Barnegat Bay Partnership

Research · Educate · Restore

State of the Bay Report | 2016

COVER PHOTOS (l. to r.):
Dragonfly in a salt marsh. Photo by Barnegat Bay Partnership.
Common reeds at sunset. Photo by New Leaf Photography.
Rain barrel at Island Beach State Park. Photo by NJDEP.
Snapping turtle in a freshwater creek. Photo by Barnegat Bay Partnership.

OPPOSITE: White-tailed deer along the Metedeconk River.
Photo by BTMUA.
BACK COVER: A tidal marsh and pool. Photo by NRCS.

Barnegat Bay Partnership
RESEARCH · EDUCATE · RESTORE

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Barnegat Bay Partnership

Director's Comments

The Barnegat Bay ecosystem and its inhabitants weathered a historic cataclysm since the publication of our *2011 State of the Bay Report* (SOTB); nonetheless, our work to assess, protect and restore the bay has continued to move forward. As has been chronicled in many places and summarized in a special section of this 2016 SOTB, Superstorm Sandy was almost unprecedented in its impacts to the bay and the human population along the Jersey Shore. We have cleaned up Sandy's wreckage as best we can and are working to rebuild our communities and waterfront neighborhoods drowned by the storm. While busy with Sandy and its aftermath, one could also argue that we have learned more about the Barnegat Bay in the past five years than in any period in the bay's history.

Perhaps most importantly, we now have a better understanding of the bay's major problem. The biggest concern in 2011 – eutrophication due to high nutrient loading – remains the bay's most serious challenge today. While eutrophication continues as the bay's biggest problem, our understanding of its causal factors has improved substantially. As a result of new science from the NJ Department of Environmental Protection (NJDEP), United States Geological Survey (USGS), and Rutgers University, specifically an assessment of the bay's hydrology and nutrient sources and/or loadings not included in previous studies, we know that the bay's total nutrient loadings are significantly higher than heretofore recognized. These previously unassessed loadings entering the bay from offshore waters have undoubtedly long been stimulating the bay's eutrophication, manifest mostly as high phytoplankton and benthic algal production in different parts of the bay. In addition to this newly recognized source, we also have the proverbial "smoking gun" about the bay's anthropogenic loadings in the form of a USGS/Rutgers study, which clearly shows that the delivery of nutrients from lawn runoff, recognized as a source but never previously quantified, is a significant and increasing source of the bay's total nutrient load. This study gives us reason to believe that the statewide fertilizer law and additional steps to reduce runoff from residential and other turf landscapes (*e.g.*, parks, athletic fields) can help improve the bay's condition.

Our 2011 SOTB also identified a disturbing number of critical information gaps. Back then, we did not have enough information to identify trends in more than one-quarter of the indicators of the bay's health. We now have quality data sufficient to assess trends in three indicators (*i.e.*, algal blooms, dissolved oxygen, turbidity) where trends previously could not be determined and thus were considered "unknown." Perhaps most important, not only do we have good data for all of these indicators, but trends in the overwhelming majority of these condition indicators are not declining. Trends in dissolved oxygen even showed some improvement, and also give us hope for the future. Unfortunately, data were also unavailable for two indicators in the 2011 SOTB (*i.e.*, Watershed Integrity in the Pinelands National Reserve and Shallow Groundwater Quality), so we must continue to invest in the bay's monitoring.

Though not directly provided in condition measures herein, other research projects during the past five years have answered some important long-standing questions about the bay. Thanks to cooperation between our federal and state partners, we now have a map of the soils that lie at the bottom of the bay to guide future eelgrass and shellfish restoration efforts. Not only have we documented the current composition of the plankton in the bay, we have a record of changes in the diatom communities since before the Industrial Revolution that gives us a glimpse at how nutrients have changed in the bay since European settlement. The list of "new science" in the bay is far longer than what I've presented here; each study helps advance us toward our goals of a healthy bay.

But there is still much work to be done. While we have a better understanding of the nutrient loads to the bay, we do not know the threshold level at which nutrients become detrimental. Passage of New Jersey's Statewide Soil Health Law, which would reduce the amount of nutrients flowing off of newly disturbed land, has not yet been implemented, despite being passed with bipartisan support from the State Legislature and the Governor more than five years ago. Because we now have proof (*i.e.*, recent USGS/Rutgers studies[1]) of the significant contributions of lawn fertilizer to the bay's nutrient loading, our collective failure to develop and implement a soil restoration standard to reduce new loadings from the developed landscape is inexcusable. The most current New Jersey Statewide Water Supply Plan, which guides the management, conservation, and development of water resources in the watershed, is more than 20 years old and clearly outdated. The NJDEP has made some notable progress in assessing the state's aquifers[2]; however, this report and the continued population growth along the Jersey Shore emphasize the importance of releasing the new State Water Supply Master Plan, so that water purveyors, water managers, municipalities, resource managers and others can work together to safeguard the economies of coastal communities and the ecology of the state's watersheds. The time to work on this critical issue is now, before the next drought.

And lastly, as we've glimpsed these past few years, climate change and sea level rise have the potential to alter ecosystem processes and our living in coastal communities in ways that we are just beginning to recognize and have yet to truly address. To face these challenges, the Barnegat Bay Partnership will continue to use the best science available to work towards restoring and protecting this unique ecosystem that we all treasure. We hope that you will join us in this endeavor. Together we can build upon the successes of the past five years. To find out how you can help, please visit our website at http://bbp.ocean.edu.

[1] Baker, R.J., C.M. Wieben, R.G. Lathrop, and R.S. Nicholson. 2014. Concentrations, loads, and yields of total nitrogen and total phosphorus in the Barnegat Bay-Little Egg Harbor watershed, New Jersey, 1989–2011, at multiple spatial scales. In U.S. Geological Survey Scientific Investigations Report 2014-5072. 64pp.

[2] Domber, S., I. Snook, and J.L. Hoffman. 2013. Using the Stream Low Flow Margin Methods to assess water availability in New Jersey's water-table-aquifer systems. In New Jersey Geological and Water Survey Technical Memorandum 13-3. Trenton, NJ. 76pp.

Barnegat Inlet lighthouse. Photo by New Leaf Photography.

Executive Summary

This report presents the current environmental conditions of the Barnegat Bay and its watershed, and compares current conditions to those previously documented in the *2005* and *2011 State of the Bay Report*. In this report, 17 indicators are used to assess the physical, chemical, and biotic conditions of Barnegat Bay using recent and ongoing research by academic, government, and private-sector scientists and engineers.

Studies conducted by the National Oceanic and Atmospheric Administration in 1999 and 2007 reported that Barnegat Bay was impacted by excessive macroalgae and nuisance algal blooms, and declared it highly eutrophic. These conditions were largely attributed to increasing watershed development and associated increases in non-point source nitrogen loads. The *2011 State of the Bay Report* documented continued excess nitrogen inputs to the bay, further losses in seagrass and tidal wetland habitats, and increases in the amount of water withdrawn from rivers, streams, and aquifers for human uses. However, good news was found in the continued preservation of open space throughout the watershed, and in the observed reductions in the number of bathing beach closures.

In an effort to reduce negative impacts to the bay associated with watershed development and to better understand the bay's response to this changing environment, a number of restoration and research projects were undertaken by the members of the Barnegat Bay Partnership. The status and trends documented in this report, while not necessarily indicative of the effects of any one project, provide us with a means for measuring our progress in restoring this jewel of New Jersey.

Controlling Pollution and Improving Water Quality

Water quality within the Barnegat Bay and its watershed continues to be a source of concern. A recent study estimating nutrient input to the bay for the time period of 1989-2011 indicated an increase in the amount of nitrogen being delivered to the bay. This excess nitrogen contributes to eutrophication, a process which can result in an increase in nuisance algal blooms, low dissolved oxygen, and other adverse effects that stress the biota of the bay. Within freshwater streams slightly more than half of sampling sites meet the water quality standards for aquatic life use, though the percentage of sites considered "excellent" has declined during the last sampling interval. On a bright note, the number of bathing beach closures due to pathogens continues to decrease as innovative projects address bacteria and other contaminants in stormwater.

Water Supplies for People and Wildlife

As the population in the watershed has grown, the amount of water withdrawn from rivers, streams, and aquifers for human uses has increased. These withdrawals can result in reductions in the base flow of our rivers and streams, causing serious ecological repercussions as changes in the timing and amount of fresh water reaching the estuary affects water quality and habitat for many of the bay's species.

Protecting Land and Water

Terrestrial and freshwater wetland habitats within the watershed continue to be lost, though the rate at which they are converted to urban settings slowed during the time period studied. Urban land (land covered with structures) now represents 34% of the land area within the watershed, and approximately 284 acres of freshwater wetlands disappeared. Tidal wetlands along the bayshore also lost approximately 238 acres; moreover, those tidal wetlands still remaining are considered moderately to severely stressed and are at risk from erosion, changes in sediment and nutrient availability, and submersion due to sea level rise. Sea grasses, a critical nursery habitat for many recreationally and commercially important fish and shellfish species, continue to struggle to recover from historic lows, though there have been some small improvements. But not all of the news is bad. Through a variety of public and private partnerships, open space preservation continues throughout the watershed, with over 11,000 acres protected over the past five years.

