



ESTUARY NEWS

A PUBLICATION OF THE PARTNERSHIP FOR THE DELAWARE ESTUARY: A NATIONAL ESTUARY PROGRAM

SPECIAL ISSUE

State of the Delaware Estuary 2008

By Jennifer Adkins, Executive Director, Partnership for the Delaware Estuary

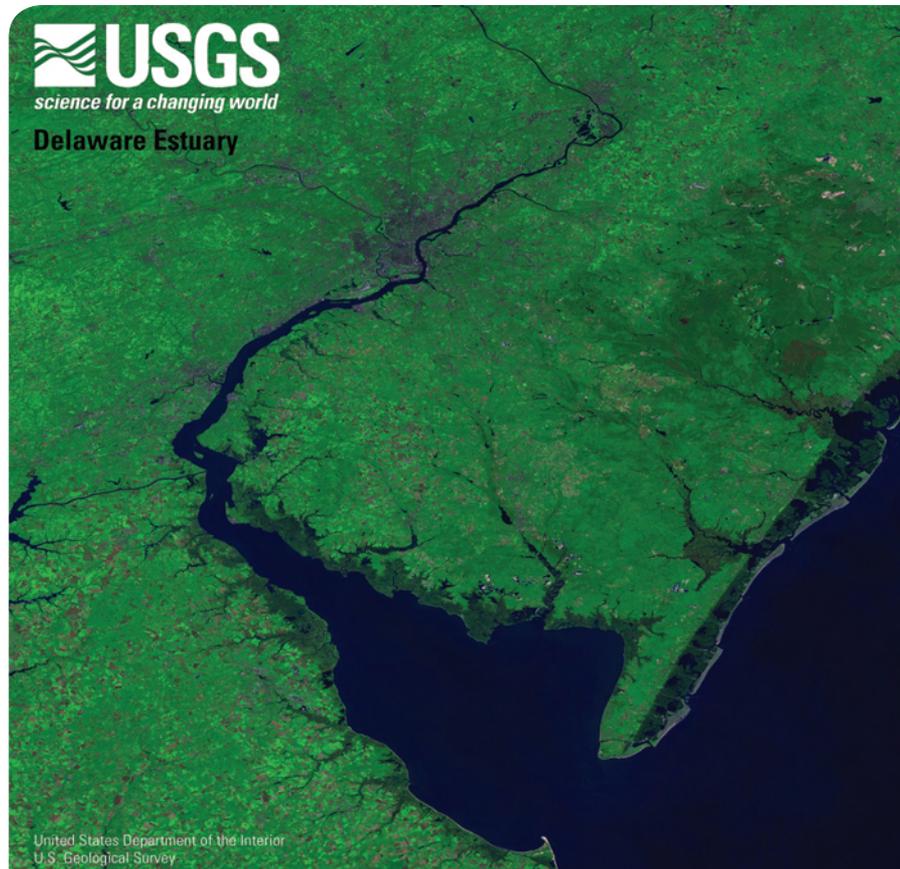
Every three to five years, the Partnership for the Delaware Estuary works with outside experts to take a comprehensive look at the health of the Delaware Estuary and its watershed. This helps the National Estuary Program track the progress it is making implementing its long-term “Delaware Estuary Comprehensive Conservation and Management Plan.” The results are presented here, for 2008, as a special issue of “Estuary News.”

The Delaware River’s dual identity as both a living river and a working river makes it an Estuary of many contrasts. On one hand, it is a principal corridor for commerce that has sustained our region since America’s Industrial Revolution, and it continues to be a major strategic port for national defense. On the other hand, it provides a wealth of natural and living resources, such as drinking water for millions of people, extensive tidal marshes that sustain vibrant ecosystems, and world-class habitats for horseshoe crabs, migratory shorebirds, and more.

Given these contrasts, it should be no surprise that the 2008 State of the Estuary Report tells a story of mixed environmental conditions. In some ways, the Delaware Estuary is healthier than ever before, thanks largely to improvements in wastewater treatment and laws enacted over time. The condition of some species, like bald eagles and striped bass, for example, have remained stable or improved. Unfortunately, the status of other species appears to be getting worse. The total population of Atlantic sturgeon may number less than 1,000 — perhaps even less than 100. Freshwater mussels and brook trout now appear to be absent from much of the region’s non-tidal waterways.

The Delaware Estuary has many important features that set it apart from other American estuaries. These include its freshwater tidal reach and extensive tidal marshes, which serve as the “kidneys” and “fish factories” of the Estuary. Less than five

continued on page 2



This report is being issued as a special summer edition of “Estuary News,” as well as technical report number 08-01 of the Partnership for the Delaware Estuary. Additional supporting materials like references can be found at www.DelawareEstuary.org, and a list of key definitions can be found on page 34. This assessment complements the State of the Basin Report, which is currently being developed by a team led by the Delaware River Basin Commission (DRBC) that also includes the Partnership. For information on that report, please call the DRBC at (609) 885-9500.

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State of the Delaware Estuary 2008 *continued from page 1*

percent of the freshwater tidal marshes are left in the Upper Estuary, but what little remains exists as an ecologically significant feature of the landscape in the urban corridor.

Tidal marshes are a major subject of current concern. Much of our remaining wetlands appear to be considerably degraded and vulnerable to storms, erosion, and sea level rise. These marshes would normally move landward as sea levels rise. However, the “buffer” lands adjacent to them have long been developed in the Upper Estuary, and buffer loss in the Middle and Lower Estuary has escalated during the past decade.

When it comes to water quality, results are also mixed. Waterborne pollutants in some areas have been decreasing, as is the case with suspended sediments, lead, and phosphorous. And dissolved oxygen, an indicator of good water quality, has generally increased in recent decades. On the other hand, concentrations of other contaminants are staying the same or increasing. For example, fish cannot be eaten in many areas because of legacy pollutants like polychlorinated biphenyls, or PCBs. And despite modern technology and new regulations, insults such as oil spills, chemical spills, and failures at wastewater treatment plants have yet to become a thing of the past.

Meanwhile, new concerns are emerging about classes of contaminants like pharmaceuticals, personal care products, and other potential endocrine-disrupting pollutants, the impacts of which are not fully understood by scientists. These contaminants of emerging concern require a shift in traditional thinking because many are produced industrially, yet are dispersed to the environment from unregulated domestic, commercial, and industrial sources.

Of the changes in the Estuary during the last decade, perhaps most troubling are the dramatic shifts in land use that have occurred in the five-year period between 1996 and 2001. The Delaware Estuary lost 52 square miles of

natural landscape — a rate of 11 acres per day. This loss is mostly attributed to increased development, which typically results in more impervious surfaces, increased water withdrawals, and lost opportunities for tidal marshes to migrate landward with sea level rise.

The effects of climate change on the Estuary are of great concern for the future, particularly when combined with projected changes in land use, water use, and population. Current projections suggest the region will continue to receive adequate precipitation, but the seasonality of rainfall may shift, causing more frequent and extreme wet and dry periods.

Changes in the pace of sea level rise could cause salinity to increase, threatening drinking water supplies and species in freshwater tidal areas. Low-lying areas would be increasingly subject to inundation under this scenario. And tidal marshes would be particularly vulnerable, especially if they face a greater frequency of strong storms.

Is it possible to address these environmental challenges while preserving prosperity in the

The Delaware Estuary lost 52 square miles of natural landscape — a rate of about 11 acres per day.

region, which has relied on our “working river” for more than 300 years? The answer is “Yes,” the Partnership for the Delaware Estuary is optimistic that a sustainable balance can be found between a working river and a living river if agencies, scientists, and others work together to:

- Increase our overall efforts and effectiveness by focusing on a set of shared priorities.
- Set science-based goals that plan for change as part of the natural landscape.
- Adopt realistic environmental targets that focus on the preservation and augmentation of key life-sustaining features and “natural capital” values.
- Gain a better understanding of how our ecosystems work by taking an ecosystem-based approach to management and monitoring.

Appropriate Indicators for the Delaware Estuary

Environmental indicators are specific, measurable markers that are used to assess whether the overall environment is improving or worsening over time. These indicators help to raise awareness about important environmental issues, and they serve as tools for evaluating the effectiveness of management actions. Indicators can forecast early warning signs that adverse changes may be right around the corner.

More than 20 indicators have been included in the 2008 State of the Estuary Report for their representative nature of the system's habitats, resources, and conditions. These indicators were selected based on data availability and their capacity to relate important information about the status of the Delaware Estuary and its large tri-state watershed.

The suite of environmental indicators used in this report were defined through collaboration among the Partnership for the Delaware Estuary, Delaware River Basin Commission, U.S. Environmental Protection Agency, and four land-grant universities that are representative of the states in the Delaware River Basin: Cornell University, Penn State University, Rutgers University, and the University of Delaware. They were later reviewed by additional experts, including many of the scientists and managers who serve on the Science and Technical Advisory Committee of the Partnership for the Delaware Estuary.

Indicator data have been compiled from various environmental agencies and partners, and these are summarized here to present a broad picture of the Estuary's health. This report relies on the best scientific information available, much of which was collected in the Delaware River Basin Commission's concurrent "State of the Basin Report," the Partnership's 2006 "White Paper on the Status and Needs of Science in the Delaware Estuary," proceedings of the 2005 and 2007 Delaware Estuary Science Conferences, the "Delaware Estuary Monitoring Report," and the Partnership's Science and Technical Advisory Committee.

The indicators in this report represent just a portion of those that could have been included, and efforts are already planned that will strengthen the quality of data and the appropriateness of indicators in the future. Therefore, this literature is not comprehensive for all issues of ecological concern. Nevertheless, taken together, these indicators do tell a story about the status and trends of both natural resources and water quality in our region, and they do serve as a useful baseline for measuring the progress of those who are working to implement the "Delaware Estuary Comprehensive Conservation and Management Plan."

Recommendations are provided throughout this text in the form of "Actions and Needs" that will strengthen our scientific understanding, as well as improve the monitoring and reporting of indicator data in the future. Examples include improved data sharing, increased coordination, and more ecosystem-based monitoring that, in addition to traditional resource-by-resource analyses, will help experts deduce the important linkages and processes that connect resources. The Partnership for the Delaware Estuary will continue to work with its partners to improve both monitoring and data management for indicators where information is incomplete or unavailable.

How to Use the State of the Estuary Report

A bar-shaped gauge is shown for each environmental indicator, except in the case of a few where doing so would be inappropriate. This has been done in an effort to summarize the given indicator's status and trend, based on the best scientific judgment of our current "weight of evidence." Each gauge contains six gradations signifying whether the condition is either excellent (green end), good, above average, below average, moderately degraded, or severely degraded (red end).

Status Ratings (dots):

- If the dot is above the center, the status is generally positive, ranging from above average to excellent
- If the dot is below the center, the status is generally negative, ranging from below average to severely degraded

Trend Ratings (arrows):

- An arrow pointing up indicates a positive trend
- An arrow pointing down indicates a negative trend
- No arrow indicates no trend or an unknown trend

Arrows describe whether the indicator status is trending toward improvement or degradation, relative to an appropriate timeframe for the indicator. Generally, at least five years of data were evaluated to establish trends. If longer-term data were available, most trends were considered in five-year increments. The text should be consulted for a description of historic conditions (50 to 100 or more years) where known.



Delaware Estuary 101

Scenes from the Estuary



River otters like this Pennsylvania pair are seen as signs of good water quality because they survive by eating species that accumulate pollutants in their tissues.

Credit: Pennsylvania Game Commission / Hal Korber



A fountain located in Philadelphia's Love Park spouts water that has been dyed green in honor of Earth Day 2008.



A table is stocked with educational literature at the 2007 Delaware Estuary Science and Environmental Summit in Cape May, New Jersey.

The Delaware Estuary makes up slightly more than 50 percent of the Delaware River Basin. This includes each watershed that drains into the Delaware River, from the falls at Trenton, New Jersey, and Morrisville, Pennsylvania, all the way south to the mouth of Delaware Bay between Cape May, New Jersey, and Cape Henlopen, Delaware. For ecological purposes, the Estuary is divided into four sub-watershed regions: the Schuylkill Valley, Upper Estuary, Lower Estuary, and Delaware Bay. Each region has its own suite of environmental and socioeconomic characteristics. The environmental indicators selected for use in this report reflect these distinguishing features.

A significant amount of drinking water is captured in New York State to meet the demands of about half the population of New York City, or roughly 6.5 million people. The remaining freshwater then flows south into the Delaware Estuary from the Delaware and Schuylkill Rivers, as well as from numerous smaller tributaries. The Delaware Estuary also exchanges water with the Chesapeake Bay via the Chesapeake and Delaware (C&D) Canal.

Oysters and blue crabs represent important shellfish resources in this system. In fact, more than 200 species of migrant and resident finfish and shellfish use the Delaware Estuary for feeding, spawning, or nursery grounds, and this includes popular sport fish like striped bass, shad, and bluefish. Recreational anglers spend an average of \$62 to \$100 per single-day or multiple-day fishing trip in pursuit of these and other species. The Estuary is also home to the largest population of spawning horseshoe crabs in the world, making it an important international link in the migratory path of a wide variety of shorebirds and waterfowl.

Natural habitats in the Delaware Estuary include extensive areas of sub-tidal sand, mud, and oyster reefs. The intertidal zone not only has important mudflats and beaches, but also salt and freshwater marshes. Landward of the tidal zone are more wetlands, as well as upland meadows and forests. Across these areas plant diversity is high, with 185 natural communities that make up 35 ecological classes throughout the watershed.

Endangered and threatened species of turtles, freshwater mussels, and fish live in many areas throughout the Estuary. A particularly important habitat for these species is the extensive tidal wetlands that fringe much of the Estuary's coastline. Historically, these wetlands have provided critical habitat for 35 percent of the region's threatened and endangered species. They also play a fundamental role in sustaining ecology and helping to maintain water quality for the overall estuarine ecosystem.

Today these natural and living resources are struggling to live in balance with modern America. Once the center of the Industrial Revolution in the New World, greater Philadelphia contains a legacy of pollutants dating back more than 300 years. The Delaware River Basin Commission, U.S. Environmental Protection Agency, the States of Delaware and New Jersey, and the Commonwealth of Pennsylvania are all working to reduce polychlorinated biphenyls (PCBs). Mercury levels, meanwhile, also make consumption advisories necessary for many of the otherwise edible fish in the Estuary. This is because PCBs and exposure to mercury are harmful to human health.

The economic might and strategic importance of the Delaware Estuary is further exemplified by some notable facts, following on the next page.

- **6.4 million people live within the Delaware Estuary's watershed, which is 83 percent of people in the overall Delaware River Basin.**
- **Together with the Upper Delaware River Basin, the Estuary provides 15.2 million people with drinking water, including 7.5 million people living outside the Basin**
- **The region has one of the world's highest concentrations of heavy industry**
- **The ports located in the Delaware Estuary make up the world's largest freshwater port complex. Altogether, these furnish 70 percent of the gasoline and heating oil that is used to fuel the East Coast, which in turn generates \$19 billion in annual revenue.**

For a complete description of the signature natural resources and environmental issues of the Delaware Estuary and its four watershed regions, please consult the Web-based "Delaware Estuary Information Gateway" at www.DelawareEstuary.org.



Credit: Delaware River Basin Commission (left image).

For the purposes of this report, the Delaware Estuary is considered as the study area for the Partnership for the Delaware Estuary, a National Estuary Program. As shown above, this consists of 6,827 square miles of tidal and non-tidal areas in the lower half of the 13,611-square-mile Delaware River Basin (yellow), and does not include the watershed of the Delaware River above the head of tide at Trenton, New Jersey (gray). However, status and trends are examined across the entire Basin wherever it is appropriate for specific indicators.

The Delaware Estuary study area is shown to the right divided into four regions, which are referred to at times in this report by their initials as follows: Schuylkill Valley (SV), Upper Estuary (UE), Lower Estuary (LE), and Delaware Bay (DB).



WATERSHED INDICATORS

Population

Studies show that population growth is directly related to new development, which puts stress on the environment. Construction often expands impervious surfaces across landscapes, which in turn affects functional attributes like soil permeability, an essential element of hydrology. The result is a negative impact on both water quality and aquatic communities due to increased quantities of stormwater runoff pollution. Stormwater runoff can pick up debris, chemicals, dirt, and other pollutants and carry them into waterways.

In 2000, 82 percent of citizens in the Delaware River Basin, or approximately 6.4 million people, lived in the watersheds that make up the Delaware Estuary. Population density in the Upper Estuary was twice that of the remaining region, with 47 percent of the Basin's population living in the Upper Estuary and another 20 percent residing in the Schuylkill Valley.

In 1990, the Estuary contained 83 percent of the Basin's population. This indicates that while the Estuary remains the focus of population density, a substantial amount of growth is occurring outside the Estuary, in the northern reaches of the Delaware River Basin.

