaceans, and other invertebrates living on stream bottoms. These creatures have known sensitivities to pollution, so a stream's health can be evaluated by studying the array of species living there.



Caddisfly larva

DEC

WAVE data augment studies conducted by DEC's Stream Biomonitoring Unit. Based on the program's protocols, training requirements, and quality control measures, WAVE assessments may be confidently used in official DEC reports, alongside professional assessments. WAVE findings of possible impairment highlight sites that may merit professional investigation.

WAVE was piloted in the Hudson River watershed in 2012 with assessments at 109 sites, 86 of which had never been assessed before. Of the 109, 47 were found to have no known impacts, and 7 were possibly impaired. Under study protocols, assessments of the other sites did not produce conclusive evidence of either high or problematic water quality.

TREES FOR TRIBS

Natural borders of trees, shrubs and grasses along streams form buffers that help to reduce pollution in waterways by slowing down and filtering runoff. They lessen erosion by stabilizing shorelines and absorbing high-velocity flows, and offer a travel corridor for wildlife.

BASELINE: From 2009 to 2014, volunteers planted 32,700 trees and shrubs along tributary streams in the Hudson watershed.

Beth Roessler/DEC

Alene Onion/DEC

WAVE volunteers collect stream macroinvertebrates to assess water quality.

Since 2007, the Hudson River Trees for Tribs (as in tributaries) Program has provided landowners with free native trees and shrubs and engaged volunteers in plantings to restore streamside buffers. From 2009 through 2014, the program planted 29,600 trees and shrubs along 12 miles of streams. Another 3,100 were planted by partnering groups in the watershed. Since DEC adopted this program as a statewide model in 2011, 13,000 trees and shrubs have been planted in seven other New York watersheds.

THE HUDSON RIVER ALMANAC

The Hudson River Almanac, a free natural history journal covering the river and its watershed from the Adirondacks to New York harbor, has compiled observations from thousands of volunteers since 1994. Contributors range from elementary school students to professional biologists. Originally published annually as a book, it began weekly distribution via e-mail in 2003. By the end of 2014, circulation had grown to 7,997 subscribers.

Rather than pursuing narrow research goals, this journal captures multiple dimensions of people's interactions with nature. While the sightings reported often contain information useful to scientists, it aims at a broader audience to promote public understanding of the river, put contemporary observations in historical perspective, and — like all the projects described here — encourage people to look more closely at the Hudson and share what they see.

Swamp white oak leaves.

W.D. Brush/USDA-NRCS PLANTS Database.

GETTING TO THE RIVER — ACCESS REAL AND VIRTUAL

Reports like this one offer an armchair look at the Hudson. To really appreciate the river, there's no substitute for going to the water. Opportunities to do so abound, thanks to the efforts of government agencies, community leaders, businesses, private non-profits, and committed citizens. Increasingly, access points are designed to accommodate an aging population and persons with disabilities. And in the virtual world offered by modern technology, digital devices can access near real-time hydrological, weather, and water quality data via the internet.

Steve Stanne/DEC

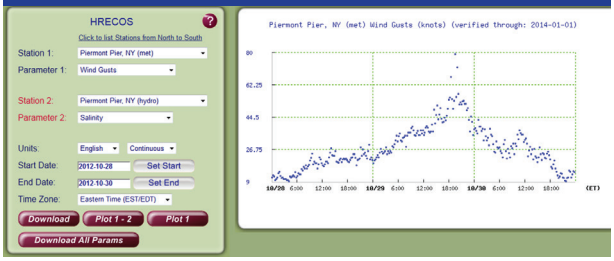
Opened in 2009, the Walkway Over the Hudson State Historic Park is the longest elevated pedestrian walkway in the world, offering splendid views from 212 feet above the river.

TREND: As community interest in river recreation grows, an increasing number of access sites and opportunities are welcoming everyone to the Hudson.

Steve Stanne/DEC

Paddlers are discovering the enjoyment of kayaking on the Hudson. Check out the Hudson River Greenway Water Trail online at www.hudsongreenway.ny.gov/trailsandscenicbyways/watertrail.aspx.