Conserving Fisheries and Wildlife

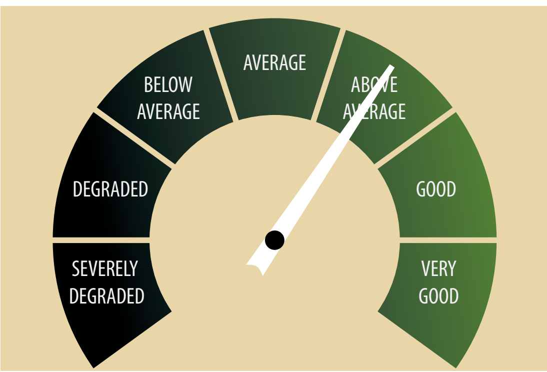
Surveys for hard clams in the estuary found a population severely depleted compared to the mid-1980s, though the abundance of hard clams in the Little Egg Harbor region have increased since the low recorded in 2001. The fish community in the northern and central segments of the bay have a diverse assemblage of species, and have been relatively stable over the past five years.

How to Use the *State of the Bay Report*

A gauge is shown for each environmental indicator, which provides a summary, except for a few indicators for which doing so would be inappropriate. The gauge provides a summary of the indicator's status and trend, incorporating quantitative measures where available and the best scientific judgment of the review panel. Determination of an indicator's status is based on data available for 2010-2015, while the trend is based on the longest complete dataset available for that indicator. In some cases it was not practicable to use a five-year indicator for the status determination.

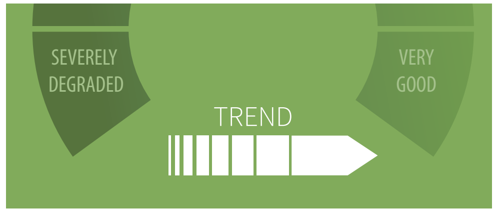
Status Ratings (needle)

The needle points to the appropriate status for the indicator.

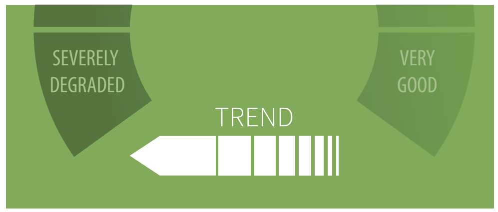


Trend Ratings (internal arrow)

A trend arrow pointing to the right indicates an improving condition.

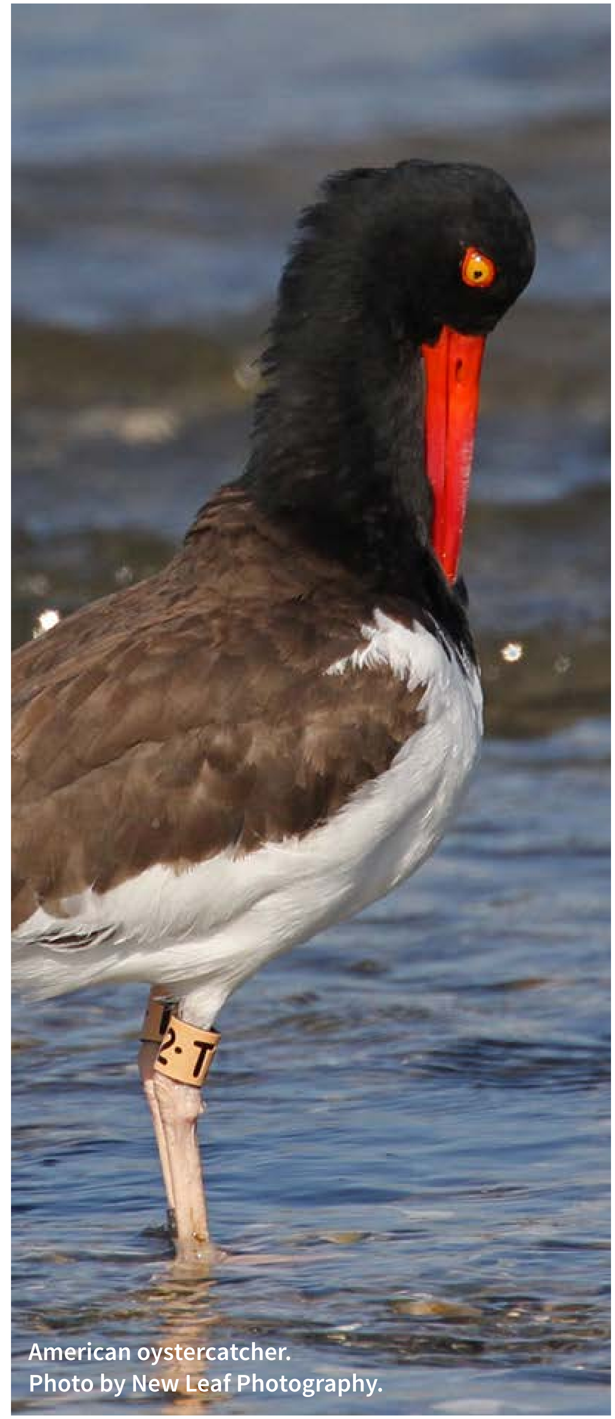


A trend arrow pointing to the left indicates a deteriorating condition.



A bar with no arrows indicates no discernible trend.

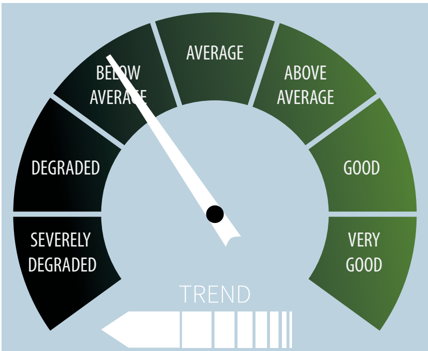
A question mark indicates there was not enough data to develop a trend.



American oystercatcher.
Photo by New Leaf Photography.

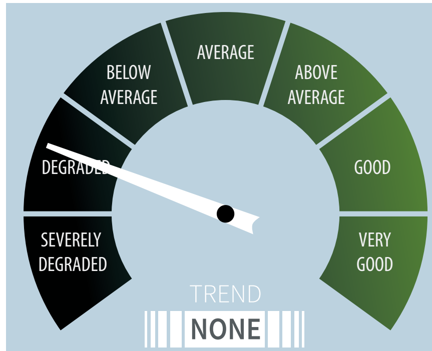
Controlling Pollution and Improving Water Quality – Estuarine Eutrophication Assessment

Nutrient Loading



In 2011, it was estimated that the combined total nitrogen load to the Barnegat Bay-Little Egg Harbor estuary was 749,000 kilograms of nitrogen per year (kg N/yr), an increase compared to the 2009 estimate. Analysis of the 1989-2011 estimates show an overall increase in nitrogen loads through time.

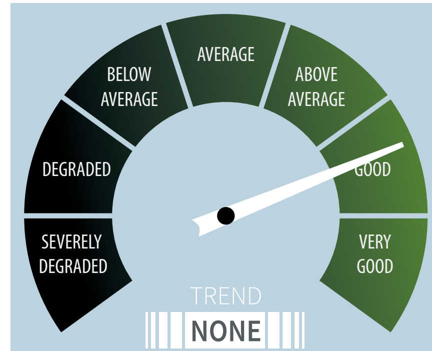
Algal Blooms



Status: (northern)

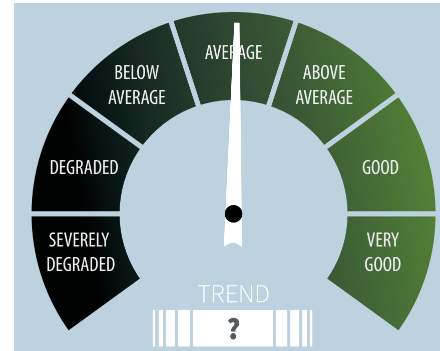
Algal blooms have been recorded occurring throughout the bay at various time and spatial scales during the 2011-2015 time period, with the largest and most frequent blooms occurring in the northern portion of the bay. While routine monitoring for Brown Tide was discontinued in 2004, studies have shown various small-scale blooms of Brown Tide during the 2011-2015 time frame.

Dissolved Oxygen



Three of the nine assessment units in the estuary were listed as impaired for dissolved oxygen on the state's 2014 *List of Water Quality Limited Waters*. Between 2011 and 2014 a total of 5 sampling locations had summer values below 4 milligrams per liter (mg/l), the level at which biota may begin to show signs of stress.

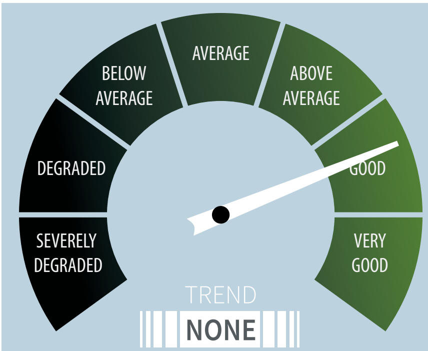
Turbidity



There are three sections of the estuary that are listed as impaired for turbidity on the state's 2014 *List of Water Quality Limited Waters*. Turbidity in Manahawkin Bay limited light transmission to below one meter during the seagrass growing season for four of the five years, a condition that can be detrimental to seagrass growth. Long-term trends in turbidity are difficult to discern due to other confounding environmental factors.