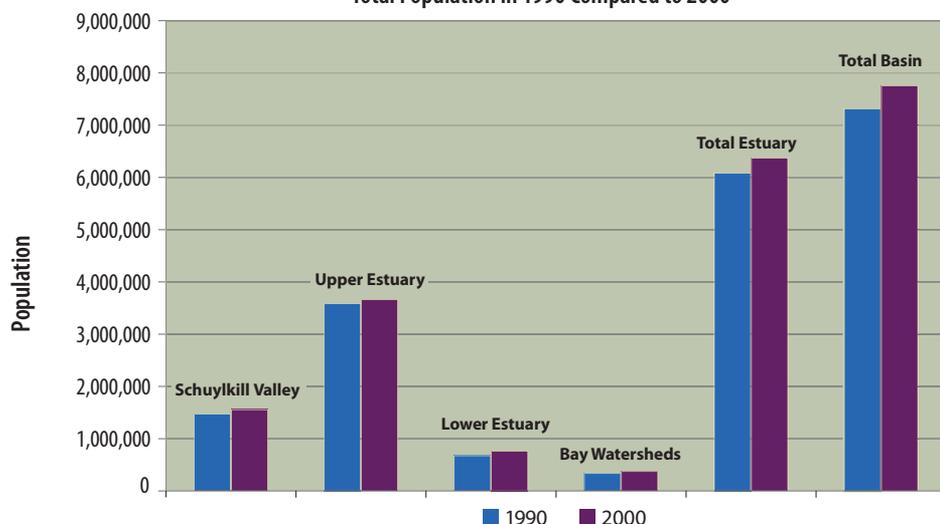
Since 2000, the population of the Estuary has increased by seven percent, including increases of 11 percent and 12 percent in the Upper Basin and Central Basin respectively. This is consistent with an increase of six percent across the entire Basin. Some declines are evident, the most substantial of which is in Philadelphia.

Population declines in the cities of New Castle and Salem are being offset by substantial growth elsewhere. Between 2000 and 2005, nine communities had increases greater than five percent. These included: Middletown, Smyrna, Odessa, Bowers Beach, Frederica, Leipsic, and Dover, Delaware; Coatesville, Pennsylvania; and Bridgeton, New Jersey.



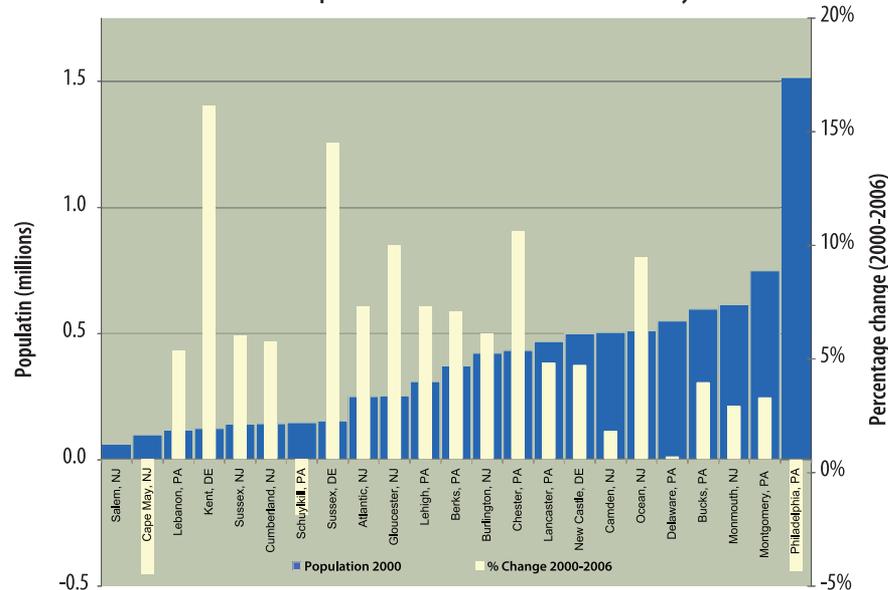
Tourists and locals alike gather at Southeastern Pennsylvania Coast Day, a Partnership-sponsored festival held annually along the Delaware Riverfront in September.

Total Population in 1990 Compared to 2000



Credit: Delaware River Basin Commission

Recent Population Trends for Counties in the Estuary



Fast Fact

In 2006, the Partnership for the Delaware Estuary worked with Riverbend Environmental Education Center of Gladwyne, Pennsylvania, to fund a porous-pavement parking lot so that others might use it as a model.

Making Connections to Tell the Story

The Partnership for the Delaware Estuary relies on creativity and collaboration in its efforts to engage approximately 6.4 million residents in the protection and enhancement of the Delaware Estuary. To accomplish this feat, the nonprofit organization reaches out in a variety of ways to key audiences, such as scientists, educators, partners, businesses, and the public.

Every two years, the Partnership brings together scientists, resource managers, and conservationists from throughout the Estuary at its Science Conference and Environmental Summit. Held in 2005 and 2007 in Cape May, New Jersey, this event provides both scientists and practitioners with the opportunity to present new findings and discuss critical issues facing the Estuary. A multidisciplinary Science and Technical Advisory Committee guides the Partnership in its efforts to engage these professionals, and it plays an integral role in shaping the biennial conference's agenda.

For over a decade, the Partnership and its sponsors have hosted the Delaware Estuary Watershed Workshop for Teachers. This week-long program introduces primary-school educators to estuarine science using classroom and field-trip experiences throughout three states. These participants get hands-on experience that helps them to bring the Estuary into their classrooms, especially when combined with annual drawing contests in Philadelphia and Delaware, or the "Delaware Estuary Water Education Resource Guide," both of which are products of the Partnership.

In addition to the many organizations listed in the "Delaware Estuary Water Education Resource Guide," the Partnership collaborates with: businesses, civic associations, community organizations, conservation groups, government agencies, and more. Our annual "Experience the Estuary" dinner and auction gives these diverse stakeholders the opportunity to come together in celebration of the Estuary.

Through public events like the Christina River Cleanup, Wilmington Earth Day Celebration, and Southeastern Pennsylvania Coast Day, the Partnership is working with local sponsors to introduce people to the wonders of the Delaware Estuary every year. The information provided at these and other events is further reinforced by the organization's newsletter, "Estuary News," and an online presence at DelawareEstuary.org, ecoDelaware.com, and ThankYouDelawareBay.org.

Since its inception in 1996, the Partnership has experienced great progress in its efforts to increase awareness, understanding, and scientific knowledge about the Delaware Estuary; this, despite its vast size and varied audiences. The Partnership is exploring new ways to engage the public in emerging issues like climate change, ecosystem-based management, and ecotourism, all while continuing to build on the events and programs that thousands have come to know and respect. Connecting people and telling these stories is, after all, a crucial component in the Partnership's vision, which is to make the Delaware Estuary the most inviting, prosperous, and healthy natural resource of its kind in the nation.



A visitor is greeted with a free native plant at the 2007 Wilmington Earth Day Celebration, an annual event organized by the Partnership for the Delaware Estuary.



Dr. Eric Powell of Rutgers University (center) fields a question during a panel discussion about Eastern oysters at the 2007 Delaware Estuary Science and Environmental Summit.

Fast Fact

Some people still refer to the Partnership for the Delaware Estuary as the Delaware Estuary Program. However, the two organizations merged in 2005, after which the Partnership assumed full responsibility for leading the effort to implement the "Delaware Estuary Comprehensive Conservation and Management Plan."



WATERSHED INDICATORS

Water Use Patterns

INDICATOR DESCRIPTION: Current and comprehensive water-use records enable the proper assessment, planning, and management of water resources.

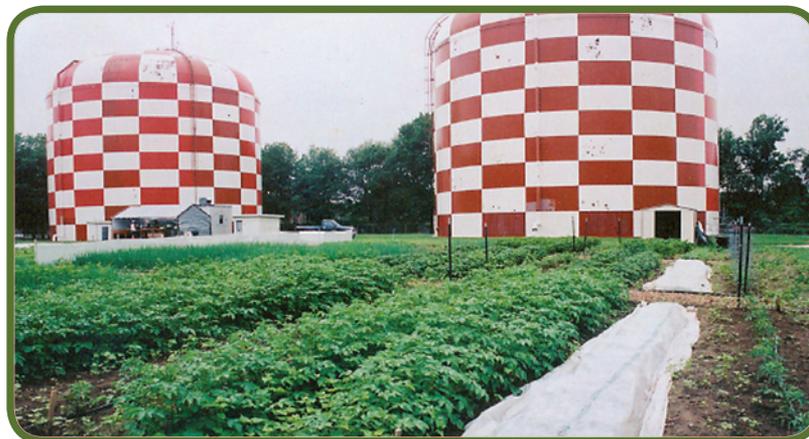
STATUS: More than 15 million people rely on drinking water from the Delaware River Basin, including water that is diverted for people living outside the Basin, such as New York City. Per capita water use in the Basin is about 133 gallons per person per day.

Water is used within the Basin for diverse purposes. The dominant use sectors are power generation (thermoelectric), public water supply, and industrial use. Collectively, these account for roughly 90 percent of total withdrawals and consumptive use. Over 90 percent of all water used is obtained from surface waters.

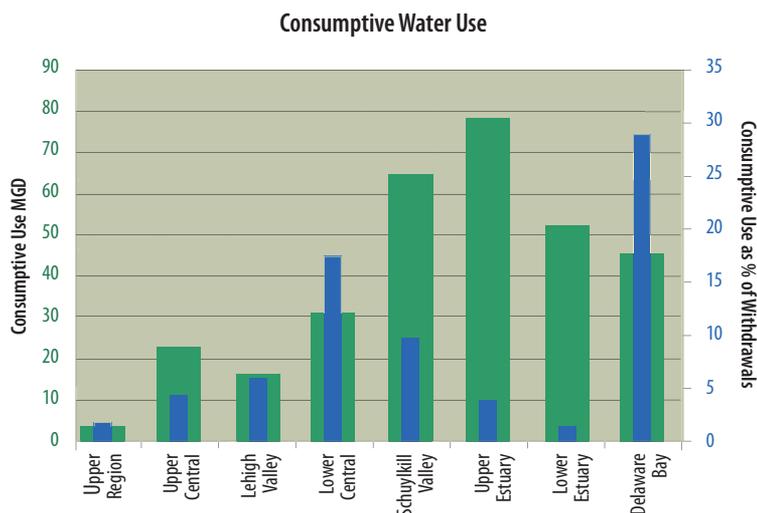
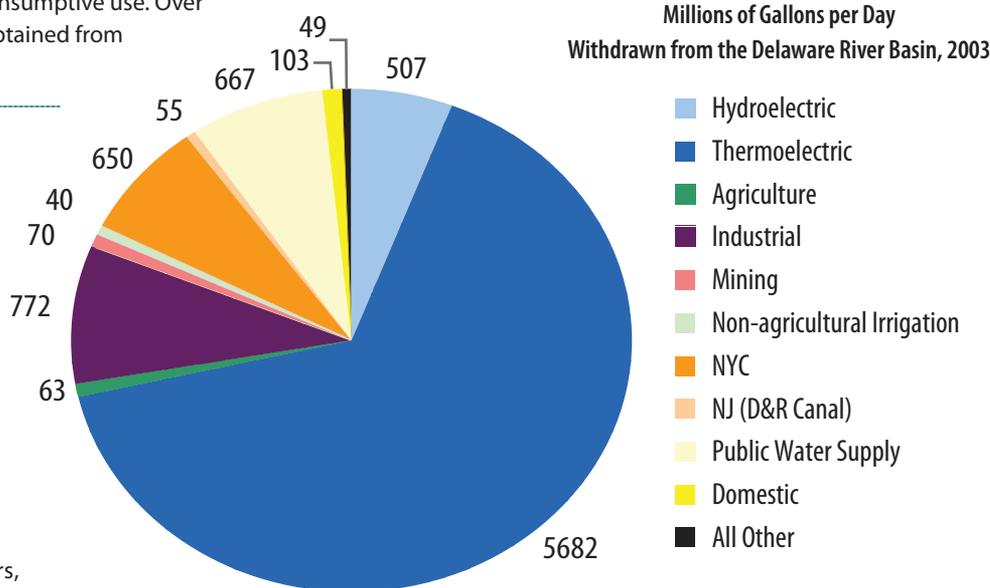
TRENDS: In the past decade, Basin-wide water use has remained fairly constant. Although there has been an overall increase in population, this has been offset by a decline in industrial water use and increased conservation.

ACTIONS AND NEEDS:

With further increases in population and requests for more water from various sectors, careful management of water supplies will continue to be of paramount importance. A better understanding of agricultural water demand is needed, and the potential growth in water demand for large, power-generating facilities should be carefully forecasted and managed. Ample freshwater is not only needed for human uses, but also so the streams and rivers of the tidal Estuary can meet their ecological needs.



The Philadelphia Water Department's Somerton Tank Farm not only stores Delaware River drinking water, but it is also used to grow produce — in Northeast Philadelphia. Credit: Philadelphia Water Department



Fast Fact

The Delaware River Watershed provides clean drinking water to more than 15.2 million people.

Water Quality Improvements That Are Right On Target

Two major watersheds in the Delaware Estuary have benefited from highly-competitive Targeted Watershed Grants (TWG) in the time since the Partnership for the Delaware Estuary last issued a State of the Estuary Report. Both watersheds are sources of water for millions of people in the Estuary.

In 2003, the Delaware River Basin Commission received a \$1 million grant on behalf of the Christina Basin Clean Water Partnership for water-quality improvement projects in the Christina River Basin, which provides drinking water for approximately half a million people in Chester County, Pennsylvania, and New Castle County, Delaware. The streams in the Christina River Basin suffer from impaired water quality due to the combined impacts of wastewater treatment plants, industry, agricultural runoff, and stormwater runoff.

Task Force members used these TWG funds to complete projects in the watershed, including one that was undertaken by the Delaware Department of Natural Resources and Environmental Control to complete a 5,000-foot stream restoration project along Pike Creek in Northern New Castle County. As seen in the before-and-after photos to the right, these improvements have made a remarkable difference in transforming a highly eroded area — one with no main channel and severely eroded and undercut banks — into what is now a gently curving stream with stabilized riparian buffers.

In 2004, the Partnership for the Delaware Estuary was awarded a \$1.15 million TWG on behalf of the Schuylkill Action Network to fund a suite of water-quality improvement projects in the Schuylkill River Watershed, a source of drinking water for more than 1.5 million people in Southeastern Pennsylvania. These funds have allowed partners in the Schuylkill Action Network to carry out more than 40 projects that not only reduce abandoned mine drainage, agricultural runoff, and stormwater runoff, but also serve as high-profile demonstrations projects.

One of the projects made possible by this TWG is a passive-treatment system installed by the Schuylkill Headwaters Association at the Pine Forest Abandoned Mine Discharge in Schuylkill County, Pennsylvania, shown in the photo above. This system uses underground limestone beds and a series of wetland ponds to remove aluminum, iron, and manganese that would otherwise flow into Mill Creek, a tributary to the Schuylkill River's headwaters.



After restoration



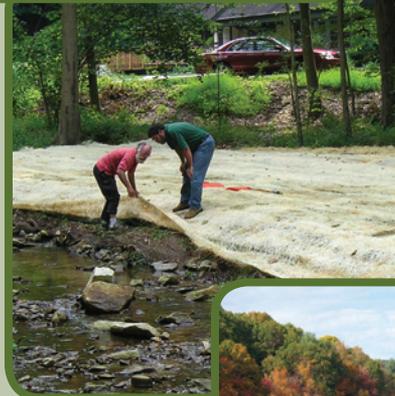
Before restoration

Above and at left: Years of degradation are now a thing of the past along this section of Pike Creek in New Castle County, Delaware, thanks to a 2003 Targeted Watershed Grant.

Credit: Steve Williams, Delaware Department of Natural Resources and Environmental Control

At right: A site is prepared for planting in 2005 so that stormwater runoff will be intercepted before it can flow into the East Branch of the Brandywine Creek Watershed, a subwatershed of the Christina River Basin.

Credit: U.S. Environmental Protection Agency, Region 3



At right: Mineral-rich water is captured from an abandoned mine in Schuylkill County, Pennsylvania, so it can infiltrate into the ground before it flows into Mill Creek nearby.

Credit: Schuylkill Headwaters Association



The Targeted Watersheds Grants Program is administered by the U.S. Environmental Protection Agency to encourage successful, community-based approaches and management techniques that protect and restore the nation's watersheds. For more information regarding this program, please visit www.epa.gov/twg.

Fast Fact

The Christina River Watershed of Northern Delaware and the Schuylkill River Watershed of Southeastern Pennsylvania are both "targeted watersheds" currently benefiting from \$2.15 million granted by the U.S. Environmental Protection Agency.