TREND: Near real-time, high frequency data on weather and river conditions are available from an expanding number of sensor installations on the Hudson and Mohawk Rivers.



Hudson River Environmental Conditions Observing System

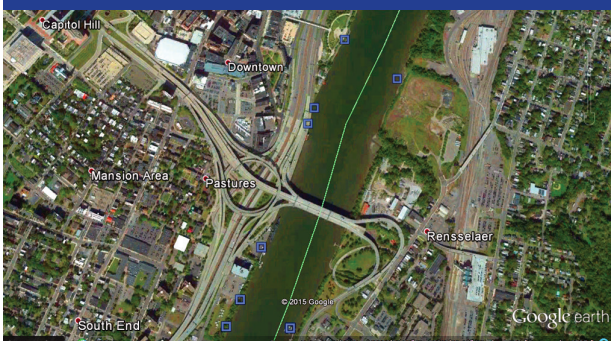
The Hudson River Environmental Conditions Observing System (HRECOS) website posts near-real time data from remote sensors at sixteen locations. Historic data is also available through the system. This graph shows wind speeds at the end of the Piermont Pier during Superstorm Sandy. Check out HRECOS at www.hrecos.org.

TREND: Participation in Day in the Life of the Hudson River increased from 1,175 in 2004 to 3,220 in 2014, as teachers took their students to the Hudson for hands-on learning experiences.

Chris Bowser/DEC

Each fall, Day in the Life of the Hudson River brings classes to the water from New York harbor to the head of tide and beyond. They study the river in their communities and then share their findings with other participants via the internet. Check out Day in the Life and other river education resources online at http://www.dec.ny.gov/lands/ 5102.html.

TREND: Access to information about sewage spills is improving thanks to the Sewage Pollution Right to Know law and efforts to communicate information to the public.



DEC is using NY–Alert, a free statewide public notification system, to make it easy for municipalities to report sewage spills and to inform the public. The agency also provides data on combined sewer overflows through an outfalls map on Google Earth. Check it out at http://www.dec.ny.gov/chemical/90315.html.

THE STATE OF THE HUDSON 2015
Hudson River Estuary Program
New York State Department of Environmental Conservation
Joseph Martens, Commissioner

ABOUT THE HUDSON RIVER ESTUARY PROGRAM
The Hudson River Estuary Program leads a unique regional partnership with the mission of helping people enjoy, protect, and revitalize the estuary. Created in 1987 by the Hudson River Estuary Management Act (ECL 11-0306), the program focuses on the tidal estuary and its adjacent watershed from the federal dam at Troy to the Verrazano-Narrows Bridge in New York City.

The Estuary Program implements the Hudson River Estuary Action Agenda to achieve six key benefits: clean water; resilient communities; a vital estuarine ecosystem; conservation of fish, wildlife, and habitats; preservation of the river's natural scenery; and enhanced opportunities for education, river access, recreation, and inspiration. The Program's partners include the Hudson River National Estuarine Research Reserve, Hudson River Valley Greenway, New York-New Jersey Harbor and Estuary Program, New York State's Office of Parks, Recreation, and Historic Preservation and Departments of State, Health, Transportation, and General Services, the U.S. Environmental Protection Agency, U.S. Geological Survey, and U.S. Department of Commerce/NOAA, and many municipal governments, non-profit groups, academic institutions and private sector organizations. For more information, visit http://www.dec.ny.gov/lands/4920.html.

ABOUT THE NEW YORK STATE WATER RESOURCES INSTITUTE
The New York State Water Resources Institute's mission is to improve the management of water resources in New York State and the nation. A federally and state mandated institution located at Cornell University, the institute is uniquely situated to access scientific and technical resources relevant to water management. It collaborates with regional, state, and national partners to increase awareness of emerging water resources issues, develop and assess new water management technologies and policies, and connect the water research and water management communities.

New York State
Water Resources Institute

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