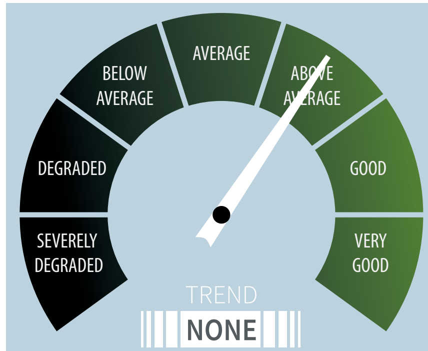
Controlling Pollution and Improving Water Quality – Freshwater Assessment

Temperature and pH



Over the past five years, monitoring for temperature and pH has occurred at 28 stations within the watershed with varying frequency. The state's 2014 *List of Water Quality Limited Waters* identifies one station within the Barnegat Bay watershed that exceeded the temperature standard and one station that exceeded the pH standard.

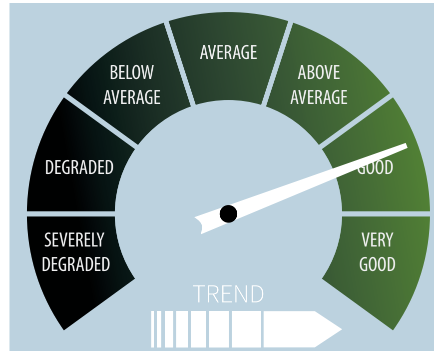
Freshwater Macroinvertebrates



Macroinvertebrates are commonly found throughout the watershed's streams, fulfilling an important role in the aquatic food web. These populations of benthic macroinvertebrates can be used as indicators of water quality. Currently, slightly more than half of the streams in the watershed meet the Surface Water Quality criteria. While the long-term trend (20+ years) in stream scores has been relatively stable, the drop in the percentage of streams classified as "excellent" over the last five years is a matter for concern.

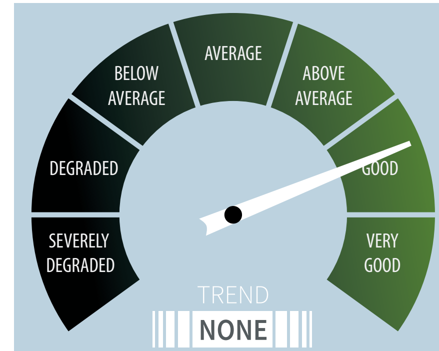
Controlling Pollution and Improving Water Quality – Human Use Impairments

Bathing Beach Closures



The Ocean County Health Department (OCHD) obtains and analyzes water samples from 35 public bathing beaches in the county on a weekly basis between Memorial Day and Labor Day. The number of closures at the county's public recreational bathing beaches varies from year to year, attributable primarily to the number, duration, and intensity of rainfall events. The total number of closures has generally declined over the past five years.

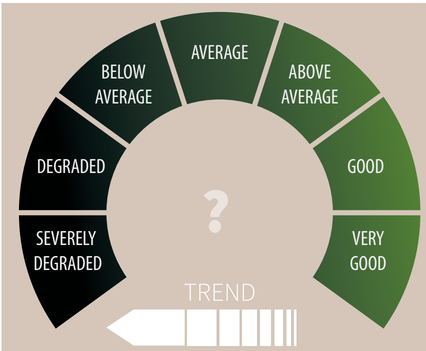
Shellfish Bed Closures



Currently, the waters of the Barnegat Bay consist of approximately 75% "approved," 6% "prohibited," and 19% "seasonal and special restricted" for shellfish harvest. There have been no substantial changes in the percentages of classified waters over the past five years.

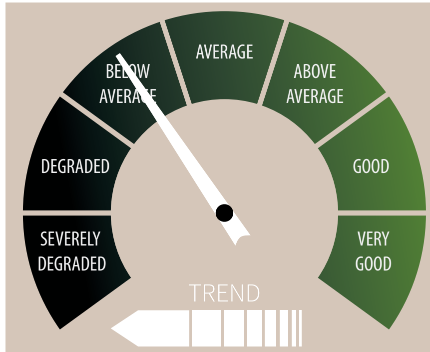
Water Supplies for People and Wildlife

Streamflow



The United States Geological Survey maintains a network of stream gauging stations that measure the rate of flow in some of the major streams in the watershed on a continuous basis. Base flow accounted for 67%-94% of total streamflow at the monitored streams in 2014, and generally reflects the north to south urbanization gradient in the Barnegat Bay watershed. Over the last 40 years the percentage of base flow in the total flow has significantly declined in the northern streams.

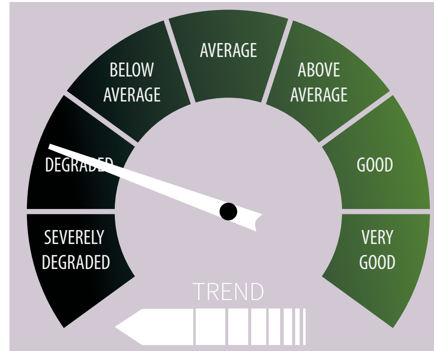
Water withdrawals



Fresh water is withdrawn from surface waterways and groundwater for a variety of purposes, including public supply, agriculture, landscape irrigation, commercial and industrial uses, mining, and power generation. The most recent estimate for 2010 shows that Ocean County's freshwater withdrawals averaged approximately 86 million gallons per day and have generally increased over the past several decades, closely linked to population growth.

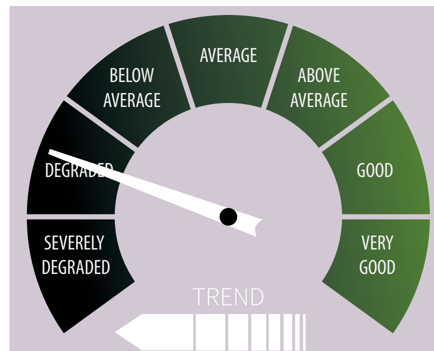
Protecting Land and Water

Land Use/Land Cover



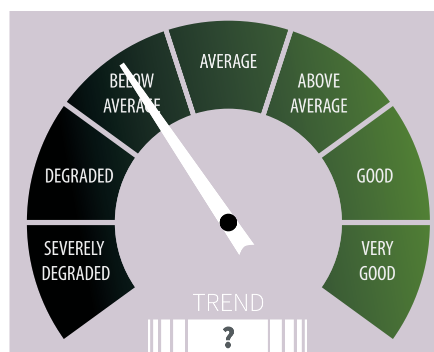
The conversion of forested areas and wetlands into urban settings reduces the amount of habitat available for plant and animal species and leads to sediment contamination, increased nutrient levels in surface waters, and increased incidences of low dissolved oxygen levels in water. Urban land use in the watershed has continued to increase, from approximately 22% of the watershed in 1986 to approximately 34% in 2016.

Wetland Area



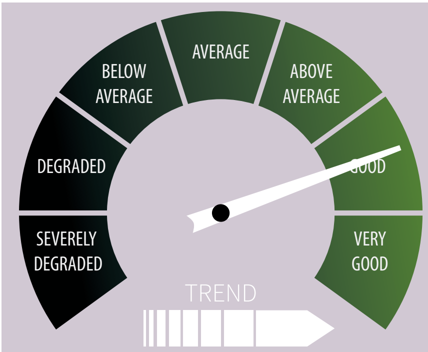
The wetlands within the watershed are an integral part of this sensitive ecosystem, providing habitat and a nursery for various fish, shellfish, and wildlife. There were approximately 22,795 acres of tidal wetlands and 67,034 acres of freshwater wetlands within the Barnegat Bay watershed in 2012. This represents a loss of 238 acres of tidal wetland area and 284 acres of freshwater wetland area since 2007.

Tidal Wetland Condition



Tidal salt marshes provide essential ecosystem services, including flood protection, water quality improvements, and biogeochemical cycling, which greatly benefit the adjacent coastal communities. The wetlands in the northern Barnegat Bay are considered severely stressed, while the tidal wetlands in southern Barnegat Bay are considered moderately stressed. This is the first round of sampling of these wetlands, so no trend information is available.

Protected Lands



Protected lands serve as important refuges for wildlife and can also serve as corridors for movement between larger parcels. These open spaces also enhance water quality and aquifer recharge by allowing rainwater to filter directly into the ground. Between January 1, 2010 and September 30, 2015, approximately 11,114 acres in the Barnegat Bay watershed were acquired by federal, state, county, local, and non-governmental agencies for conservation purposes.

Seagrass

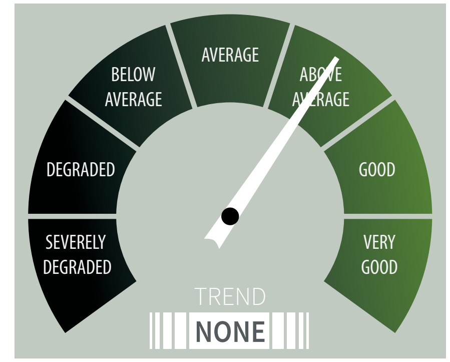
The long-term decline of seagrass in New Jersey's coastal bays is a major concern because it is critically important as a source of nutrition and because it provides feeding and refuge habitats for many fish and invertebrates. In the spring of 2015, there were encouraging signs of eelgrass biomass recovery, though biomass in the fall was similar to previous years. Widgeon grass biomass in central Barnegat Bay has increased substantially since the last seagrass survey.