WATERSHED INDICATORS

Land Use



INDICATOR DESCRIPTION: Land is an important component of every watershed. Changes in its use by people, or “land use,” and alterations to the landscape cause major changes in ecological processes. Most of a watershed’s physical and chemical changes are linked to land-use changes, and these in turn affect biological processes and plant and animal health. The U.S. Geological Survey reports that a watershed’s total area of forests and wetlands has a positive effect on aquatic invertebrates, an indicator of good water quality. Meanwhile, urban-area growth, impervious cover, population density, and discharges into waterways all yield negative effects. In fact, a recent report in the State of New Jersey put land-use changes at the heart of many environmental problems.

STATUS: The Delaware Estuary’s 6,827 square miles makes up slightly more than half of the Delaware River Basin. Nearly 54 percent of this land is developed or cultivated, while roughly 46 percent is made up of forests, wetlands, and small water bodies. Many of these natural lands are severely fragmented. For example, a 2004 analysis of Delaware’s tree cover showed 4,150 wooded patches larger than 10 acres, but with a median size of only 34 acres. Of those, less than 0.1 percent had sufficient interior habitat to sustain bird species like cerulean warbler and black-and-white warbler, both of which require larger forest patches.

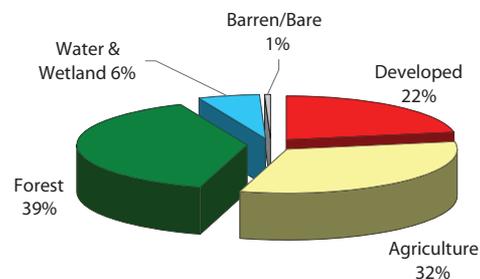
TRENDS: Nearly 52 square miles of the Estuary’s natural landscape was developed between 1996 and 2001, mostly through the loss of forests. The rate of loss among forests in the Estuary during that timeframe was about 11 acres per day.

ACTIONS AND NEEDS: Satellite imagery used in this report is too coarse and obsolete for accurate analysis at fine scales, so newer aerial photo methods would improve resolution and provide more timely information. Land-use assessments should be enhanced with more readily available and compatible datasets utilized among the states in the region. Land-use studies should be coordinated throughout the Estuary, preferably in sync with census analyses and population projections.

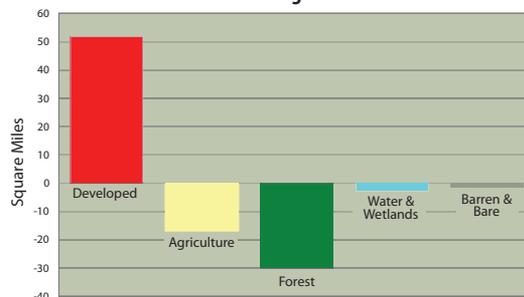


Many municipalities have bulldozed riparian buffers and effectively armored their coastlines, leaving storm drains to intercept stormwater before it washes pollutants into nearby waterways.

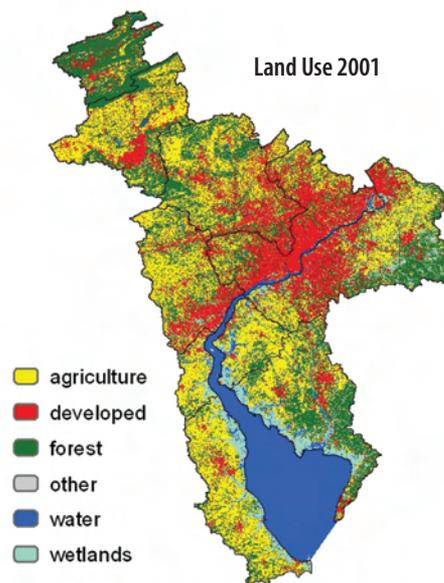
Estuary Region Land Use 2001



Land Use Change 1992-2001



Land Use 2001



Credit: Delaware River Basin Commission

Fast Fact

Rather than mowing acres of open space, try mowing only the exterior fringe of your land. The result will be a native-grass meadow that soaks up stormwater and serves as wildlife habitat.

Protected Forest Lands



INDICATOR DESCRIPTION: Protected lands are associated with conservation efforts. Using forests as an example here, land protection includes all public-owned land that is a part of federal and state forests, forest preserves, and game lands. Forested lands provide bird and wildlife habitat, maintain clean water, improve the health of aquatic communities, and enrich landscapes for people.

Within the Estuary, protected forests account for 88 percent of state and federal landholding, but there are still vast tracts of unprotected land. Unprotected forests may be just as functional as protected forests, and all forests benefit the Estuary. For example, trees provide shade, moderate ground-level temperature, absorb carbon dioxide, and give off oxygen.

STATUS: In 2001, only 11 percent of the 6,888 square miles of forested land in the Delaware River Basin was protected under federal or state ownership. Approximately 30 percent of these forests were within the Estuary's watershed. Most forests, both protected and unprotected, are highly fragmented, which hurts their usefulness to wildlife relying on large acreage (i.e., some bird species).

TRENDS: The percentage of protected forest land is increasing each year, suggesting that conservation efforts are yielding important benefits. But the pace of protection is not keeping up with the loss of forest land. In one comparison of land-use datasets between 1992 and 2001, for example, as much forested land appeared to have been lost across the Basin as that which had been protected in federal and state forests, preserves, and game lands in the past 100 years combined. Based on conservative estimates of functional and product value, the Basin's remaining forest assets are worth approximately \$252 billion.

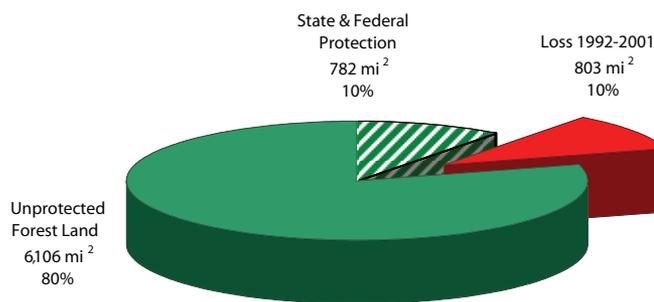
ACTIONS AND NEEDS: Efforts are needed to develop a more complete assessment of all the protected lands within the Estuary, not just forests and publicly-owned land. Conservation easements, land trust tools, and management tactics can provide incentives to protect more lands. A natural capital assessment of ecological services and functions would facilitate appraisal of the values of these lands in natural versus developed states.



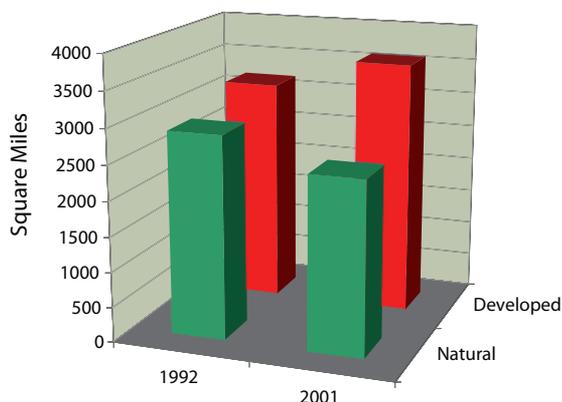
A sign is unveiled in May of 2005 that commemorates the restoration of 30 acres of native-grassland habitat in Southern New Jersey.

Credit: Robert Limbeck of the Delaware River Basin Commission.

Forest Land Status 2001



Landscape Status



Credit: Delaware River Basin Commission

Fast Fact

Perhaps the largest tree-planting effort in the Estuary is TreeVitalize, which is seeking to restore 1,000 acres, plant 20,000 shade trees, and train 2,000 volunteers in Pennsylvania.



WATER QUALITY

Water Quality Health



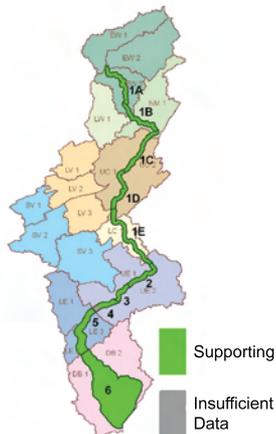
INDICATOR DESCRIPTION: Water quality in the Delaware Estuary is an important factor in the protection of drinking water, aquatic life, recreation, and fish and shellfish consumption. Experts have delineated 10 water-management zones along the main stem of the Basin, and each supports a different suite of human- and aquatic-life uses. Every two years the Delaware River Basin Commission (DRBC) conducts an Integrated Assessment in accordance with the Clean Water Act to determine whether water quality is supporting designated uses. The non-tidal portion of the Delaware River, above the head of tide at Trenton, New Jersey, is Zone 1. Zones 2, 3, 4, and 5 traverse the Estuary region, and Zone 6 consists of Delaware Bay. In each zone, water quality is assessed using criteria that aid experts in determining whether or not aquatic life, recreation, and fish consumption are being supported. Zones 1, 2, and 3 are also assessed for drinking water. Zone 6 is assessed for shellfish consumption, which is carefully managed. For a full explanation, please refer to the “2008 Delaware River and Bay Integrated List - Water Quality Assessment,” available at www.drbc.net.

STATUS: Criteria to support drinking water and recreational activities were met in all zones, although a portion of Zone 4 had insufficient data. Fish advisories limited consumption due to “legacy contaminants,” which stay in the system a long time, degrade slowly, and bioaccumulate in fish. Although every zone had at least one fish-consumption advisory, many of these were specific to certain fish in certain areas. Water quality met standards for supporting aquatic life in Zones 3 and 6, but not in Zones 2, 4, and 5. Based on the current criteria used by DRBC, aquatic life was affected by temperature problems in Zones 2 and 4, and low levels of dissolved oxygen affected some samples from Zone 5.

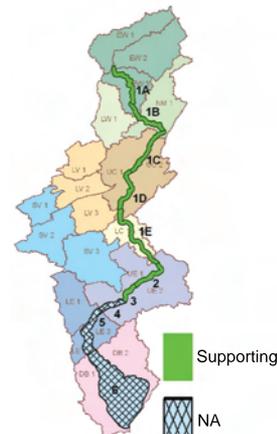
TRENDS: The number of water-quality impairments along the main stem of the Delaware River and Bay have not changed appreciably in recent years, although no formal trend analysis was undertaken for this report. In 2003, the U.S. Environmental Protection Agency adopted a polychlorinated biphenyl (PCB) total maximum daily load (TMDL) for Zones 3, 4, and 5 (see definitions on page 34). A TMDL for PCBs was adopted for Zone 6 in 2006.

ACTIONS AND NEEDS: A comprehensive reassessment of water-quality standards is needed to reflect changing conditions in the watershed. This will be an ongoing need, to ensure that human health and sustainable uses are protected in the future. This ongoing review will need to incorporate the latest science and federal requirements.

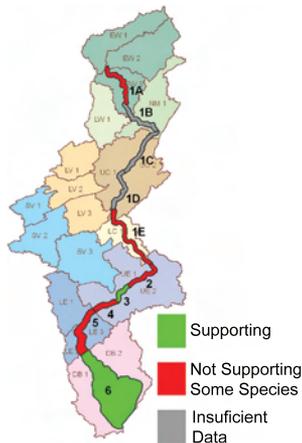
Areas Supporting Recreation



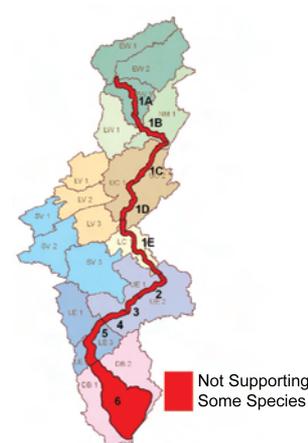
Areas Supporting Drinking Water



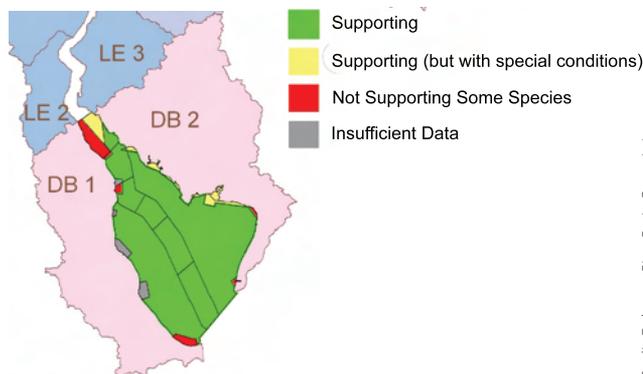
Areas Supporting Aquatic Life



Areas Supporting Fish Consumption



Areas Supporting Shellfish Consumption



Credit: Delaware River Basin Commission

Fast Fact

The Water Quality Act of 1965 was the first piece of legislation to require that states institute a set of water-quality standards for interstate waters.

Dissolved Oxygen



INDICATOR DESCRIPTION: Dissolved oxygen (DO) in surface water is one of the most basic and important measures of a water body's health, affecting a wide array of aquatic plants and animals. Low DO has immediate and long-term effects, ranging from shifts in biological communities, disruption of fish migration, and (under the worst conditions) fish kills. Oxygen enters water at the surface and through aquatic-plant and algae photosynthesis. DO becomes too low to support healthy aquatic communities when concentrations of oxygen-demanding organic materials are too high, and/or when high concentrations of nutrients, like nitrogen and phosphorus, cause excessive plant growth. When excess plants die and decompose, respiration by bacteria and other decomposers use DO in the water, potentially resulting in too little oxygen for fish and other aquatic organisms.

STATUS: DO in the Upper Estuary routinely meets the minimum criteria set by the Delaware River Basin Commission (DRBC) for aquatic life. In the Lower Estuary, however, near Reedy Island, continuous monitoring has shown that DO concentrations often do not meet these criteria, leading the State of Delaware to list this segment of the Estuary for TMDL development by 2019. DRBC and other agencies are working to better understand the factors contributing to frequent DO criteria violations in the Lower Estuary.

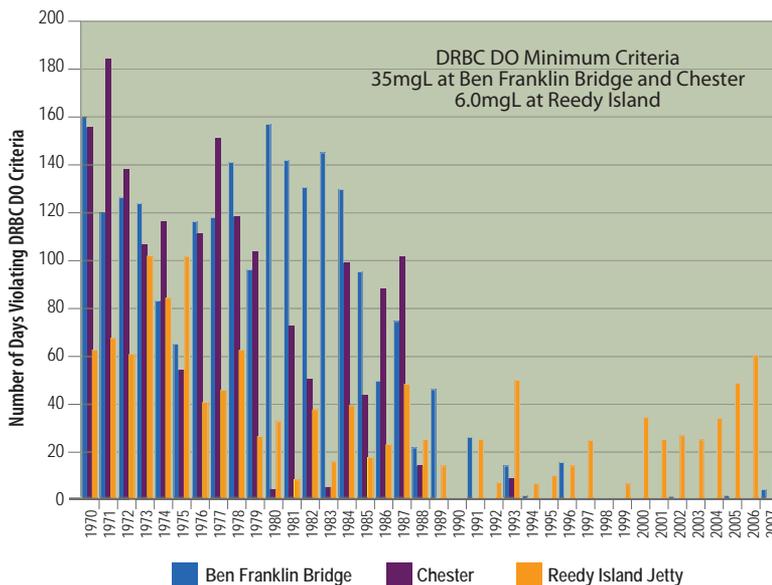
TRENDS: Until the mid 1980s, the Estuary's summer DO levels routinely did not meet minimum criteria, sometimes prohibiting fish from migrating through the river. The main cause was the input of sewage, which placed large demands on biological oxygen as the organic matter decomposed. With installation of better wastewater treatment, the number of days of low DO was dramatically reduced, and migratory fish returned. The DO criterion in the lower Bay is higher than in the urban river, and there still continues to be many summer days when this criterion is exceeded.

ACTIONS AND NEEDS: Because DO tends to be higher in the daytime and lower at night, it is important to measure around the clock, to ensure that levels remain healthy. It is also important to incorporate the latest scientific information and periodically reevaluate DO



A volunteer with the Delaware Nature Society's Stream Watch program collects water-quality data in a highly populated Northern Delaware watershed.
Credit: Delaware Nature Society

Comparison of Dissolved-Oxygen Violations From 1970 to 2007 at Three Delaware Estuary Continuous-Monitoring Sites



Credit: Delaware River Basin Commission

criteria to ensure they remain appropriate and protect water quality in different areas, and under changing conditions in the watershed.

Fast Fact

Fish breathe by taking up dissolved oxygen across their gills. If too much oxygen is used by bacteria and other decomposers, then fish and other animals can suffocate, resulting in a "fish kill."