Conserving Fisheries and Wildlife

Shellfish Resources

Bay-wide surveys for hard clams conducted in 2011 (Little Egg Harbor) and 2012 (Barnegat Bay) estimated a standing stock of approximately 224 million clams. Overall, the abundance of hard clams in Barnegat Bay in 2012 was down approximately 23% from the last survey completed in 1985/1986. For Little Egg Harbor, the overall abundance in 2011 was down approximately 57% compared with the 1985/1986 survey. However, the abundance of hard clams in Little Egg Harbor increased 32% between 2001 and 2011.

Estuarine Fish Communities



More diverse aquatic communities are typically more resilient to disturbances as there are multiple species that can occupy a particular role or take advantage of new or changing conditions. Estuarine fish communities in northern and central Barnegat Bay have a high degree of diversity, with no substantial changes in diversity across the sampling period.

Contents

Introduction

The National Estuary Program

The National Estuary Program was established by Congress in 1987 via the Clean Water Act (33 U.S.C. 1330; P.L. 100-4, *et seq.*) to protect "estuaries of national significance." The Act directs the U.S. Environmental Protection Agency (USEPA) to develop plans for attaining and maintaining water quality in an estuary. The plan should include protection of public water supplies and the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife, and should allow recreational and other activities and uses in and on the water, and require control of point and non-point sources of pollution to supplement existing regulatory controls of pollution.

Point source pollution:
a single identifiable *localized* source of air, water, thermal, noise, or light pollution.

Non-point source pollution *(below)***:**
pollution affecting a water body from diffuse sources.

Barnegat Bay Partnership

The Barnegat Bay National Estuary Program (BBNEP) was established in 1997, following the nomination of former Governor Christine Todd Whitman to provide an inclusive, local stakeholder-based mechanism to protect the Barnegat Bay for its economic, environmental, and cultural resources. Establishment of the BBNEP built upon the foundation that was provided by the state of New Jersey via P.L. 1987, Chapter 397, which created the Barnegat Bay Study Group. The BBNEP's *Comprehensive Conservation and Management Plan* (CCMP) was completed and approved by the partners in May 2002. The CCMP was supplemented by a *2008-2011 Strategic Plan* in which the BBNEP partners identified key priority issues and tasks to accomplish the objectives of the CCMP.

In 2010, the BBNEP changed its name to the Barnegat Bay Partnership (BBP) to better represent its mission, and a second Strategic Plan was completed for 2012-2016, focusing the efforts of all partners on those priority challenges facing the ecosystem using a manageable time frame which allows for improved progress and performance measures.

Today, the BBP is one of 28 National Estuary Programs and comprises federal, state, and local government agencies, academic institutions, nongovernmental organizations, and businesses working together to restore and protect a nationally significant estuary, the Barnegat Bay.

Barnegat Bay: A Coastal Lagoon

The Barnegat Bay-Little Egg Harbor estuary (BB-LEH) is considered a lagoonal estuary, a semi-enclosed feature where fresh water and saltwater mix. A nearly continuous barrier island complex extends along the eastern edge of Barnegat Bay, separating it from the Atlantic Ocean. Seawater enters the bay at three locations: the Point Pleasant Canal via the Manasquan Inlet in the north, and the Barnegat Inlet and Little Egg Inlet in the south. Salinity in the bay is highest (close to seawater) near the mouths of the southern inlets and lowest near the mouths of the large rivers. Freshwater flow into the bay is primarily through surface waters, (*i.e.,* rivers and streams such as the Metedeconk River, Toms River, Cedar Creek, and Westecunk Creek) but also through groundwater input. Tidal range near the Little Egg Inlet is 3.3 feet, 4.5 feet near the Barnegat Inlet, and 1 foot at the Point Pleasant Canal. Water circulation in the bay is generally from Little Egg Inlet northward, though there is some southerly flow from the Manasquan Inlet towards the Barnegat Inlet. Residence time, or the amount of time a drop of water spends in the bay, varies from 0 to 30 days depending on starting location, with an average of 13 days.

Watershed:
the geographic region within which water drains into a particular body of water.

The watershed of the Barnegat Bay is approximately 670 square miles and encompasses nearly all of Ocean County and includes small portions of Monmouth and Burlington Counties.

Nutrient (substances used by living things to promote growth, generally nitrogen and phosphorous in estuaries) inputs into the Barnegat Bay are predominately from non-point sources such as stormwater runoff, groundwater, and atmospheric deposition. The types and amounts of nutrients are mostly determined by the surrounding land uses—suburban development, compared to forests or wetlands. In general, the northern portions of the watershed are more highly developed than the southern portions, and this is reflected in the nutrient loads (amounts) reaching the bay.

Environmental Indicators

"Indicators" are specific, measureable characteristics that can be used to observe changes in environmental conditions over time. Each indicator helps us understand the current condition of a key component of the Barnegat Bay ecosystem, and whether the trend for that element is positive or negative. They also provide a tool for evaluating the effects of management actions. Collectively, the indicators provide a picture of the overall ecological condition of the Barnegat Bay.

Introduction

continued

How were the indicators selected?

The 17 indicators in this *State of the Bay Report* were included for their representativeness of the bay's habitat, resources, and concerns. We reviewed recent and ongoing research and evaluated what data were available and how they could describe the current conditions and the ways in which the bay has changed over the last five years.

The indicators were selected through a collaborative effort among the Barnegat Bay Partnership office, U.S. Geological Survey (USGS), New Jersey Department of Environmental Protection (NJDEP), Pinelands Preservation Alliance (PPA), U.S. Environmental Protection Agency (USEPA), and Brick Township Municipal Utilities Authority (BTMUA). Subsequent to selection, additional review of the indicators was provided by experts in the field, many of whom serve on the Barnegat Bay Partnership's Science and Technical Advisory Committee (STAC).

This report contains only a portion of the indicators that could have been included, but they provide an accurate representation of the changes to the bay. All but one of the "primary indicators" identified in the Barnegat Bay National Estuary Program's *2003 Monitoring Plan* have been included in this report (post-2003 data for the "Watershed Integrity" indicator was not available at the time of publication). Primary indicators were defined as "environmental or other resource characteristics that will provide the most effective subject areas for communicating Comprehensive Conservation and Management Plan progress to the public." Further, "secondary indicators" that provide additional detailed information were included. Taken together, they tell a story about the status and trends of both the natural resources and water quality in our watershed. As such, they serve as the basis for measuring the progress of those who are working to implement the *Barnegat Bay Comprehensive Conservation and Management Plan* and the *BBP 2012-2016 Strategic Plan*.

The data utilized in this report were generated by a number of federal and state agencies and academic institutions. The sources of data for each indicator are included at the conclusion of each indicator section. While the Barnegat Bay Partnership has strived to use only the highest quality data available (please see our Quality Assurance Performance Plan available at http://bbp.ocean.edu/pages/386.asp), we rely upon the expertise of the contributors to determine its accuracy. Therefore, questions concerning data should be addressed to the appropriate contributing source. A separate technical document has been prepared that includes the rational and statistical reasoning (if appropriate) for status and trend determinations, and can be found at http://bbp.ocean.edu/pages/386.asp.

Estuarine Eutrophication Assessment

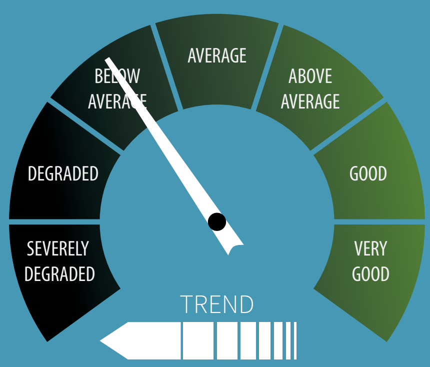
"Eutrophication," an increase in the rate of supply of organic matter into an ecosystem, is an important driver of Barnegat Bay's current condition. This process can lead to a cascading chain of negative environmental impacts, fueling algal blooms, creating hypoxic (low dissolved oxygen) or anoxic (no dissolved oxygen) conditions, and ultimately leading to changes in the bay's biotic communities. In the brackish and saline portions of the Barnegat Bay watershed, eutrophication is primarily driven by increases in nitrogen from non-point source pollution, but may also be affected by changes in temperature and other water-quality parameters (*e.g.* phosphorus). In freshwater rivers, creeks, and streams, phosphorous is the major nutrient of concern. The challenge that eutrophication poses begins at the headwaters of the bay in the westernmost reaches of the watershed and requires our collective action.

Sunset over Barnegat Bay. Photo by Barnegat Bay Partnership.

Indicator

Nutrient Loads

Indicator Status



Black-crowned night heron fishing in algal mats. Photo by New Leaf Photography.

Background

Nitrogen and phosphorus are essential nutrients for plant growth, but in excess quantities, they can adversely affect the quality of water in the Barnegat Bay-Little Egg Harbor estuary. Nitrogen and phosphorus can enter the estuary by way of groundwater discharge to streams, groundwater discharge directly to the bay, stormwater runoff, atmospheric deposition, ocean water entering the estuary, and through the release of nutrients stored in bottom sediments.