Existing Contaminants

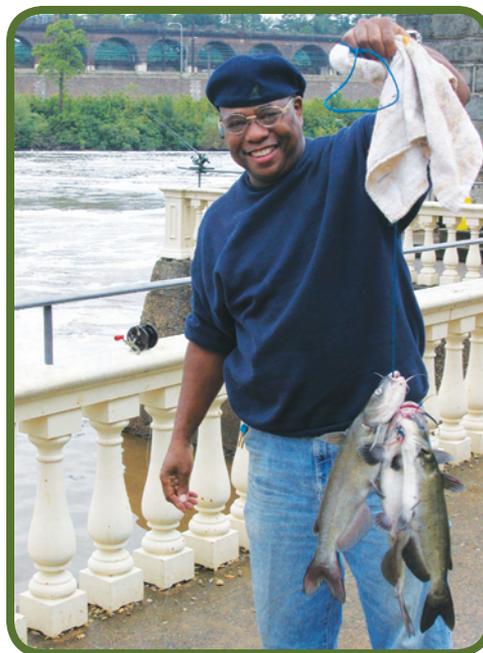


INDICATOR DESCRIPTION: Bioaccumulation is an organism's (including humans) retention of harmful chemical contaminants found in its environment and food. This process results in the build-up of specific chemicals in the body over time, possibly resulting in impaired health, as well as reproductive and behavioral effects. There are many types of contaminants in the Delaware Estuary that can be harmful to people and the environment, including legacy pollutants. Even decades after being banned, many of these pollutants can still pose problems because they have accumulated over hundreds of years and degrade very slowly. For example, polychlorinated biphenyls (PCBs) and mercury that bioaccumulate in aquatic life (e.g., fish) can lead to fish-consumption advisories. These advisories help protect public health and identify areas where further pollution management may be needed.

STATUS: Currently, fish-consumption advisories exist for waters in all Estuary states and along the Delaware River. Contaminants found in estuarine fish that result in consumption advisories include PCBs, mercury, dioxins/furans, and chlorinated pesticides, including dichlorodiphenyltrichloroethane, better known as DDT. The amount of contaminants fish bioaccumulate depends on species, size, age, sex, and feeding area, with older and larger fish accumulating the most contaminants. The fishes' lifestyle, food sources, and amount of time spent in contaminated areas also affect contaminant levels. Given that fish accumulate many contaminants in their fatty tissues, certain species with higher oil content can pose more risk than others.

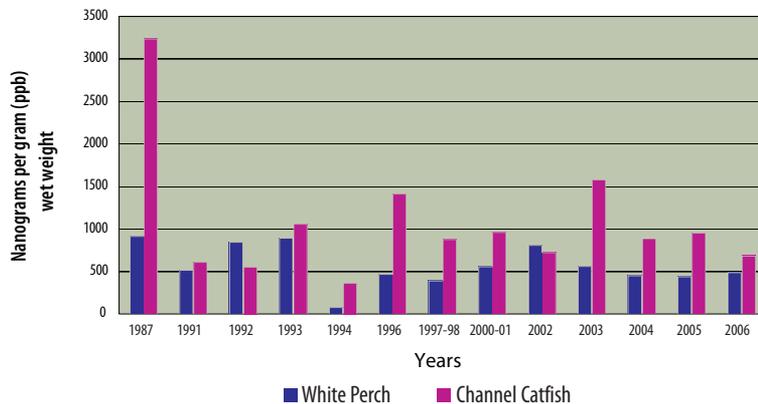
TRENDS: Data collected since 1988 suggest that some contaminants may be decreasing in fish in certain areas near the Delaware-Pennsylvania border. Decreasing trends are also evident for some legacy contaminants that cause problems for other fauna (see eagles, for example.) However, resident fish species such as white perch and channel catfish do not show a decreasing trend in PCB levels.

ACTIONS AND NEEDS: Contaminants were rated the top priority in the Partnership's "2006 White Paper on the Status and Needs of Science in the Delaware Estuary," and continued vigilance will be needed to monitor and manage pollutant effects in the watershed's environment.



A fisherman displays his catch near the Schuylkill River's Fairmount Dam in Philadelphia. At the time, it was safe to eat one serving per month of these channel catfish.

Historical Trend of PCBs in Fish Tissue Delaware Estuary



Credit: Delaware River Basin Commission

Bioaccumulation: The process by which organisms, including humans, uptake and retain chemical contaminants from the surrounding environment and their food. This process causes the amount of a chemical in a body to accumulate over time.

Fast Fact

Many fish in the Delaware Estuary are only safe to eat in limited quantities, if at all. Please consult your state's environmental protection agency for current guidelines.

Emerging Contaminants

Contaminants of emerging concern include a broad array of chemicals that are still unregulated in water-quality programs, but are of interest to scientists because of their potential persistence, bioaccumulation, and possible toxicity to aquatic life and humans. Some of these substances may affect human health by contributing to cancer or reproductive complications, for example.

Emerging contaminants include pharmaceuticals, personal care products, flame retardants, insecticides, plasticizers, nanoparticles, and resistant pathogens (bacteria, viruses, and prions). These different compounds enter and move through our ecosystem in various ways, and their eventual fate

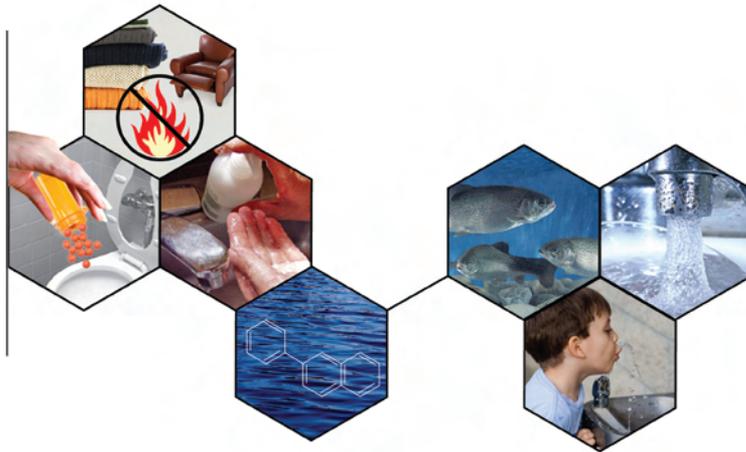
The Assunpink Creek, a tributary to the Delaware River in Central New Jersey, was part of a national USGS study in 1999-2000 that measured pharmaceuticals, hormones, and other organic wastewater contaminants in 139 streams nationwide. Out of 96 target analytes, 40 compounds were detected including pharmaceuticals, herbicides, flame retardants, plasticizers, surfactants, insecticides, and numerous other potentially harmful ingredients from personal care products and consumer goods. The concentrations of individual quantified compounds were very low, measuring between one and 500 parts per trillion.

varies widely. Significant work is being conducted to study emerging contaminants in the Delaware Estuary and its watershed.

Polybrominated diphenyl ethers (PBDE) represent one example of a contaminant of emerging concern. PBDE's are flame retardants used in everyday items such as computer casings, carpet pads, and foam cushions in chairs and couches. PBDEs accumulate in the fatty tissue of humans and animals. Concentrations are measured in nanograms (10⁻⁹) of PBDE per gram of tissue.

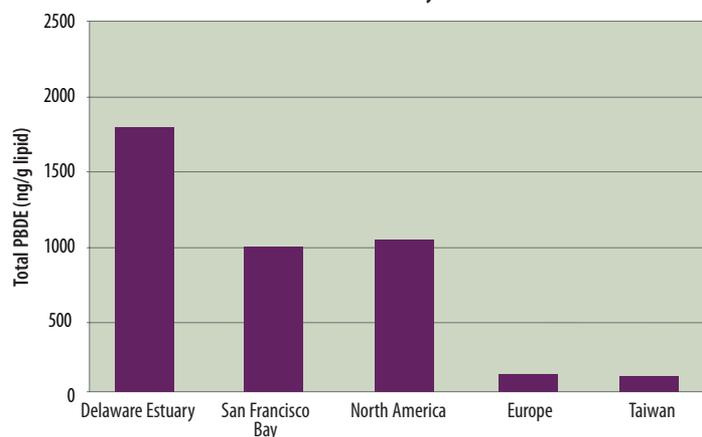
The levels of PBDEs in peoples' bodies are reported to be doubling every two-to-five years, and are 40 times higher in North America than on other continents. The effects of these PBDE concentrations on human health have yet to be established.

ACTIONS AND NEEDS: Systematic monitoring is needed to understand how and where these substances are entering the environment, what is happening to them once they enter the environment, and the risk they pose to humans and to our ecosystem. Additional information on contaminants of emerging concern in the Delaware Estuary and Basin is available at www.state.nj.us/drbc/emc.htm.



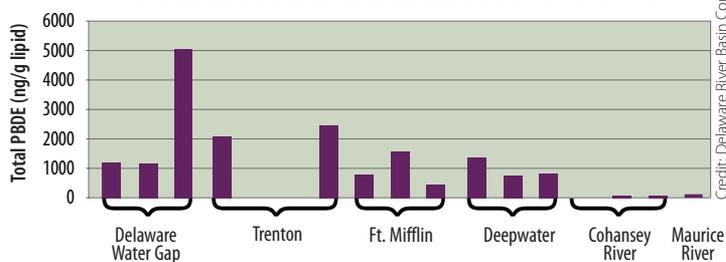
Credit: Sue Owens, Delaware River Basin Commission

Mean PBDEs in Delaware Estuary Fish vs. Fish Elsewhere



PBDE concentrations in fish from the Delaware Estuary appear to be somewhat higher than fish from other parts of North America, and much greater than those from Europe and Taiwan.

PBDE Concentrations in American Eels at Delaware River Sites



The relative concentrations among 18 tissue samples of eel from six sites in the Delaware River are shown in the figure.

Fast Fact

An easy way for citizens to preserve water quality is to take their household hazardous wastes to local collection events. To find one near you, please call the Partnership for the Delaware Estuary at (800) 445-4935.

Credit: Delaware River Basin Commission



Nutrients



INDICATOR DESCRIPTION: Nutrients, such as total nitrogen (TN) and total phosphorus (TP), are critical to supporting aquatic life. However, an overabundance of nutrients can lead to excessive plant and algal growth, which causes dissolved oxygen (DO) to drop when plant and algal matter decay. This phenomenon, known as “eutrophication,” refers to the condition when high nutrients trigger excessive plant production, leading to low DO, which can impair aquatic life and lead to fish kills. Whether or not a body of water becomes eutrophic can be controlled by water clarity, temperature, and availability of trace nutrients like silica. Because of these interacting factors, the same TN and TP concentrations that cause eutrophication in one river or stream may have no adverse effects in another. Therefore, appropriate water-quality criteria for nutrients may vary from stream to stream.

STATUS: Concentrations of TN and TP are higher in the urban-river region than near the head of tide, and they decrease as you get closer to the mouth of the Bay. Current nutrient concentrations do not typically cause harmful algal blooms or excessively low DO in the Estuary, making it difficult to determine whether current concentrations warrant regulatory control.

TRENDS: Long-term data from a station in the Upper Estuary showed a very large phosphorus decrease by 1980. This was due to improvements in sewage treatment and the discontinuation of phosphorus detergents. A similar, but smaller nitrogen decrease was observed by 1990. Although nutrient levels in the Delaware Estuary remain very high compared with other estuaries, concentrations are stable and there is currently no evidence of major effects resulting from nutrients.

ACTIONS AND NEEDS: The regional science and management community, led by each state in the Estuary and the Delaware River Basin Commission, need to continually define the relationships among nutrients, water clarity, algal growth, and DO to determine what TN and TP concentrations and water-quality criteria will protect aquatic resources in the Delaware Estuary. Furthermore, we need to understand how the balance and chemical forms of nutrients may affect natural resources, because eutrophication may not be the only environmental impact of high nutrient concentrations.

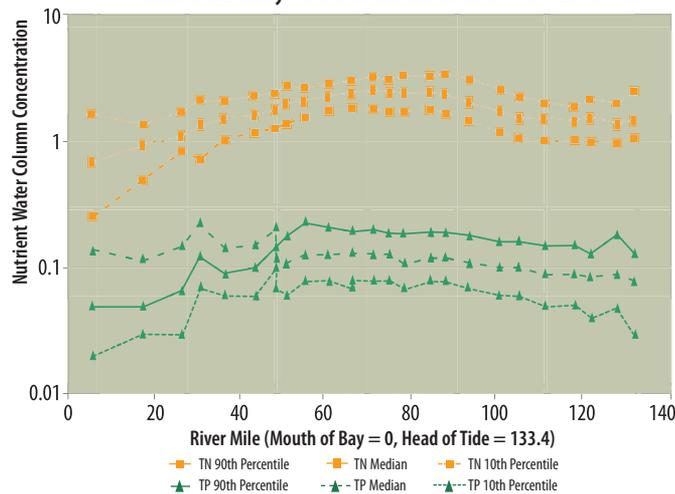


Pollution is discharged from a point-source drain into Shellpot Creek in Northern Delaware. This orange color is usually indicative of iron oxide.

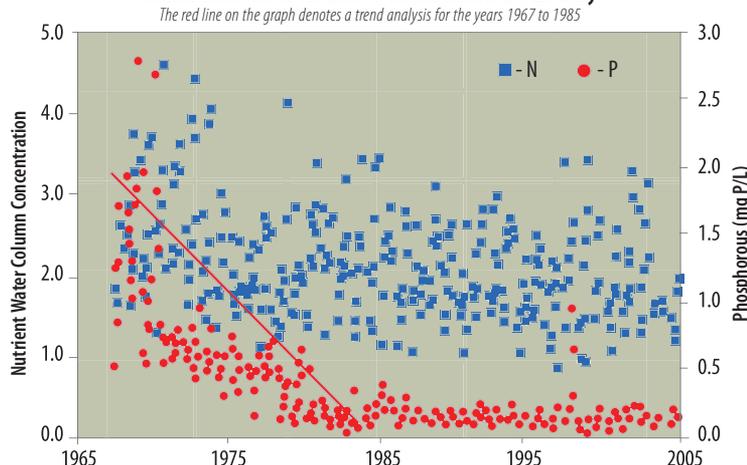
Boat Sampling Locations



Delaware Estuary Nutrient Concentrations 1990-2005



Concentrations of TN and TP in the Delaware Estuary



Credit: Delaware River Basin Commission

Suspended Solids



INDICATOR DESCRIPTION: Total suspended solids (TSS), turbidity, and chlorophyll-a are distinct but related indicators pertaining to suspended particulate concentrations found in the water that provide information on a water body's overall health. TSS measures the total amount of particulate solids (i.e., living, non-living, organic, and inorganic particles) per unit volume of water. Turbidity is an optical property of water where particles and colloidal matter from living and non-living sources cause light to scatter, rather than pass through the water column. Chlorophyll-a is a photosynthetic pigment found in plants, and its concentration indicates how much phytoplankton is in the water. Phytoplankton is an important food for animals such as oysters. The non-living component of suspended solids is largely inorganic sediment, and much of this material gets deposited in tidal marshes, providing a critical sediment "subsidy" that helps them accrete vertically and keep pace with sea level rise. However, in disturbed systems, phytoplankton and TSS can become too concentrated, causing high turbidity and the alteration of natural processes. Excessive turbidity can impair bottom plants by filtering out sunlight needed for photosynthesis. Therefore, these three measurements provide some indication of a water body's ecological status and overall health, especially related to eutrophication.

STATUS: In the Delaware Estuary, TSS concentrations and turbidity are naturally high in the "turbidity maximum" in the Middle Estuary, where freshwater and seawater mix. In other areas, TSS and turbidity are comparatively low. Turbidity levels are well below the water-quality criteria set by the Delaware River Basin Commission (DRBC) that would indicate impairment. Chlorophyll-a concentrations also vary widely, but neither chlorophyll-a or TSS levels are currently regulated by DRBC.

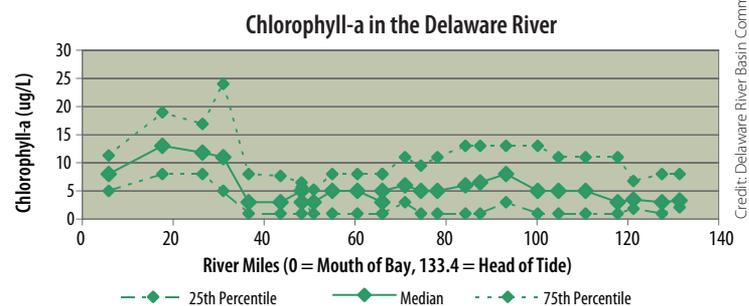
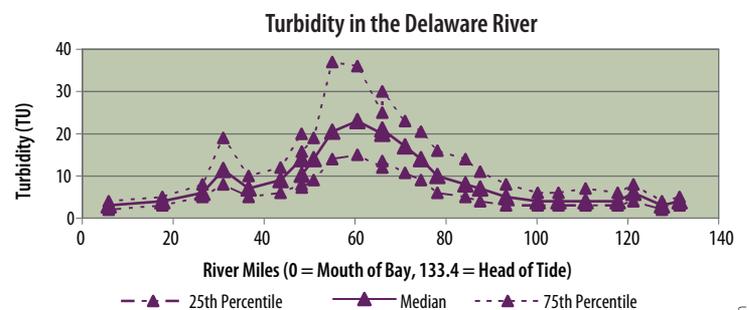
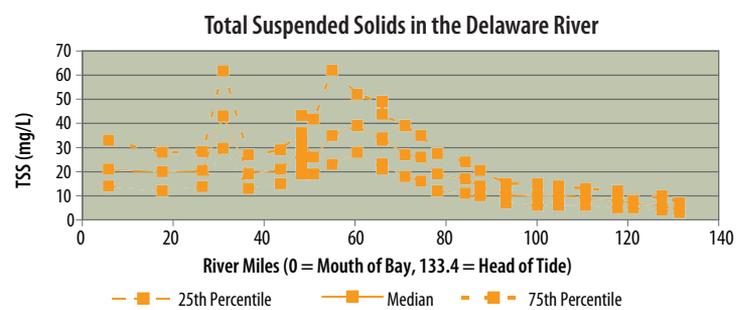
TRENDS: TSS, turbidity, and chlorophyll-a concentrations change with location, temperature, season, and tidal and freshwater flows. Therefore, identifying specific trends in concentrations is very difficult. Overall, these indicators appear to be stable throughout the period from 1990 through 2005.

ACTIONS AND NEEDS: Given that suspended matter forms and concentrations are important for a multitude of ecosystem processes, enhanced efforts to monitor and potentially manage TSS, turbidity, and chlorophyll-a will help ensure good water quality in the Delaware Estuary while enhancing our understanding of the ecosystem's food web and sediment budget.



A steady supply of suspended sediment, visible in this photograph taken from space, is important for sustaining tidal marshes.

Credit Rutgers University



Credit: Delaware River Basin Commission

Fast Fact

The number-one threat to water quality in the Delaware Estuary is stormwater runoff pollution. This occurs whenever rain or melted snow washes pollutants off the land into storm drains that empty into waterways.



Eagles

Haliaeetus leucocephalus



INDICATOR DESCRIPTION: The bald eagle is the only eagle unique to North America, and it is the national symbol of the United States. Besides their ecological value as top predators, bald eagles appear on U.S. currency and are the mascot of the popular, local football team, the Philadelphia Eagles. The Bald Eagle Protection Act of 1940 prohibited shooting or harming these birds, but this protection did not prevent dangerous pesticides from damaging their eggs. By the 1960s only about 400 breeding pairs of bald eagles remained in the lower 48 states, and in 1967 they were declared an endangered species. After DDT, or dichlorodiphenyltrichloroethane, was banned in 1972, bald eagles launched an amazing comeback, and by 1995 their status was upgraded from endangered to threatened. With more than 6,000 breeding pairs, the U. S. Fish and Wildlife Service recently removed the bald eagle from the nation's endangered species list.

STATUS: Bald eagle populations are in good condition in the Delaware Estuary's watershed. In 2007, a pair of bald eagles established a nest near the confluence of the Schuylkill and Delaware Rivers in South Philadelphia. This pair may be the first nesting bald eagles within the city limits since colonial times.

TRENDS: The return of the bald eagle to the Delaware Estuary's watershed is an astonishing success story. Bald eagle nests have increased significantly in all states in the region. In 2004 for example, 96 nests were spotted in the Basin, up from 44 in 2001. Some fluctuation from year to year can be expected, but the overall trend is positive.

ACTIONS AND NEEDS: Fish constitute the bald eagle's main diet, making continued efforts to protect water quality and prevent compounds (i.e., DDT) from getting into the environment important for maintaining the Delaware Estuary's growing bald eagle population. Although problems associated with pesticides have improved, development pressures continue to threaten the bald eagle's nesting and foraging habitats, and so diligent habitat protection is needed.

A pair of bald eagles tends to their nest high above the Pennsylvania habitat they call home.

Credit: Pennsylvania Game Commission / Hal Korber.

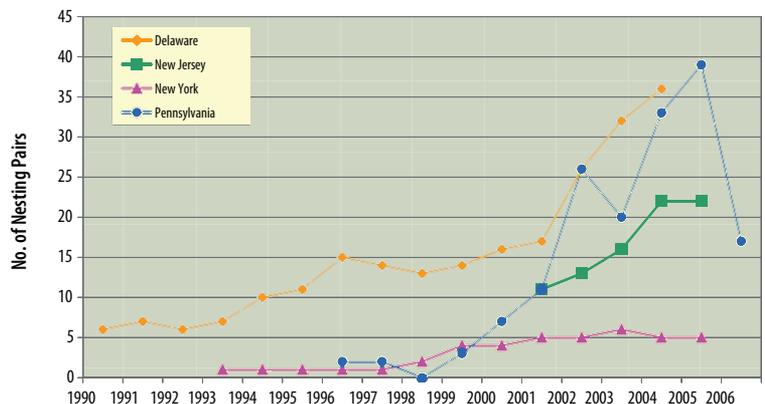


A bald eagle surveys its habitat in the Maurice River Watershed of Southern New Jersey, an area that is home to more than half the state's threatened species.

Credit: Jane Morton Galetto, Citizens United to Protect the Maurice River and Its Tributaries



Population of Bald Eagle Nesting Pairs in Delaware River Basin



Credit: Technical Summary of the Delaware River Basin, Water Resources Agency, University of Delaware

Fast Fact

Eagles need large trees near rivers, lakes, and wetlands to support their massive nests. After years of use, these nests can weigh up to 2,000 pounds and reach almost 10 feet across.

Brook Trout

Salvelinus fontinalis

POSITIVE

INDICATOR DESCRIPTION: Brook trout are the only trout species native to streams in the Delaware Estuary's watershed. Brook trout thrive in cold-water streams within heavily forested watersheds that have low densities of human population. Once abundant across the Piedmont section of Southeastern Pennsylvania, brook trout are now relegated to headwater areas, such as the Upper Schuylkill Valley. Brook trout are ideal biological indicators because they cannot tolerate most of the watershed changes caused by human development, such as increased sediment loads in spawning areas. Brook trout populations are also sensitive to acid deposition, deforestation, and may be harbingers of climate-change effects.

STATUS: Today, only a few remaining areas of the Delaware Estuary region support native brook trout. Brook trout habitat has been virtually eliminated in urban corridors and greatly reduced elsewhere throughout the Delaware River Basin.

TRENDS: Historic records indicate that the brook trout's range has shifted northward. While this may partly result from the effects of warming conditions on this cold-water species, habitat-based analysis suggests that brook trout have been extirpated, or severely reduced, in the Delaware Estuary's watershed because of land-use change and development associated with increased human populations.

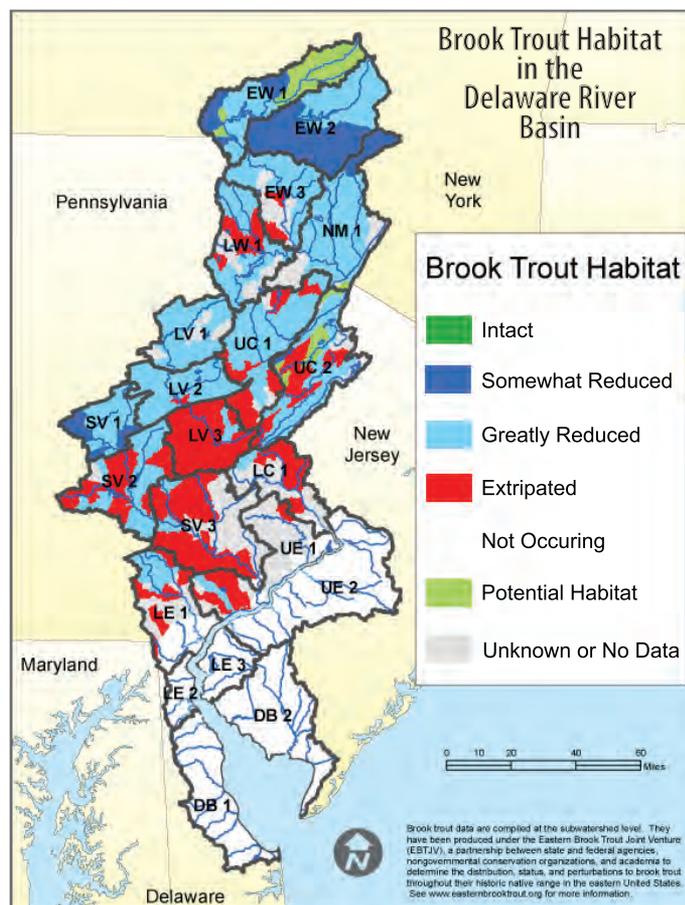
ACTIONS AND NEEDS: As development pressures continue to mount, conservation, restoration, and management attention will be needed, particularly in headwater areas, to safeguard and possibly even reclaim the habitat and water quality required to sustain naturally-reproducing populations of brook trout. As harbingers of human-induced environmental degradation and climate-change impacts, brook trout statistics should be monitored and reported similarly among states in the Basin to foster more accurate use as an indicator in future reports.

NEGATIVE



A brook trout is cataloged as part of the Philadelphia Water Department's ongoing effort to monitor the city's water quality and fisheries.

Credit: Philadelphia Water Department



Credit: Eastern Brook Trout Joint Venture

Fast Fact

Not only is the brook trout the official state fish of both New Jersey and Pennsylvania, but this is also the case in: Michigan, New Hampshire, New York, North Carolina, Virginia, and West Virginia.



Freshwater Macroinvertebrates

INDICATOR DESCRIPTION: Aquatic macroinvertebrates are bugs larger than .5 millimeters (the size of a pencil dot) that are found in lakes, streams, ponds, marshes, and puddles. Macroinvertebrates are important prey for other animals. They also maintain and improve aquatic health by eating bacteria and dead, decaying plants and animals.

Macroinvertebrates are one of the nation's top biological indicators of environmental conditions in freshwater systems. Different taxonomies vary widely in their pollution tolerance, and therefore their presence or absence in a system can be directly related to specific attributes of environmental conditions.

A macroinvertebrate's life cycle can vary from less than two weeks to more than two years, making them particularly useful for tracking short-term changes in water quality. Coupled with information from larger and longer-lived invertebrates, such as crayfish and freshwater mussels, the overall invertebrate assemblage can reveal a great deal about base-of-food-chain conditions.

STATUS: An analysis of macroinvertebrate diversity indicates that water quality and environmental conditions vary widely across the watershed. Unsurprisingly, urban corridors contain the most broadly impaired waters; however, some level of impairment is found within almost all regions of the watershed. The uppermost Basin contains the best conditions, where human population remains low and streams are forested.

TRENDS: No comprehensive data are available for the watershed regarding long-term patterns in macroinvertebrate community conditions. Where stream habitats and wetlands are being restored and riparian buffers strengthened, improvements in macroinvertebrate health can be expected. Scientific studies suggest, however, that overall conditions may decline with continued development and loss of natural habitats.

ACTIONS AND NEEDS: Although all three states in the Delaware Estuary's watershed monitor macroinvertebrates, they report their findings differently, which limits Estuary-wide, watershed-based assessments. Interstate coordination may facilitate standardized, consistent reporting. Similarly, coordination between estuarine and freshwater biological monitoring programs would facilitate ecosystem-based assessment. More trend data are also needed.



An adult female mayfly rests atop a leaf during its brief lifespan of just a few days, during which the absence of pollution is critical.



A scientist with The Academy of Natural Sciences of Philadelphia uses a Surber sampler to capture freshwater macroinvertebrates in the Schuylkill River, near Pottstown.

Credit: R.L. Thomas, Philadelphia Academy of Natural Sciences

Fast Fact

Macroinvertebrates are vital to aquatic ecosystems because they make up the bottom of the food chain, serving as prey for fish, birds, and other large animals.



Freshwater Mussels

POSITIVE

INDICATOR DESCRIPTION: Freshwater mussels are filter-feeding bivalve mollusks that live in lakes, rivers, and streams. Similar to oysters, freshwater mussels benefit water quality, enrich habitats, and furnish other important ecosystem functions. Unlike marine species, freshwater mussels grow more slowly, live longer (50 years or more), and have complicated reproduction strategies dependent on fish hosts. Therefore, freshwater mussels cannot rebound quickly after they become impaired.

As they are sedentary creatures that filter large amounts of water, freshwater mussels are sensitive indicators of water quality and habitat conditions.

Consequently, they lay claim to being the most imperiled taxonomic group in the nation. These long-lived animals are often unable to recolonize their habitats following disturbances due to their complicated life history. The status of freshwater mussels provides different environmental information than macroinvertebrates, the latter of which are good indicators of short-term changes in conditions. The health, reproductive status, population abundance, and species diversity of the mussel assemblage therefore represents an excellent bioindicator of watershed conditions over long periods of time.

STATUS: North America has the world's greatest diversity of native freshwater mussels (more than 300 species), however, more than 75 percent have special conservation status. The leading causes of mussel decline are habitat and water-quality degradation. For example, dams that block fish passage can affect reproduction, gene flow, and may prevent recolonization from adjacent tributaries following disturbance. Of the 12 or more native species in the Delaware Estuary Watershed, even the most common mussel is patchy in abundance and may not be successfully reproducing across much of its range.

TRENDS: The most recent comprehensive mussel survey in the region was conducted in Pennsylvania between 1909 and 1919. Even by that time, dams and water-quality degra-

NEGATIVE



Behold the squawfoot mussel, or *Strophitus undulatus*, one of the many once-abundant filter-feeders that is currently in decline in the Delaware Estuary's streams and rivers.

Common Name	Scientific Name	State Conservation Status		
		DE	NJ	PA
Dwarf Wedgemussel	<i>Alasmidonta heterodon</i>	Endangered	Endangered	Critically Imperiled
Triangle Floater	<i>Alasmidonta undulata</i>	Extirpated	Threatened	Vulnerable
Brook Floater	<i>Alasmidonta varicosa</i>	Endangered	Endangered	Impaired
Alewife Floater	<i>Anodonta implicata</i>	Extremely Rare	No Data	Extirpated ?
Eastern Elliptio	<i>Elliptio complanata</i>	Common	Common	Secure
Yellow Lampmussel	<i>Lampsilis cariosa</i>	Endangered	Threatened	Vulnerable
Eastern Lampmussel	<i>Lampsilis radiata</i>	Endangered	Threatened	Imperiled
Green Floater	<i>Lasmigona subviridis</i>	No Data	Endangered	Imperiled
Tidewater Mucket	<i>Leptodea ochracea</i>	Endangered	Threatened	Extirpated ?
Eastern Pondmussel	<i>Ligumia nasuta</i>	Endangered	Threatened	Critically Imperiled
Eastern Pearlshell	<i>Margaritifera margaritifera</i>	No Data	No Data	Imperiled
Eastern Floater	<i>Pyganodon cataracta</i>	No Data	No Data	Vulnerable
Squawfoot	<i>Strophitus undulatus</i>	Extremely Rare	Species of Concern	Apparently Secure

This chart shows the state conservation status of freshwater mussel species that were historically documented from the Delaware Estuary and River Basin. Gray-shaded cells indicate that these mussels may never have been found in that state. Note the different status descriptions used among the three states.

dition may have impaired mussel communities. Nevertheless, the study provided an excellent benchmark for gauging mussel losses for the past 90-plus years. State surveys and recent anecdotal information suggest that all native mussel species in the region are impaired to some degree, with most being severely depressed or extirpated altogether.

ACTIONS AND NEEDS: More proactive monitoring is needed to assess the species presence and population health of freshwater mussels across the entire Delaware River Basin. Improved coordination and data sharing among states and the Partnership for the Delaware Estuary would greatly facilitate indicator development and watershed restoration planning.

Fast Fact

The Partnership for the Delaware Estuary is currently devising methods to reintroduce mussels into waterways where they once flourished, like the Brandywine River, Chester Creek, and White Clay Creek.



Fish Passage

POSITIVE

INDICATOR DESCRIPTION: The main-stem Delaware River is the longest free-flowing river east of the Mississippi, and it supports a high-quality Upper Basin ecosystem. The story is much different in the tributaries, particularly in the Delaware Estuary region, where dams were historically built for water power, agricultural use, municipal supply, and recreational purposes. Dams create ecological problems by changing water flow and stream habitats, and preventing fish (e.g., shad) from completing their upstream spawning migrations. Today, a nationwide effort is underway to remove obsolete dams or install fish passage systems that restore historic migratory fish runs and reconnect resident aquatic populations.