In residential and commercial areas, sources of nitrogen and phosphorus to surface- and groundwaters include lawn fertilizers, septic-system wastes, leaky sewer pipes, and industrial discharge; in agricultural areas, sources include crop fertilizers, animal manure, and septic-system wastes. Additionally, nitrogen can enter the atmosphere through automobile emissions, industrial emissions, and natural nitrogen-fixation processes, with subsequent deposition on land or water surfaces.

Estimates of the nitrogen and phosphorus load (amount that is delivered) to the Barnegat Bay-Little Egg Harbor estuary are needed to help assess the importance of nutrient sources within the watershed and to develop nutrient management strategies which can be used to help maintain or improve the ecological health of the estuary. Factors that can affect the amount of nutrients that enter a system include land use, season, and hydrologic condition (high flow or low flow).

Status

The U.S. Geological Survey recently completed a study focusing on the watershed surface- and groundwater inputs of nutrients to the estuary. Concentrations, loads, and yields (amount that is delivered per unit area) of total nitrogen and total phosphorus were calculated for 1989-2011 for all subbasins in the Barnegat Bay-Little Egg Harbor watershed at annual and seasonal time scales using surface-water quality, precipitation, streamflow, and land-use data. For this study, the watershed was divided into three segments—north, central, and south—to coincide with the natural segmentation of the estuary (Figure 1).

The median concentration of total nitrogen for sampling stations in the north segment was 0.79 milligrams per liter (mg/L). Median total nitrogen concentrations were significantly lower in the central and south segments (0.23 mg/L and 0.31 mg/L, respectively). Median total phosphorus concentrations were 0.030, < 0.010, and < 0.015 mg/L in the north, central, and south segments, respectively. Higher median concentrations of nutrients in the north segment are consistent with a greater percentage of agricultural plus urban land use.

It was estimated that 749,000 kilograms (kg) of nitrogen and 28,000 kg of phosphorus were transported to Barnegat Bay-Little Egg Harbor estuary from the watershed in 2011. Approximately 79% of this load was contributed by groundwater discharge to streams (base flow) and 21% was contributed by stormwater runoff. Other studies are underway to quantify additional non-watershed inputs of nutrients to the estuary.

Subbasins with the highest yields of nutrients are concentrated in the northern part of the watershed, and have the highest percentages of urban or agricultural land use (Figure 2). Subbasins with the lowest total nutrient yields are mostly forested. Contributions of nutrients from turf (lawn)-covered areas also were assessed in cooperation with Rutgers University's Center for Remote Sensing and Spatial Analysis. It was determined that calculated concentrations of total nitrogen and total phosphorus were greater for developed–turf areas than for developed–nonturf areas, which, in turn, were greater than those for undeveloped areas.

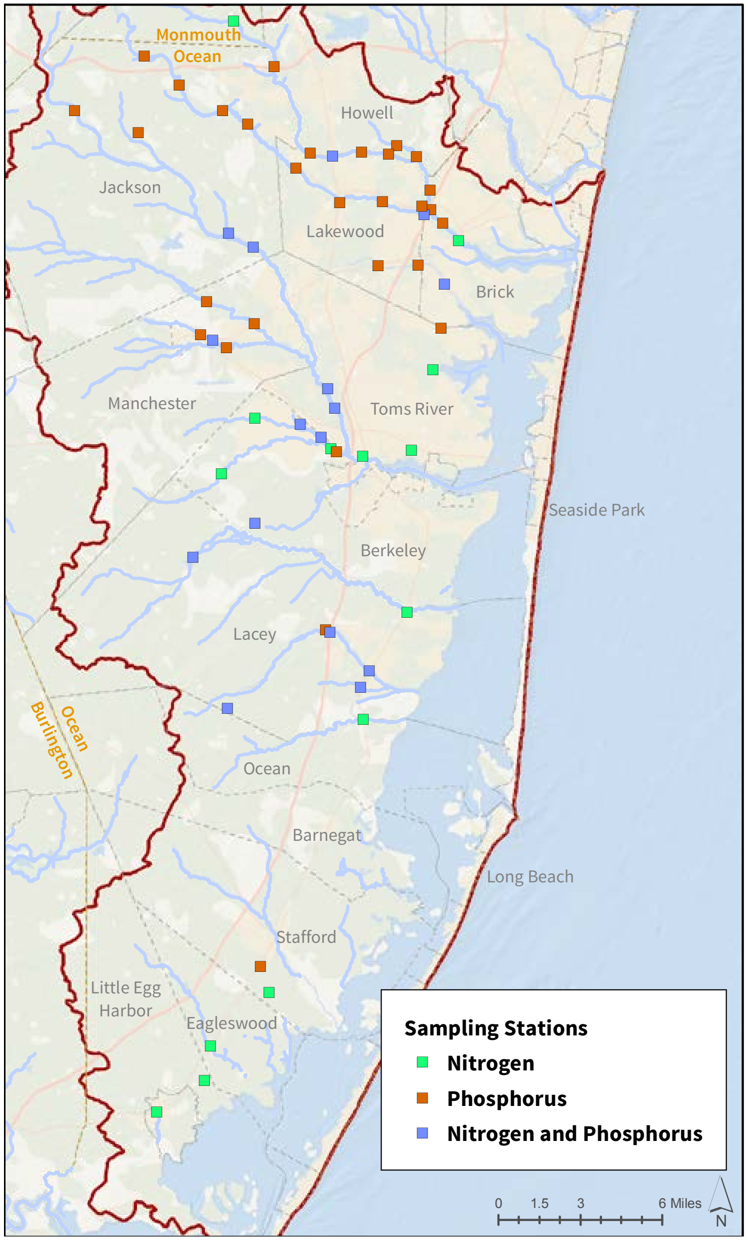
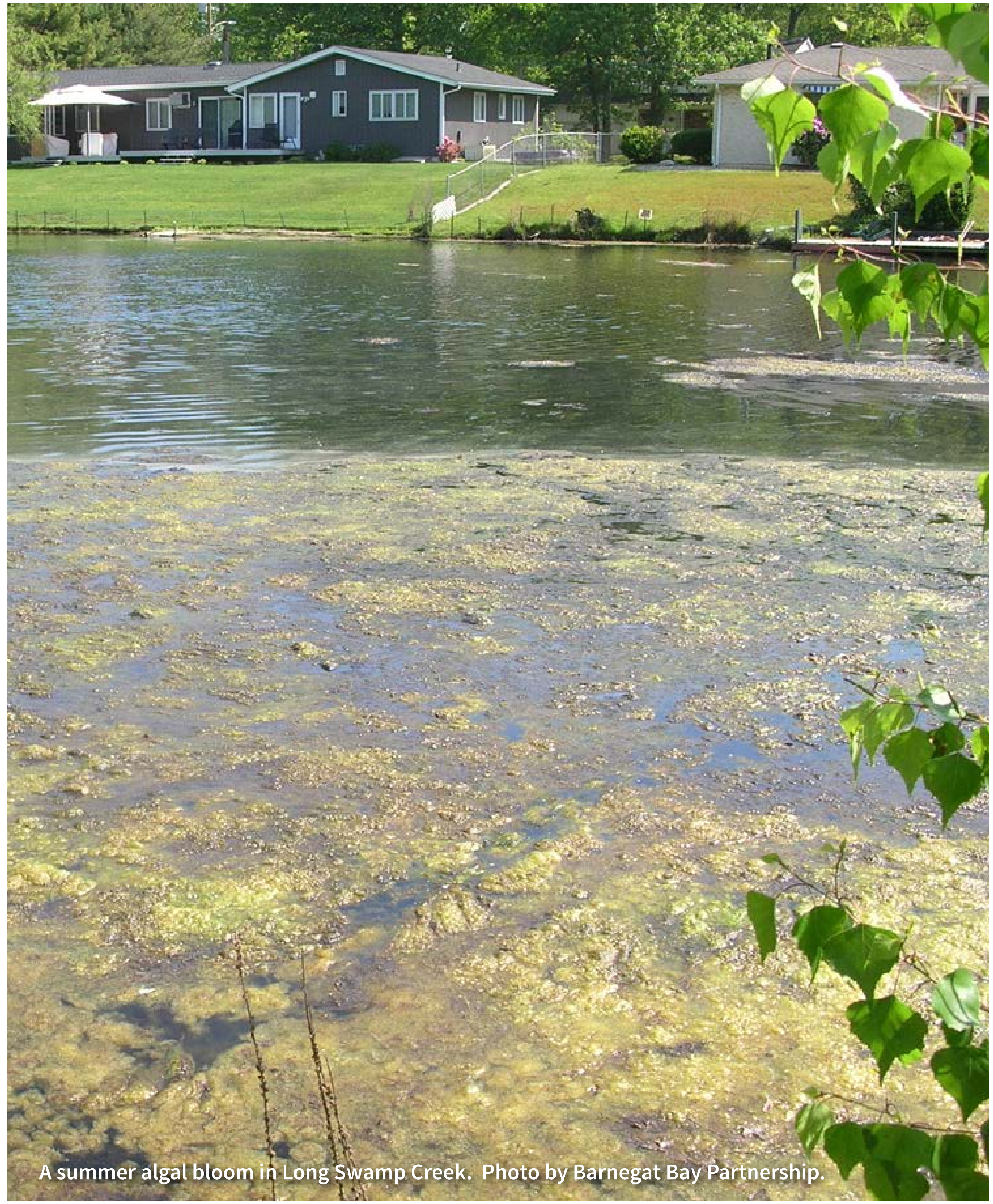


Figure 1: Locations of water-quality sampling stations used to estimate base-flow loads of total nitrogen (TN) and total phosphorus (TP) in the Barnegat Bay-Little Egg Harbor watershed.



A summer algal bloom in Long Swamp Creek. Photo by Barnegat Bay Partnership.

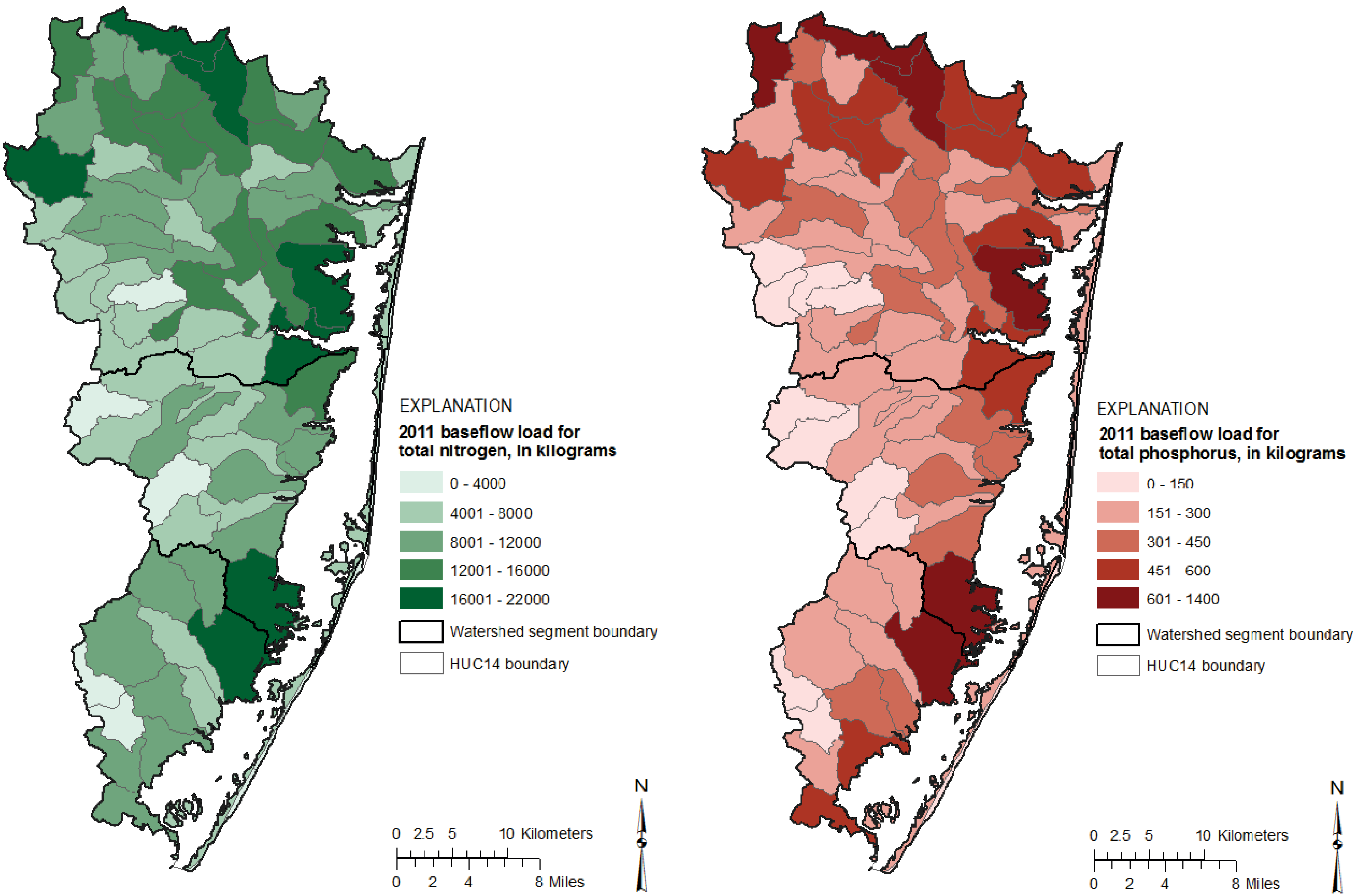


Figure 2: Base-flow loads for each subbasin in the Barnegat Bay-Little Egg Harbor watershed: A, total nitrogen, 2011; B, total phosphorus, 2011.

In a separate study, five streams in the Barnegat Bay-Little Egg Harbor watershed were sampled in 2010 for nutrient concentrations and stable isotope composition under base-flow and stormflow conditions to quantify and identify sources of nitrogen loading. Concentrations of total nitrogen in the five streams appeared to be related to land use, such that streams in subbasins characterized by extensive urban development (and historical agricultural land use) exhibited the highest total nitrogen concentrations (0.84–1.36 mg/L in base flow). Two streams in subbasins with the least development exhibited the lowest total nitrogen concentrations (0.16–0.26 mg/L in base flow). Measurements of nitrogen and oxygen stable isotope ratios of nitrate in surface-water samples revealed that a mixture of multiple subsurface sources, which may include some combination of animal and septic waste, soil nitrogen, and commercial fertilizers, likely contribute to the base-flow nitrogen load, and that atmospheric deposition is not a predominant source of nitrogen transported to the BB-LEH estuary from the watershed.

Trends

Over the period of study 1989–2011, surface-water loads (base flow plus runoff) of total nitrogen for the entire BB-LEH watershed ranged from about 455,000 kg (1995) to 857,000 kg (2010) (Figure 3). Total phosphorus loads for the watershed ranged from 17,000 (1995) to 32,000 kg (2010). Total loads fluctuated with precipitation and hydrologic conditions and patterns, with precipitation having a short-term and immediate effect on runoff loads and a longer-term and sometimes delayed effect on base-flow loads. Loads also were a function of land use; the increase in loads in more recent years can be attributed at least in part to increases in urban development in the watershed.

Data Gaps

At the time of the study (using data available through 2011), streams in the northern part of the watershed were well represented in terms of water-quality monitoring data; however, there were several streams in the southern part of the watershed for which a sufficient amount of nitrogen or phosphorus data were not available.

The loading estimates produced in this investigation are most suitable for making comparisons among seasons and years, and among subbasins. A more complete understanding of nutrient cycling in the watershed could be achieved with the use of additional, targeted water-quality monitoring in conjunction with a watershed water-quality model that considers in-stream processes, incorporates shorter time steps, and targets individual streams and reaches.

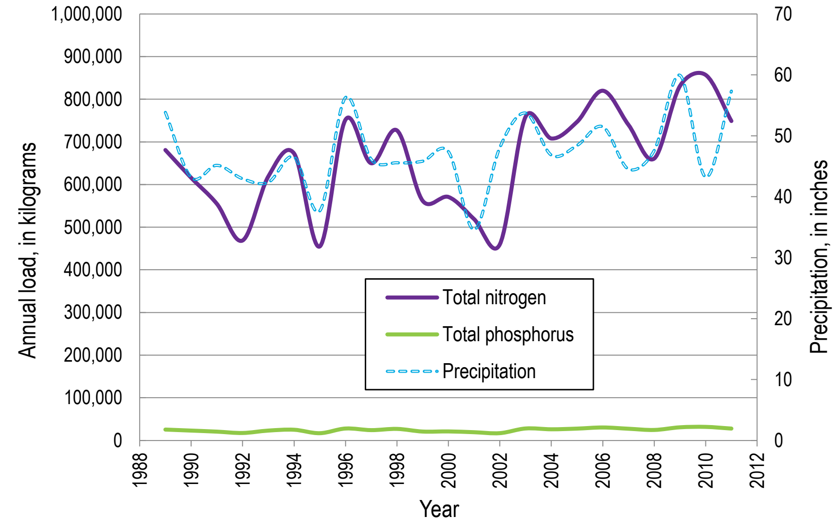


Figure 3: Load of total nitrogen and total phosphorus entering Barnegat Bay-Little Egg Harbor from the watershed, 1989–2011.

For more detailed information, please see the full report Concentrations, loads, and yields of total nitrogen and total phosphorus in the Barnegat Bay-Little Egg Harbor watershed, New Jersey, 1989-2011, at multiple spatial scales, available at http://dx.doi.org/10.3133/sir20145072

and

Nutrient concentrations in surface water and groundwater, and nitrate source identification using stable isotope analysis, in the Barnegat Bay-Little Egg Harbor watershed, New Jersey, 2010–11, available at http://pubs.er.usgs.gov/publication/sir20125287 .

Indicator

Algal Blooms

Indicator Status (Northern Section)

Rockweed, a common macroalgae in the intertidal zone. Photo by New Leaf Photography.