TRENDS: In Delaware and New Jersey, numerous fish ladders have been constructed along coastal plain tributaries with broad support from state and federal agencies, municipalities, and corporations. In Pennsylvania, several dams were recently removed in the Schuylkill River Watershed and along Pennypack Creek in Philadelphia. In the Brandywine River, the Brandywine Conservancy is working to install fish passages and remove dams. Since 1991, fish ladders have opened approximately 165 river miles for fish migration in the Estuary's watershed.

ACTIONS AND NEEDS: Efforts have mounted across the region to remove obsolete, hazardous dams and provide fish passage. These efforts to reconnect the watershed's freshwater systems are ecologically beneficial for other native fauna and flora, not just fish. New approaches should continue to be explored and implemented to facilitate fish passage, such as dam notching, constructing rock ramps, and removing or redesigning tide gates. A more coordinated watershed approach to reconnecting aquatic ecosystems may further enhance fish passage improvements across the Estuary.

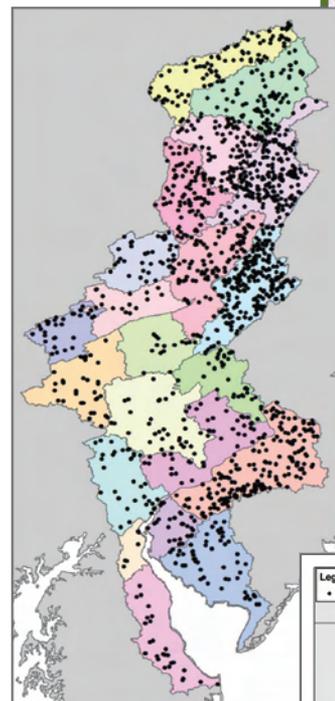
NEGATIVE



This small dam at the Brookside Country Club in Pottstown, Pennsylvania, was partially removed to allow fish passage as part of a stream-restoration project funded by the Schuylkill Watershed Initiative Grant.

Credit: Dave Williams, Delaware Riverkeeper Network

Spectators watch with interest as a hydraulic hammer is used to demolish a dam on the Manatawny Creek in Pottstown, Pennsylvania, in August of 2000.



Current Dam Locations Within the Delaware River Basin



Dam Locations in 1900, Before Their Proliferation in the 20th Century

Anadromous fish (e.g., American shad and sturgeon) live in the ocean and return to the river of their birth to spawn. Catadromous fish (e.g., American eel) live in freshwater and spawn in salt.

Fast Fact

Fish ladders are installed so that fish can swim or jump into waters upstream of a dam. To see one live via Webcam, please visit www.FairmountWaterWorks.com/FishCam.php.

Credit: Bareille 2007

Shad

Alosa sapidissima



INDICATOR DESCRIPTION: The American shad is the largest North American member of the herring family. The shad is an anadromous fish that migrates each spring to the Delaware Estuary's watershed to spawn. Between 1880 and 1890, fishermen in the Delaware River caught 10 to 20 million pounds of shad annually. Around 1910, shad numbers began to decline rapidly, and populations were so low by 1920 that shad fisheries were no longer a viable industry. Overfishing, dammed spawning tributaries, and degraded water quality, such as low dissolved oxygen levels, were the principal factors in the shad's decline. As a once-abundant fish that travels between tidal and non-tidal areas of the watershed, shad represent a valuable indicator of environmental conditions in the Delaware Estuary and Basin.

STATUS: Today, the Delaware River supports a viable commercial and sport shad fishery, but harvests are small compared to historic benchmarks. In 1896 over 14 million pounds of shad were caught, valued at \$10 million in 2006. Although current populations cannot sustain that level of harvest, the economic value of today's recreational fishery is nearing levels reported more than 100 years ago. In 1996, for example, the economic value of the shad sport fishery in the Delaware was estimated at \$3.2 million.

TRENDS: Once blocked by a lack of oxygen, shad now move more freely through the tidal freshwater zone during spawning runs. Sewage facility upgrades improved water quality and increased dissolved oxygen, which helped shad return to the Estuary. Still, shad abundance is low, even compared with numbers from the 1990s. Pennsylvania leads the nation in removing obsolete dams, and fish ladders are being installed throughout the Estuary. These efforts have reopened approximately 165 stream miles for shad migration.

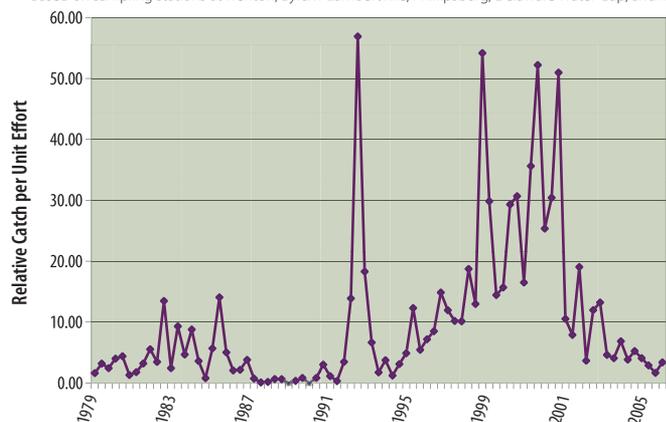
ACTIONS AND NEEDS: Increases in the shad population in the Delaware Estuary should continue if water quality and fish passage are continually maintained or improved (e.g., by removing dams and installing fish ladders). Habitat conditions in the spawning reaches of tributaries must also be maintained and monitored.



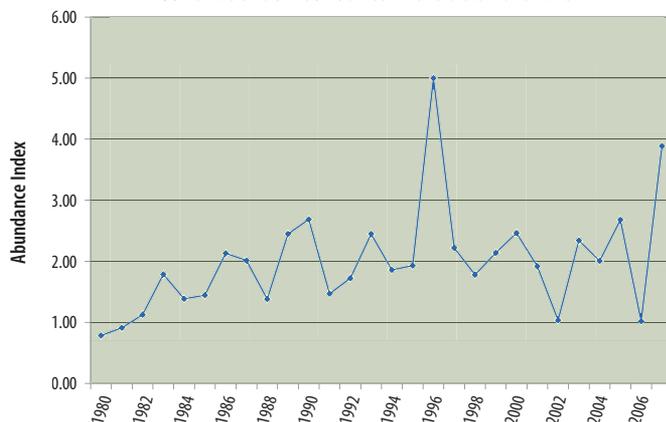
Joe Perillo of the Philadelphia Water Department's Office of Watersheds displays an American shad just downstream from the Fairmount Dam on the Schuylkill River.
Credit: Philadelphia Water Department

Number of Shad Collected Along the Delaware River

Based on sampling stations at Trenton, Byram-Lambertville, Phillipsburg, Delaware Water Gap, and Milford



Juvenile Shad Abundance in the Delaware River



Credit: Atlantic States Marine Fisheries Commission

Fast Fact

The Fishtown neighborhood of Philadelphia was so named because of its status as the center of the shad-fishing industry on the Delaware River in the 1800s.



Atlantic Sturgeon *Acipenser oxyrinus*



INDICATOR DESCRIPTION: The shortnose and Atlantic sturgeon are long-lived species that spend at least part of their life cycle in the Delaware Estuary. The shortnose is currently an endangered species, but the Atlantic sturgeon may be even more imperiled and is the focus here as an environmental indicator. The Atlantic sturgeon is an ancient fish that, when abundant, can represent an important bottom consumer in large eastern rivers. The Delaware Estuary was once the hub of the American sturgeon fishery, having the largest population of Atlantic sturgeon in the world. Record harvests and the virtual elimination of spawning and nursery habitats, combined with poor water quality and low reproduction, likely caused the population collapse during the late 1800s. Still, as recently as 1986 an adult female sturgeon was valued at \$3,000 per fish for its caviar.

STATUS: The population of shortnose sturgeon in the Delaware Estuary currently appears stable at about 13,000 fish, despite being listed as an endangered species. Today's numbers of Atlantic sturgeon, on the other hand, are estimated to be less than 1,000 and probably less than 100 across the Estuary. The Atlantic sturgeon is on the endangered species list in Delaware and it may be a good candidate for federal listing.

TRENDS: The Atlantic sturgeon was nearly fished to extinction over a century ago and they have not yet rebounded despite increasing management attention and harvest restrictions. In 1991, a seven-foot size minimum was adopted, and by 1998 a complete harvest moratorium was imposed.

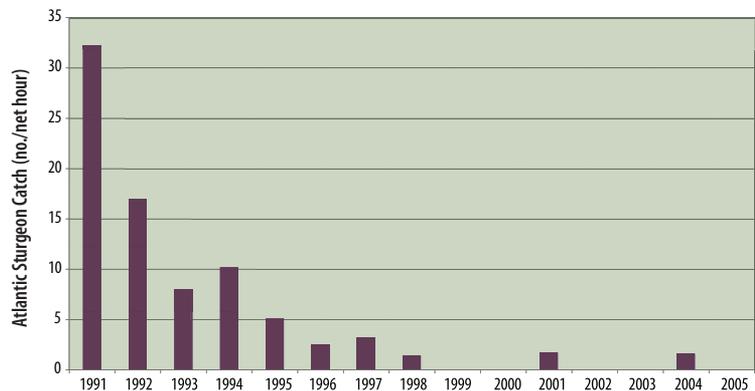
ACTIONS AND NEEDS: Scientists have stepped up their studies of sturgeon population dynamics and ecology. Telemetry indicates that sturgeon use main-channel habitats, but large alterations such as dredging may have changed salinity and bottom habitats, causing sturgeon to spawn further upstream from their historic reaches. This, coupled with boat strikes and by-catch incidents, are thought to be impeding their recovery. A better understanding of these relationships is needed for sturgeon restoration and management, and for their full indicator potential to be realized.



Undergraduate research assistants Kelvin Barthelmeh (left) and Brandon Martin (center), along with graduate student Phil Simpson (right), haul in a sturgeon as part of their studies at Delaware State University.

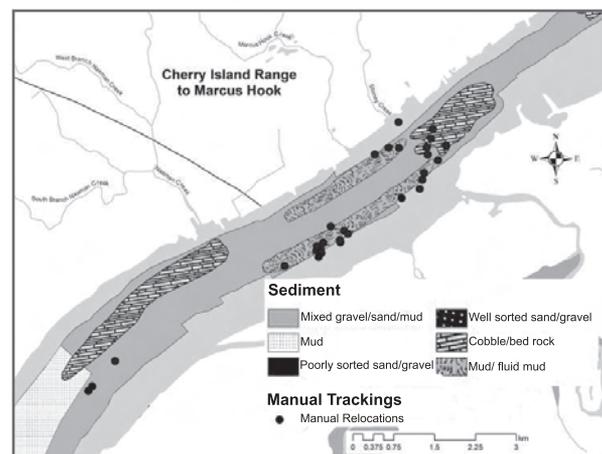
Credit: Delaware State University

Annual Catch Rates of Atlantic Sturgeon Collected in the Delaware River From 1991-2005



Credit: Technical Summary of the State of the Delaware River Basin, Water Resources Agency, University of Delaware

Sediment Substrate and Tracking Locations of the Atlantic Sturgeon in the Delaware Estuary in 2006



Credit: Fox and Simpson, 2006

Fast Fact

If you find an Atlantic sturgeon with a tag attached, please report the tag number to researchers at the Delaware Division of Fish and Wildlife by calling (302) 653-2887.

Striped Bass and Weakfish

Morone saxatilis and *Cynoscion regalis*



INDICATOR DESCRIPTION: As premiere sport fish and top predators in the aquatic food web, striped bass and weakfish are economically and ecologically important in the Delaware Estuary. The striped bass is a large anadromous species that lives mostly in the ocean and Estuary but spawns in freshwater. They are found throughout the tidal ecosystem from spring to fall, and are sought-after game fish from Philadelphia to the lower Bay. The weakfish is Delaware's state fish, and it uses the Bay and its tidal tributaries as summer breeding and feeding grounds.

STATUS: The return of the striped bass to the Delaware Estuary is a success story. Fishery-management decisions that span the Mid-Atlantic region, combined with water-quality improvements in the Delaware Estuary, have returned striped bass stocks back to highs not seen in over 50 years. In contrast, weakfish numbers have declined somewhat in recent years after being higher from 1994 to 2002. Striped bass abundance may suppress weakfish through competition and predation.

TRENDS: Striped bass were nearly eliminated from the Estuary by the 1940s. Low dissolved-oxygen levels prevented them from migrating past the oxygen block to reach their spawning grounds. A dramatic decline in the late 1970s led to a fishery closure, which also helped the striper's resurgence in the region. Survival of striped bass larvae also improved with upgrades in wastewater treatment into the 1980s. In comparison, weakfish populations have been more stable. In the 1980s, trawl surveys yielded less than 50 weakfish per mile. In the 1990s, more than 50 were caught per mile with a peak of over 200 in 2000. By 2005, numbers were back down to less than 50 fish per mile, possibly due in part to increased striped bass numbers.

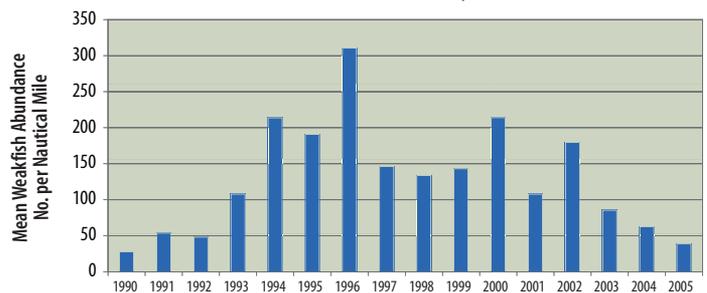
ACTIONS AND NEEDS: The apparent inverse relationship between striped bass and weakfish shows how finfish population dynamics may affect each other. More study of how their life histories interrelate under different environmental and climate conditions would help predict future status and trends.



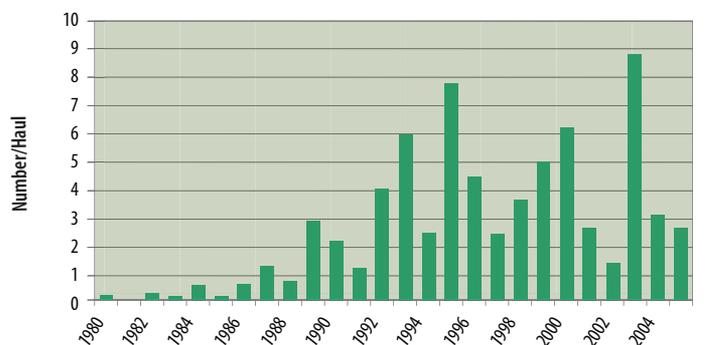
A large striped bass is caught and then released into the tidal Schuylkill River by Fisheries Biologist, Joe Perillo, of the Philadelphia Water Department.

Credit: Philadelphia Water Department

Mean Weakfish Abundance 1990-2005 Delaware Estuary



Delaware River Striped Bass Juvenile Index



Credit: Technical Summary of the State of the Delaware River Basin, Water Resources Agency, University of Delaware

Fast Fact

The Delaware Estuary and its tributaries provide habitat for more than 200 species of fish.



Shorebirds

Each spring close to a million shorebirds descend on Delaware Bay prior to resuming their northward migrations. Common sightings include red knots, dunlins, ruddy turnstones, sanderlings, and semi-palmated sandpipers, just to name a few. Of these, the red knot is perhaps the best known shorebird in the Delaware Estuary. The National Audubon Society describes these as champion, long-distance migrants, a title that is well deserved given their annual round-trip flights between breeding grounds in the Arctic and wintering grounds in South America.

During their spring migration, red knots depend on the eggs of horseshoe crabs, which are deposited in the billions on the Bay's sandy shores. Successive pulses of spawning horseshoe crabs, along with wind and wave action, help bring a portion of these eggs to the beach's surface. There they are eaten by shorebirds in an effort to put on fat they later burn as fuel during their transcontinental journey.

Aerial surveys conducted in Delaware Bay and South America, along with counts made in Canada, all show that shorebird populations, particularly the red knot, have declined during the past 30 years. In the 1980s, for example, up to 100,000 red knots descended on Delaware Bay, but in 2006 they numbered less than 13,500. Several factors could be playing a role in this decline, and there is uncertainty concerning the risk each factor may be contributing.

Other factors affecting shorebird survival include delayed migration, die-offs in other parts of their ranges, and habitat suitability. At their current low numbers, the shorebird population is more vulnerable than ever to extinction. One model of survival has predicted extinction within the next five years if survival rates do not improve. For these reasons, the "U.S. Shorebird Conservation Plan" lists red knots as a "Species of High Concern."