Background

Phytoplankton blooms have been documented in Barnegat Bay, which are symptomatic of eutrophication problems. These blooms are typically characterized by the explosive growth of a single phytoplankton species, which can create an array of negative impacts. Excessive growth of some phytoplankton species generates **harmful algal blooms** (HABs), also known as brown, yellow, and red tides. Toxic forms are particularly dangerous to numerous organisms, including macroalgae, shellfish, finfish, and humans. Secondary impacts of algal blooms include shading of benthic habitats, altered grazing patterns, and changes in trophic dynamics that are detrimental to estuarine function. HAB-forming species that have been recorded in the BB-LEH estuary, include *Aureococcus anophagefferens, Dinophysis* spp., *Gymnodinium* (*Karlodinium*) spp., *Heterosigma* sp., *Pseudo-nitzschia* sp. and *Prorocentrum* spp.

Brown-tide blooms caused by the minute algal pelagophyte, *Aureococcus anophagefferens*, were first reported in New Jersey coastal bays in 1988. These blooms have typically been observed in dry years. These algal blooms can discolor the water brown and may cause negative impacts on shellfish, notably the ecologically and commercially important hard clam and scallop, as well as on seagrasses. Adverse shellfish impacts include a reduction in the growth of juvenile and adult hard clams and mussels, reduced feeding rates of adult hard clams and other shellfish, recruitment failures, and increased mortality of bay scallops. The dense shading of benthic habitats caused by these blooms may also contribute to the loss of seagrass beds, which serve as important habitat for finfish and shellfish.

Chlorophyll *a* is a plant pigment used to determine the amount of algal biomass present in a body of water. While there will be a background amount of chlorophyll *a* in a water sample due to naturally occurring phytoplankton, excessive amounts indicate an algal bloom may be occurring. Concentrations of chlorophyll greater than 5 ug/l are considered moderate degradation. The NJDEP's Bureau of Marine Water Monitoring and partners in the Barnegat Bay intensive and long-term monitoring programs, part of the Governor's Barnegat Bay Initiative, collected an average of 163 chlorophyll *a* samples per year in the estuary during the summer season from 2011-2015. In addition to this long-term data, a subset of samples from the Bureau of Marine Water Monitoring's (the Bureau) National Shellfish Sanitation Program bacteria sampling are analyzed for species composition, focusing on potential toxic species. The Bureau has also worked with NJDEP Forest Fire Service and Rutgers University, conducting routine aircraft remote sensing for chlorophyll *a* over the estuary for the spring and summer season since 2008, to monitor the spatial extent and duration of algal blooms. The aircraft data collection frequency is approximately six days a week during the summer months, and supplies a spatial data set across the bay by recording a result every one second during the flight, resulting in the ability to determine the size, duration, intensity and movement of algal blooms over time.

Status

Algal blooms have been recorded occurring throughout the bay at various time and spatial scales during the 2011-2015 time period. While routine monitoring for Brown Tide was discontinued in 2004, studies have shown various small-scale blooms of Brown Tide during the 2011-2015 time frame. The Bureau of Marine Water Monitoring has also developed the capability to analyze for the presence of the Brown Tide organism, and does analysis when there is an abundance of small unidentifiable algae that could potentially be *Aureococcus anophagefferens.*

Trends

Average summer chlorophyll *a* concentrations have fluctuated both by year and bay segment (Figures 1 and 2). Overall, the cholorphyll *a* concentrations are the highest in the Barnegat Bay segment, an area from near Barnegat Inlet in the south to the Metedeconk River in the north. A comparison of the average aircraft-collected spatial data compared to the fixed station data shows differences in distribution of algae. Fixed boat monitoring from discrete points can sometimes overestimate the chlorophyll *a* concentration that would be extrapolated to the estuary. This suggests that high levels were in local areas, not bay-wide (Figure 3), and that the duration of the blooms is not long. Comparison of historical data collected by Kent Mountford for a 22-month period from 1969-1970 for the mean of five stations in the central- lower western portion of the Barnegat Bay (from Forked River south to Barnegat) to a 25-month period ending September 2015 from two stations in the same portion of the bay, shows an overall decreasing trend in concentrations (Figures 4 and 5). Some of this difference may be due to the different location of the stations for the two data sets. As mentioned above, algae densities can be very site-specific, and not bay-wide. Some identification of a Brown Tide was found during the Barnegat Bay researchers' work, but seemed to be smaller-scale blooms in localized areas.

Data gaps

There continues to be a need for routine Brown Tide monitoring in high probability areas.

More information regarding the NJDEP phytoplankton monitoring program, including the data used in this analysis, can be found at http://www.state.nj.us/dep/wms/bmw/phytoplankton.htm.

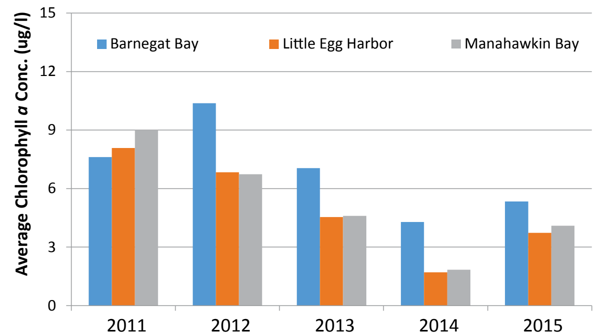


Figure 1: Average summer chlorophyll *a* concentrations in Barnegat Bay by year and bay segment from the NJDEP and partners' Barnegat Bay discrete monitoring program, 2011-2015.

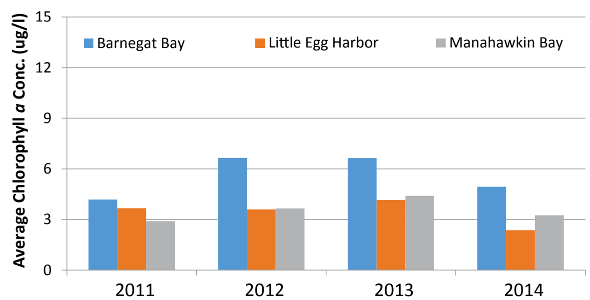


Figure 2: Average summer chlorophyll *a* concentrations in Barnegat Bay by year and bay segment from the NJDEP Bureau of Marine Water Monitoring aircraft remote sensing, 2011-2014.

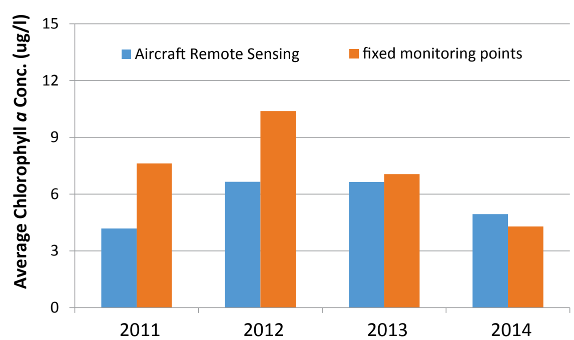


Figure 3: Comparison of annual average chlorophyll *a* concentrations in Barnegat Bay collected through aircraft remote sensing and discrete monitoring, 2011-2014.

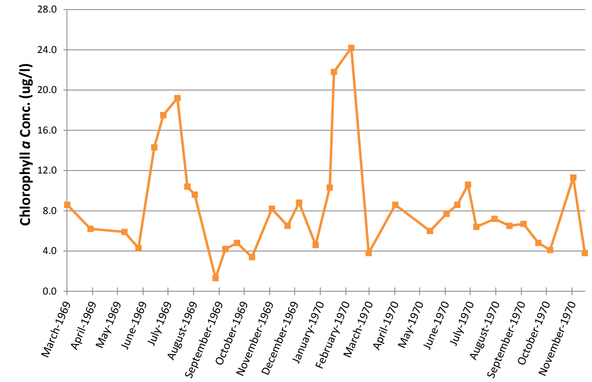


Figure 4: Historical mean chlorophyll *a* concentration of 5 stations in the central-lower western portion of Barnegat Bay.

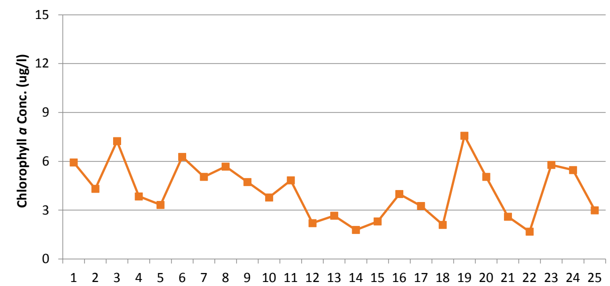


Figure 5: Mean chlorophyll *a* concentration of 2 stations in the central-lower western portion of Barnegat Bay for the 25 months ending Septermber 2015.

Indicator

Dissolved Oxygen

Indicator Status

Cedar Creek in Double Trouble State Park. Photo by New Leaf Photography.

Background

Dissolved oxygen is a fundamental requirement for the maintenance of balanced populations of fish, shellfish, and other aquatic organisms. The nature and extent of the organism's response to low oxygen concentrations depends on several factors, including the concentration of oxygen in the water, how long the organism is exposed to reduced oxygen, and the age and condition of the organism.

Because dissolved oxygen is so important to marine life, New Jersey has established surface water criteria for oxygen levels in marine waters. The surface water criterion for estuarine water is four milligrams per liter. Dissolved oxygen concentrations below two milligrams per liter are considered lethal to aquatic life, while concentrations above two, but below the four milligrams per liter designation, may support aquatic life, but warrant further study. However, prolonged periods of exposure to below-optimum conditions (between 4 and 5 milligrams per liter) may stress some aquatic life.