Due to uncertainty surrounding the decline of shorebirds, a risk-averse approach and continued monitoring are essential. Collaboration among scientists and resource managers is also critical as we strive to better understand the factors leading to the decline of all shorebirds.

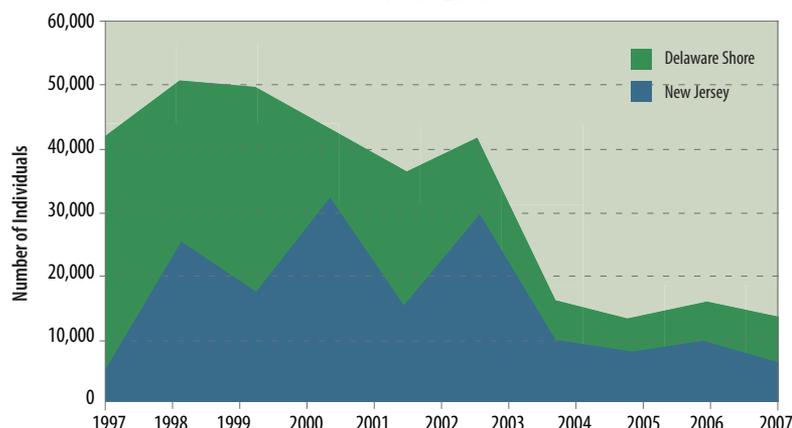
The most important factor for shorebirds migrating to the Delaware Bay is food supply. Weight gained at Atlantic stopovers affects the shorebird's breeding success and survival. In the 1990's the horseshoe crab spawning population declined due to overharvest, which in turn reduced the Bay's available egg supply for migrating shorebirds.



A red knot (number "KM3" according to its tag) searches the sands of Delaware Bay for high-protein foods such as horseshoe crab eggs.

Credit: Gregory Breese, U.S. Fish and Wildlife Service

Peak Counts of Red Knots on the Delaware Bay Migratory Stopover 1997 - 2004



Credit: New Jersey Department of Environmental Protection

Since 2000, horseshoe crab harvest restrictions have been imposed, a sanctuary has been established, and watermen have reduced their use of horseshoe crabs as bait. Despite these efforts, it takes 9 to 12 years for horseshoe crabs to reach spawning age, so food supply for shorebirds has not yet increased substantially.

Fast Fact

The Delaware Estuary is the largest stopover for shorebirds in the Atlantic flyway and the second-largest staging site in North America.

Horseshoe Crabs

Limulus polyphemus



INDICATOR DESCRIPTION: The Delaware Estuary's signature resource, commercially and ecologically, is the horseshoe crab, whose population health is one of our region's most important environmental indicators. Delaware Bay is home to the world's largest spawning population of horseshoe crabs, which are also the State of Delaware's official marine animal. More closely related to spiders than crabs, they have seen few physical changes in the past 350 million years. These arthropods' hard, curved shell defends a soft underbelly and protects a body able to survive for up to a year without eating. Economically viable, they are used as bait by watermen and their blood has important pharmaceutical uses for testing medications and biomedical devices. The horseshoe crab's greatest importance, however, is ecological. Their sheer abundance makes them an important consumer along the bottom where they prey on marine worms, bivalves, and other infauna. Their eggs get deposited on beaches and are a draw as a food source for migrating shorebirds such as the red knot, which is a candidate for the endangered species list.

STATUS: The horseshoe crab population appears to be robust and stable, but reduced in numbers from historic levels. Also, current population levels are not high enough to support historic levels of shorebirds during the spring stopover. There are indications that management actions to limit harvests combined with voluntary reductions in bait use by watermen are allowing the population to increase. Because horseshoe crabs are long-lived and do not reproduce until at least eight-to-12 years old, it can take a decade or more for management actions to result in a measurable increase in the spawning population.

TRENDS: Little data is available for measuring trends prior to 1990, but the population probably declined in the early 1900s due to overharvest and then increased through the 1970s. Bait overharvest led to another decline in the 1990s, followed by stability and recovery in the late 1990s and early 2000s. Baywide female spawning activity has remained stable since 1999, whereas male spawning activity has significantly increased for the same period. Since males mature earlier, this increase in males may signal an increase in females to come.

ACTIONS AND NEEDS: Continued monitoring and management in Delaware and New Jersey are needed to benefit horseshoe crab populations. New Jersey currently has a harvest moratorium, while Delaware allows only limited harvests of males. Habitat restoration projects would also benefit horseshoe crab spawning and



Horseshoe crabs swarm the beaches near Milford, Delaware, in an effort to deposit and fertilize their eggs, otherwise known as spawning.

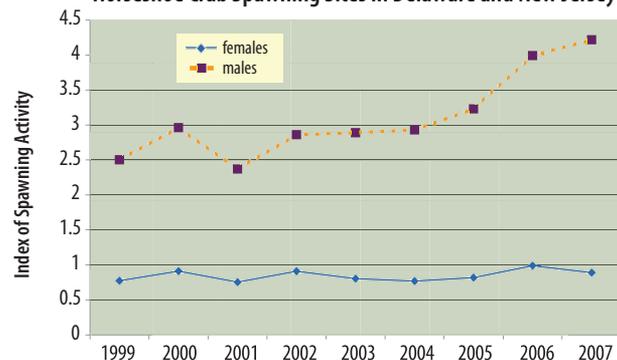
Credit: Gregory Breese, U.S. Fish and Wildlife Service

Horseshoe Crab Spawning Sites in Delaware Bay



Credit: U.S. Geological Survey

Horseshoe Crab Spawning Sites in Delaware and New Jersey



Credit: Michels et al., 2008

could potentially increase the number of eggs available for shorebirds. Since horseshoe crabs are both a commercially and ecologically important species, a natural capital assessment would also be beneficial.

Fast Fact

The waters of Delaware Bay are home to the largest breeding population of horseshoe crabs in the world.



NATURAL RESOURCES

Blue Crabs *Callinectes sapidus*



INDICATOR DESCRIPTION: The Atlantic blue crab is one of the Delaware Estuary's most popular natural resources and a local favorite of seafood lovers. Blue crabs are the most economically important shellfishery in the Estuary. Juvenile and adult blue crabs inhabit the entire Estuary, even the tidal freshwater areas of Philadelphia. Adult males prefer low-salinity areas upstream, while females congregate in the high-salinity areas where spawning takes place. During warmer months, the crabs live in both shallow and deeper water, but in winter they migrate to deep channels where they borrow into the mud. Blue crabs are ecologically important predators, and juveniles are also prey for eels, striped bass, and weakfish. Due to both their ecological and economic importance, blue crab population health is indicative of regional environmental conditions.

STATUS: In 2005, 70,000 bushels of crab yielded \$3.4 million in Delaware. Even greater harvests occur in New Jersey, where more than 2 million crabs are caught recreationally each year. Old-fashioned crab houses still dot both sides of the Bay, attracting tourists and locals alike. Blue crabs are hardy animals, and their continued success can be attributed to their tolerance of stressful conditions, rapid growth, frequent spawning, and high numbers of larvae that disperse widely. Further, crabs can quickly recover following major disturbances.

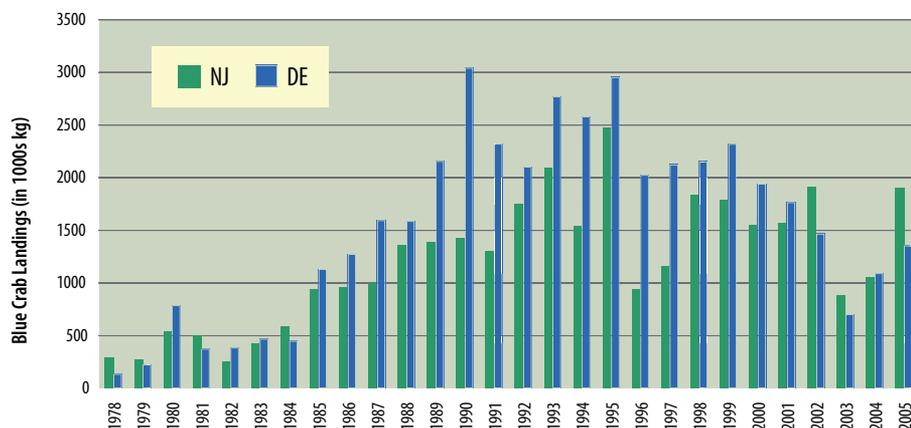
TRENDS: Harvest numbers are useful indicators of population status. After major increases in blue crab landings in the mid-1980s, harvests dropped in the late 1990s and early 2000s, with a low point occurring in 2003 due to winterkill resulting from a severe winter. In recent years, harvests have rebounded across the Estuary. Scientists have suggested that these stock improvements might be attributed to the reduced frequency of severe winters that can cause high winter mortality.

ACTIONS AND NEEDS: State fisheries managers have successfully monitored and managed blue crab populations in the Estuary, providing a model for other natural resources. Hence, it is important to continue these efforts.



Children prepare to race blue crabs at the 2007 Delaware Bay Days festival, an event that is hosted annually by the Bayshore Discovery Project in Bivalve, New Jersey.

Blue Crab Landings in the Delaware Estuary 1978-2005



Credit: Technical Summary of the State of the Delaware River Basin, Water Resources Agency, University of Delaware

Fast Fact

The scientific name for blue crab is *Callinectes sapidus*. *Callinectes* translates to "beautiful swimmer," which stems from the crab's ability to swim sideways. *Sapidus*, on the other hand, requires no explanation. It means "savory."

Oysters

Crassostrea virginica

POSITIVE

DESCRIPTION: Eastern oysters are a nutritious food and an important fishery in Delaware Bay. In 1887, about 1,400 sailing vessels harvested approximately 1.5 million bushels, or 22 million pounds of oysters. Today, harvests deliver about 100,000 bushels with a dockside value of \$3 million to \$5 million, but efforts are under way to boost those numbers. Oysters also provide important ecosystem services by creating reef habitats for fish and other organisms, filtering water, recycling nutrients, and stabilizing sediments. However, these filter-feeders can be sensitive to degraded water conditions. Like other bivalve mollusks, oysters are world-renowned as excellent bioindicators of environmental conditions.

STATUS: Although only a fraction of their historic size, today's oyster populations are carefully managed to maintain and increase abundance through the interplay of harvest, oyster disease mortality, and recruitment. Fortunately, oysters in Delaware Bay have developed some resistance to MSX disease, which devastated the population from 1957 to 1986. However, Dermo disease has been a persistent problem since 1990, especially in the lower Bay's high-salinity waters. After an unprecedented seven years of low "recruitment" by juvenile oysters (a.k.a., spat), 2007 marked a return to average levels.

TRENDS: Oyster abundance was not accurately assessed before the 1950s, but landings data suggest that populations are a fraction of their historic size in the 19th and early 20th Centuries. Seed-bed data indicate that current abundance is 39 percent of the 1953 to 2007 long-term average and 78 percent of the 1989 to 2007 short-term average. While recruitment in 2007 was 54 percent of the long-term average, it represents 135 percent of the short-term average. In fact, populations in Upper Delaware Bay remain relatively robust. Therefore, it is likely the oyster population will continue to support commercial harvests.

ACTIONS AND NEEDS: Oyster population health and recruitment are presently monitored over the New Jersey seed beds by Rutgers University, with Delaware seed beds being monitored by the Delaware Department of Natural Resources and Environmental Control. While current monitoring is satisfactory, a comprehensive program is needed, along with continued study of both oyster biology and food supplies. Meanwhile, careful attention should be paid to the effects of climate change on salinity. Recent estimates also show that shell-planting activities are crucial to maintaining and enhancing the oyster resource.

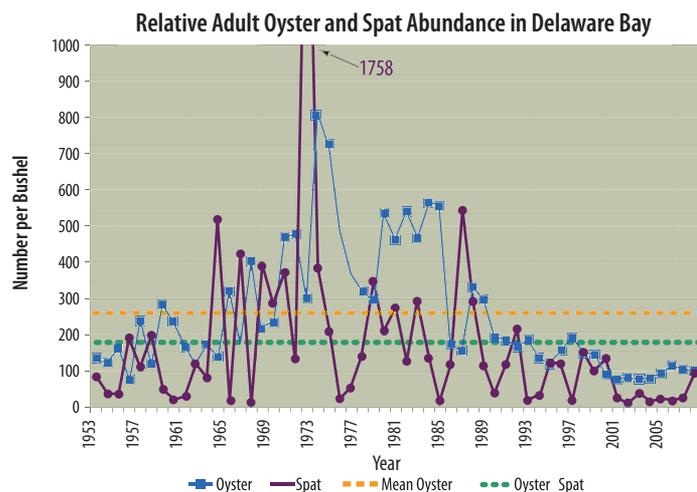
NEGATIVE



Surf clam, ocean quahog, and oyster shells are deposited, or "planted," into Delaware Bay by the Delaware Bay Oyster Restoration Task Force in June of 2006.



Oyster Seed-Bed Locations in Delaware Bay



Credit: John Kraeuter and Dave Bushek Rutgers University's Haskin Shellfish Research Laboratory

Fast Fact

The annual harvest of Eastern oysters from the Delaware Estuary exceeds \$1.5 million in market value. This represents a fraction of the revenues watermen raked in one century ago.



NATURAL RESOURCES

Tidal Wetlands



INDICATOR DESCRIPTION: Coastal wetlands are one of the Delaware Estuary's most important and characteristic habitats, and they are a premier environmental indicator for the area's ecosystem. The Estuary has one of the largest freshwater tidal prisms in the world running from Trenton, New Jersey, to approximately Wilmington, Delaware. The gradual transition from fresh to salt water allows for abundant and rare freshwater tidal wetlands in the Upper Estuary, brackish marshes in the Middle Estuary, and salt marshes surrounding Delaware Bay. Together, these marshes form a nearly continuous perimeter fringing the tidal system. Tidal wetlands furnish essential spawning, foraging, and nesting habitat for fish, birds, and other wildlife. These wetlands are considered by many scientists to function like the ecosystem's "kidneys," absorbing contaminants, nutrients, and suspended sediments. Other scientists regard them as "fish factories" that are crucial to the success of important finfisheries. They also provide a first line of defense against storm surge and flooding. Acre for acre, tidal wetlands likely provide more ecosystem services than any other habitat type in the region.

STATUS: A 1992 to 2001 land cover data comparison (for both tidal and non-tidal wetlands combined) showed wetland loss throughout the Estuary, except along the New Jersey side of Delaware Bay where extensive marsh restoration may have offset this trend (see map). During the preceding decade, a more in-depth analysis showed that Delaware's tidal marshes dropped by 12 percent and the proportion of marshes with degraded conditions almost doubled.

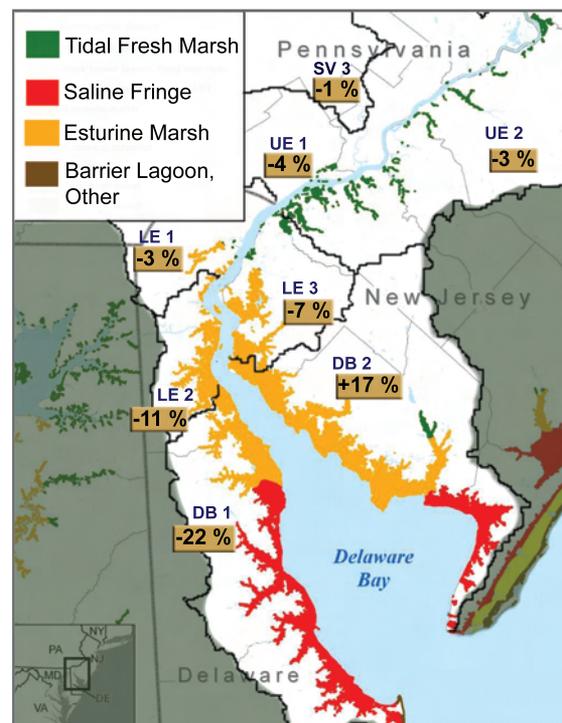
TRENDS: For over 300 years, the extent and integrity of tidal wetlands has been under assault across the Estuary. Perhaps 50 percent of the natural marshes have been lost to development, conversion, or degradation associated with human activities. Losses have been most severe in the urban corridor where perhaps only five percent of pre-settlement acreage of the nationally rare freshwater tidal marsh remains. Despite proactive laws protecting marshes, a growing awareness of their ecological value, and mounting restoration attention, marsh acreage and condition are still lost from human-caused impairments, land uses, and sea level rise.

ACTIONS AND NEEDS: Tidal wetlands are a hallmark feature of our watershed that suffer continued losses of both area and condition. Coordinated monitoring and assessment programs are urgently needed to regularly and carefully track tidal marsh extent and condition across the three Estuary states. A better scientific understanding is also needed of the factors that govern wetland well-being, such as sediment supply, water quality, and ecology. Studies of their ecosystem services and natural capital value would benefit land-use and regional-restoration planning.



A coconut fiber log is deployed along the edge of a tidal marsh in Bivalve, New Jersey, in an effort to establish a "living-shoreline" reef that may soon protect against erosion.

Relative Change in Wetland Acreage 1992-2001



Please refer to the map on page 31 to view the full range of each region.

Tidal Wetland Buffers



INDICATOR DESCRIPTION: A tidal wetland buffer refers to the type and characteristics of the habitat immediately landward of tidal marshes. Buffers that still exist in a natural, undeveloped state are critical to tidal wetlands and the Delaware Estuary's health because they provide an opportunity for wetlands to migrate landward as the seas rise. Although some sea level rise is natural, tidal marshes will be lost if this natural migration is impeded by man-made barriers. If marshes cannot keep pace with increasing sea level rise, then wetlands will continue to disappear. The condition of tidal marsh buffers is therefore an important environmental indicator because it predicts the watershed's ability to maintain one of its core habitats in the future.

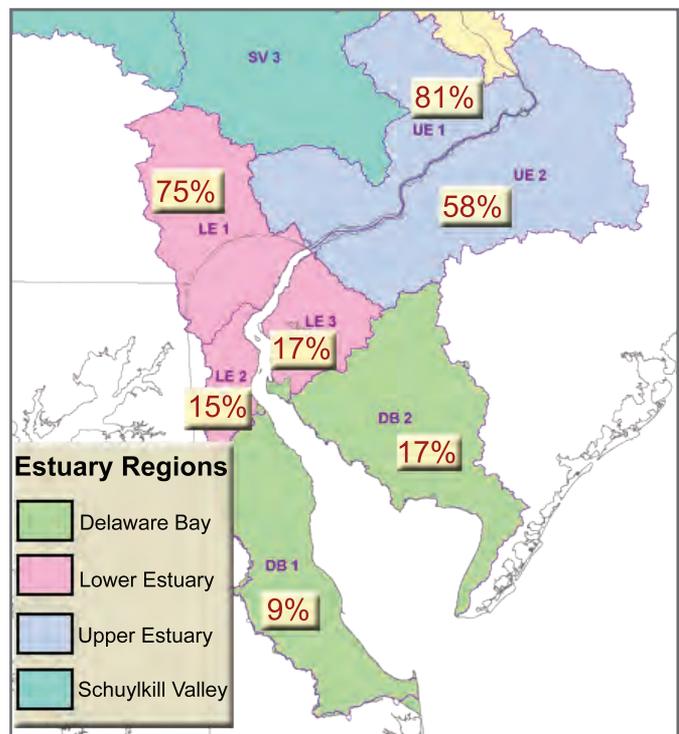
STATUS: The majority of buffer habitat in the Upper Estuary is already developed and unavailable for conversion to tidal marsh. In 1992, only nine percent of Southern Delaware was built out, whereas the Philadelphia area contained the greatest proportion of development in the Estuary at 82 percent. Landward migration of tidal marshes (referred to as transgression) depends on several factors, one of which is slope. A gentler slope is easier for marshes to cross, signifying greater opportunity for landward migration. The Delaware side of Delaware Bay (DB1) has the smallest slope and the most undeveloped lands, representing the greatest potential. The least opportunity exists in the Upper Estuary and urbanized regions where rare freshwater tidal marshes are more threatened.

TRENDS: Although most buffer zones in the Upper Estuary are already developed, human population continues to expand and open space is still being lost. In the Lower Estuary, buffer zones are being lost to development as agricultural lands are transformed into residential properties and infrastructure, such as roads.

ACTIONS AND NEEDS: An analysis of status and trends should be completed often enough to be useful for targeting areas for preservation. New policies and restoration strategies should be developed to facilitate the landward transgression of marshes. Further discussion will be needed to determine how best to manage sea level rise and marsh loss in areas with significant development and infrastructure.



LEFT: An early 1800s map of the Schuylkill and Delaware Rivers shows extensive freshwater tidal marshes. RIGHT: The landward migration of a typical freshwater marsh has been halted by development on all sides. Perhaps less than five percent of the Estuary's original freshwater tidal marshes remain today.



The percentages in each watershed region denote the proportion of land that is unavailable for marsh encroachment due to development in the one-kilometer buffer just landward of tidal marshes.

Fast Fact

A nearly continuous fringe of tidal wetlands lines the eastern and western shores of the Delaware Estuary.



Climate Change: Regional Concerns

Centuries of data indicate that global temperatures are on the rise. The implications of shifting weather patterns; shifting fauna, flora, and ecological processes; and rising seas from melting glaciers and thermal expansion of ocean water are potentially devastating. Although sea level rise is natural, the pace may be hastening. Combined with land sinking in some areas, the effective increase in sea level (and attendant effects) can be more locally severe than global rates might suggest.

Tidal marshes respond quickly to the subtle effects of even small changes in sea level. An aerial photograph of the Maurice River Cove in Southern New Jersey depicts shoreline problems likely exacerbated by climate change. Tidal marsh loss threatens the town of Bivalve through increased wave energy and possible redirection of the main river channel. The International Panel on Climate Change (IPCC) predicts that by 2100 sea levels will rise between 28 and 43 centimeters, and this estimate appears conservative compared with other scientists' recent estimates.

Rising air and water temperatures displace regional native plant and animal species by interfering with ecological processes dependant on winter freezes, snow packs, and the seasonal timing of biological events. Increased sea-surface temperatures can alter gas exchange processes and acidity, profoundly affecting marshes, mud flats, and reef-building organisms such as oysters and worms. The 2007 IPCC determined that by the year 2100 temperatures will rise between 1.8 to four degrees centigrade.

The U.S. Climate Extremes Index shows an upward trend in extreme weather events, which is predicted to continue. These more frequent or severe extreme weather events could upset natural ecosystem balance or breach natural thresholds. For example, even slight increases in water saltness could push oyster populations past a critical tipping point because the non-native diseases that currently impair oysters are more problematic at higher salinities.

ACTIONS AND NEEDS: Indicators that specifically monitor the effects of warming and stress in the Delaware Estuary are needed. Although the physical changes associated with climate change (e.g., temperature and sea level rise) are generally gradual, biological and ecological responses could be sudden if the interrelationships between species become severed, or if critical tolerance limits are breached for species that perform crucial ecosystem services.

An ecosystem-based monitoring approach would help track early warning signs that complex interactions and functions might be on the verge of becoming upset, decoupled, or otherwise impaired. Predictive modeling of future changes in temperature, sea level, and shifting ranges of plant and animal communities would help managers and policymakers protect and build system resilience through smart, adaptive, and imaginative efforts focused on preserving and enhancing buffers and function. Regional coordination and planning is needed to help ensure that limited resources are invested most wisely and directed at sustaining the most crucial ecosystem goods and services.



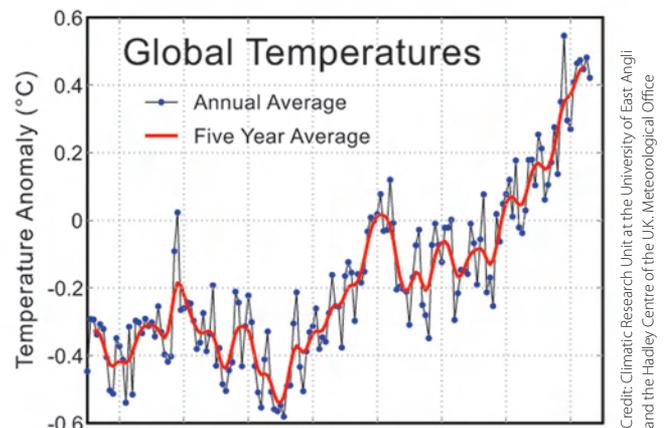
This inset photo depicts marsh erosion at Gandys Beach.

Credit: David Bushek of Rutgers University

This 2001 aerial photograph shows how erosion, combined with sea level rise, has altered the coastline of Cumberland County, New Jersey, since it was originally mapped

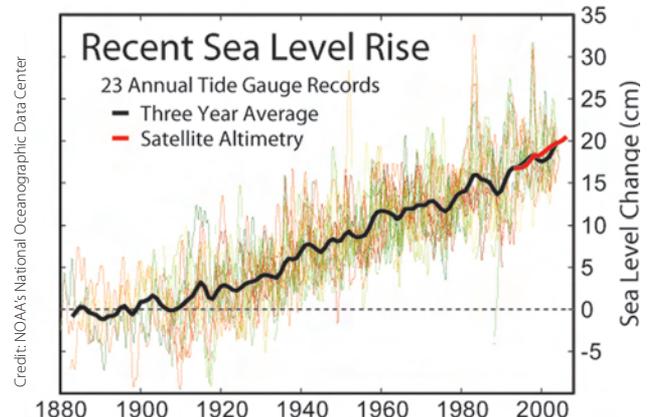
Credit: J. Gebert, U.S. Army Corps of Engineers, Philadelphia District in 1890.

Global Annual Temperatures 1860 - 2000



Credit: Climatic Research Unit at the University of East Angli and the Hadley Centre of the UK Meteorological Office

Recent Sea Level Rise 1880-2000



Credit: NOAA's National Oceanographic Data Center

Salinity



INDICATOR DESCRIPTION: The Delaware Estuary's saltiness is measured as salinity. Salinity throughout the Estuary depends on many factors, including the amount of freshwater inflow, tidal currents, and climate conditions such as temperature, rainfall, and snowmelt. The "salt line" represents the boundary between freshwater and slightly salty water in the Upper Estuary. The salt line's location is variable, moving with changes in flow and climate. The proximity of the salt line and the salinity gradient in the Lower Estuary play important roles in the Estuary's ecology. For example, salt water is a threat to the nationally rare plant and animal communities that are uniquely adapted to the freshwater tidal region, such as the once-expansive tidal freshwater marshes. Increases in salinity can also threaten public water supplies and human health. Since upstream migration of the salt line threatens public water supplies, it is carefully tracked and managed by releasing water from upstream reservoirs if needed. Increased salinity in the Lower Estuary also threatens resources such as oysters.

STATUS: The salt line naturally advances and retreats with each tidal cycle and with seasonal variation in freshwater flow. For most of the year, the location of the salt line is between the Commodore Barry Bridge (River Mile 82) and Reedy Island (River Mile 54). During droughts and periods of very low flow, more freshwater is released from upstream reservoirs to augment flows of the main-stem Delaware River. These controlled releases keep the salt line below drinking-water intakes in urban areas.

TRENDS: Through careful management of river flows by the Delaware River Basin Commission, the location of the salt line has been kept below the Philadelphia region, protecting the ecology and drinking-water intakes in that area. Since 1970, low flows that once occurred 10 percent of the time now occur only one percent of the time due to this management intervention.

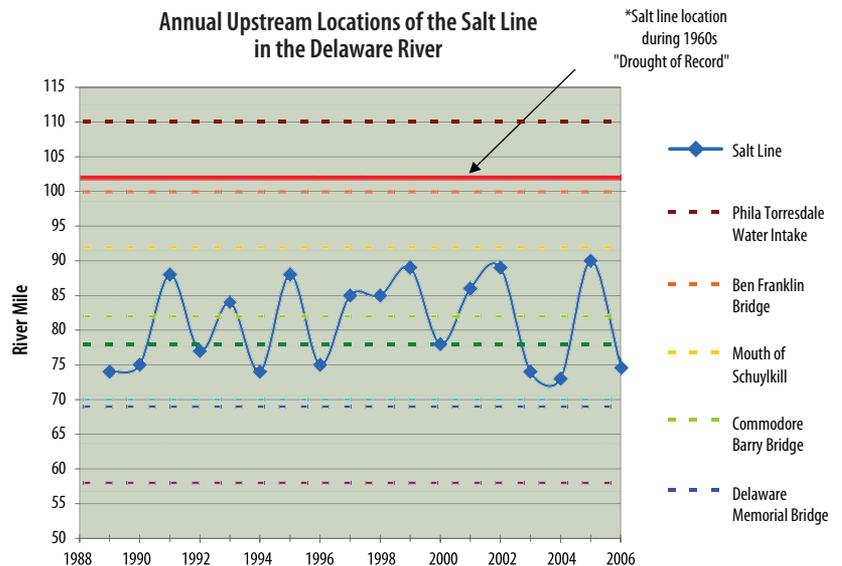
ACTIONS AND NEEDS: Sea level rise and the increasing variability in freshwater flow associated with other climate factors may create additional challenges for management of the salt line in the future. Additionally, the Philadelphia Water Department is investigating other sources of chlorides, such as from runoff in the non-tidal watershed. Estuarine salinity will need to be monitored and managed carefully in consideration of both climate change and any



For most people, salt water conjures up images of the ocean, but in truth, a mix of fresh and salt water, otherwise known as an Estuary, can extend far inland.

Credit: Amie Howell, U.S. Environmental Protection Agency, Region 3

Annual Upstream Locations of the Salt Line in the Delaware River



Credit: Delaware River Basin Commission

other human-induced alterations to the seawater-freshwater balance of the watershed. Projections are needed for salinity and the salt-line changes associated with various combinations of freshwater diversion, drought, channel deepening, and sea level rise.

Fast Fact

Philadelphia's water supply could be threatened by climate change, particularly if salt water from sea level rise and higher tides is not kept out of urban areas during droughts by adequate fresh water flowing down waterways.



Definitions of Terms

Basin: A region drained by a river and its tributaries.

Benthic: The bottom habitat of a lake, estuary, or seabed with its associated organisms.

Bioaccumulation: The process by which organisms, including humans, take up and retain chemical contaminants from the surrounding environment and their food. This process can cause the amount of a chemical in a body to accumulate over time.

Bioindicator: A biological indicator of the well-being or abundance of an organism, which is then used to describe the quality of the ecosystem.

Chlorophyll: The green-colored material in plants where photosynthesis occurs and carbohydrates are produced.

Ecological Services: Resources and processes supplied by natural ecosystems from which humankind benefits.

Ecology: The scientific study of the relationships between living things and their environments.

Estuary: A partially enclosed body of water along the coast where fresh water from rivers and streams meets and mixes with salt water from the ocean.

Fauna: Animal life in a particular region or period.

Flora: Plant life in a particular region or period.

Headwaters: The water from which a river rises, or its source.

Hydrology: The science dealing with the properties, distribution, and circulation of water.

Impervious Cover/Surfaces: Artificial structures — such as pavements, rooftops, sidewalks, roads, and parking lots — that are covered by impenetrable materials such as asphalt, concrete, brick, and stone.

Invertebrate: An animal lacking a backbone or spinal column.

Macroinvertebrate: An animal lacking a backbone or spinal column that is large enough to be seen without magnification.

Mercury: A silvery-white, dense, poisonous, metallic element that is a liquid at room temperature and is used in thermometers, barometers, batteries, and pesticides.

Natural Capital: The resources of a natural ecosystem that yields a flow of valuable ecosystem goods and services in the future.

Nonpoint Source Pollution: Water pollution originating from many sources rather than from a single location, or “point source.”

PCBs: Short for polychlorinated biphenyls, or any of a family of industrial compounds that are used as lubricants, heat-transfer fluids, and plasticizers. The manufacture and use of PCBs has been restricted since the 1970s because they are very harmful to the environment, being especially deadly to fish and invertebrates, and because they stay in the food chain for many years.

Permeability: The ability of a substance to allow another substance to pass through it, especially the ability of a porous rock, sediment, or soil to transmit fluid through pores and cracks.

Point Source: Water pollution originating from one source rather than from many locations, or “nonpoint sources.”

Porous Pavement: A permeable pavement surface with an underlying stone reservoir that temporarily stores surface runoff before infiltrating into the soil.

Recruitment: The act of a larval shellfish landing and attaching onto a clean, hard surface, such as a reef.

Riparian: Situated or dwelling on the bank of a river or other natural body of water.

Stormwater: The portion of rainfall that moves over the ground toward a lower elevation and does not infiltrate into the soil.

Tipping Point: The levels at which the momentum for change becomes unstoppable.

Total Maximum Daily Load: A calculation of the maximum amount of a pollutant that a water body can receive and still meet water-quality standards, and an allocation of that amount to the pollutant’s sources. The calculation must include a margin of safety to ensure waterways can still be used for the purposes the state has designated. The calculation must also account for seasonal variation in water quality. The Clean Water Act, section 303, establishes the water-quality standards and TMDL programs.

Water Quality Standards: Water quality standards are the foundation of the water quality-based control program mandated by the Clean Water Act. They define the goals for a water body by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants.

Watershed: The region draining into a river, river system, or other body of water.



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