The NJDEP Bureau of Marine Water Monitoring assessed summer dissolved oxygen conditions from the data collected as part of the Barnegat Bay intensive and long-term monitoring programs between 2011-2015. Over the past 5 years, an average of 14 fixed stations were sampled each year, both bottom and surface water, throughout the estuary 1 to 4 times per month (Figure 1). This program included three intensive sampling events during which data was collected several times throughout the day. These data can detect daily fluctuations that may not be seen in routine monitoring, because low dissolved oxygen conditions are expected to occur in the early morning hours, which are not usually sampled by routine station monitoring. Additionally, four continuous water quality monitoring buoys, located from Toms River south to Little Egg Inlet, have been in operation from 2012-2015 (Figure 1). The buoys measure dissolved oxygen at a frequency of every 15 minutes at 3 feet below the surface; the number of summer dissolved oxygen results during this time range from 2,353 to 8,825.

Status

There are three sections (Barnegat Bay Central West, Toms River Estuary, and Lower Little Egg Harbor Bay) of the estuary that are listed as impaired for dissolved oxygen on the state's 2014 *List of Water Quality Limited Waters*, known as the "303(d) List" (named after a section of the Clean Water Act). These listings were based on dissolved oxygen measurements obtained as part of the NJDEP's Barnegat Sampling Program between 2011-2014. However, these impaired areas are only 1/3 of the 9 sampling areas in Barnegat Bay. Furthermore, the low dissolved oxygen observed in the Lower Little Egg Harbor Bay is based on data from a sampling site located at the Little Egg Inlet, and the limited low readings there may be due to ocean upwelling.

Trend

From 2011 to 2015, a total of 5 sampling stations had summer minimums below 4 milligrams per liter. All other stations sampled during those years did not drop below the 4 milligrams per liter threshold. The results of the continuous monitoring buoys show less than 2% of samples dropping below 4 milligrams per liter (Figure 2). Differences may be seen between the fixed and continuous monitoring locations, as fixed station data incorporates bottom samples which, at times, can be lower than mid-depth or surface results. The combined data show that low dissolved oxygen can be localized in the estuary, and may not be low through the entire water column. Variation in dissolved oxygen from year to year can be caused by a variety of factors, including the weather preceding the sample collection, water temperature, other water-quality parameters (*e.g.*, nutrients, chlorophyll *a*), and the time of sample collection.

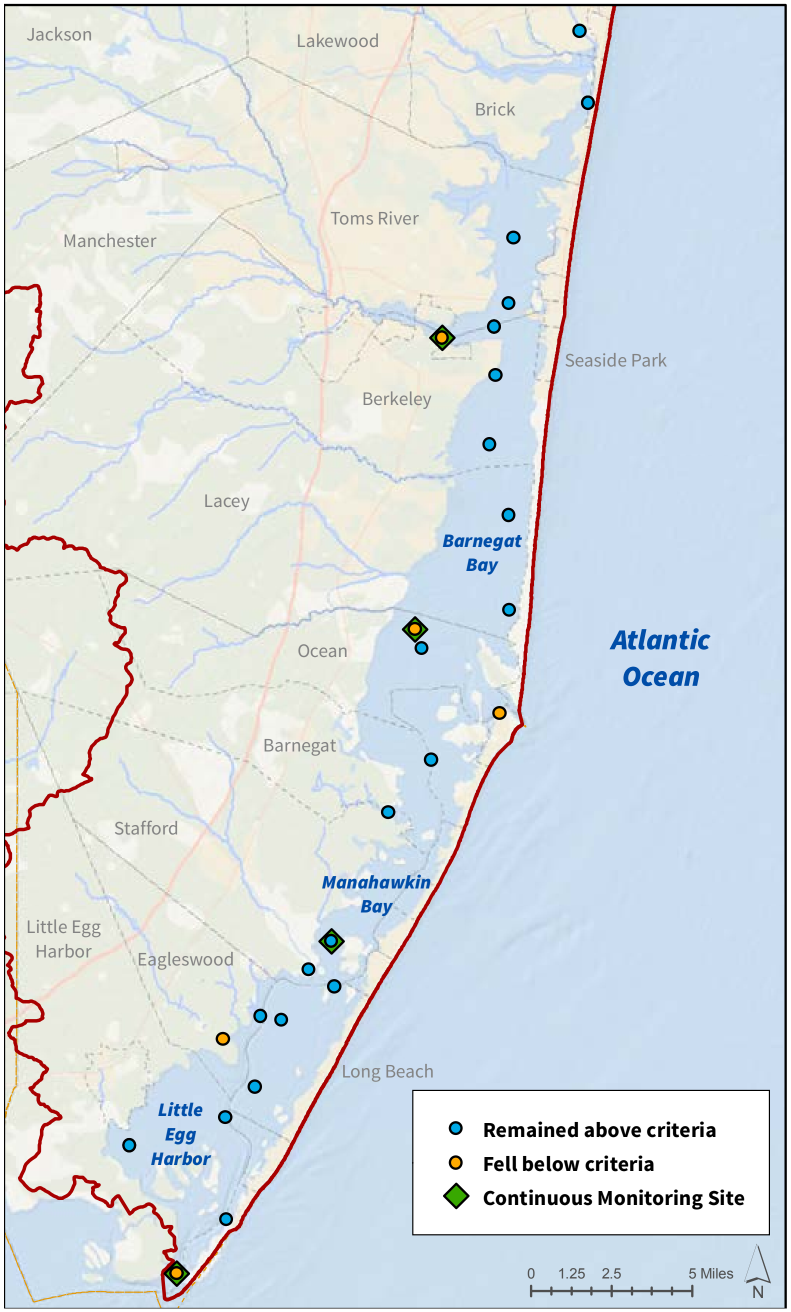


Figure 1: Locations of the fixed routine (circles) and continuous (diamonds) water monitoring stations within the Barnegat Bay. Blue circles are fixed stations that did not record summer dissolved oxygen readings below 4 mg/l. Yellow circles indicate fixed stations where summer dissolved oxygen readings fell below the 4 mg/l threshold.

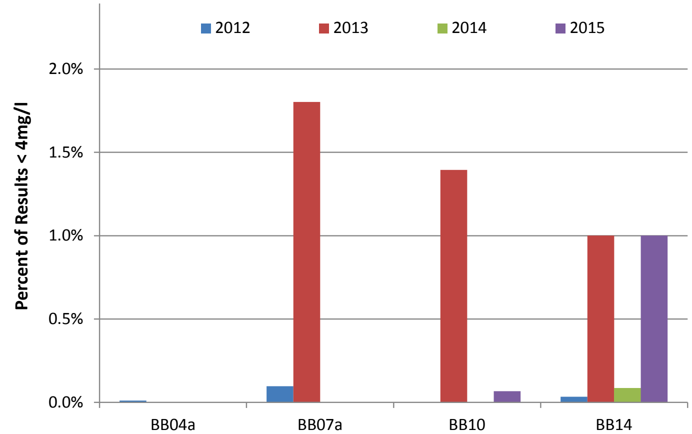


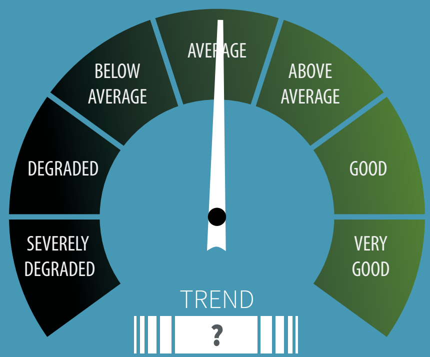
Figure 2: Percentage of continuous monitoring samples collected during the summer that fell below the 4 mg/l threshold for dissolved oxygen. BB04a is the northern continuous monitoring site and BB14 is located at Little Egg Inlet. See Figure 1 for locations.

Data courtesy of NJDEP Bureau of Marine Water Monitoring, NJDEP Bureau of Water Quality Standards and Assessment.

Indicator

Turbidity

Indicator Status



Great egret hunting in the shallows. Photo by New Leaf Photography.

Background

Poor water clarity in shallow estuaries can be attributed to a number of sources, including organic material (especially living or dead algae), dissolved tannins, and suspended sediments due to wind and wave action or human activity such as boating. Turbid waters may supply building material for maintaining estuarine structures and provide food and protection to resident organisms; however, the extensive particle loads of turbid waters are harmful if they bury benthic communities, inhibit filter feeders, or block light needed by seagrasses.

The New Jersey Department of Environmental Protection Bureau of Marine Water Monitoring measures turbidity directly and utilizes a secchi disk as indicators of water clarity as part of Coastal Water Quality Monitoring. Over the past 5 years, an average of 14 fixed stations were sampled each year throughout the estuary 1 to 4 times per month. Turbidity is directly measured using a turbidimeter, which is calibrated using standard solutions of known turbidity, and results are reported as nephelometric turbidity units (NTU). The turbidity standard in saline and estuarine waters contains two parts: a single sample value of 30 NTU and a 30-day average value not to exceed 10 NTU. A secondary measurement, secchi depth, is determined by lowering a disk into the water to see how far light can penetrate into the water column. Secchi depths of one meter or greater are considered healthy for seagrasses.

Status

Three sections of the estuary (Metedeconk and Lower Tributaries, Manahawkin Bay and Upper Little Egg Harbor, and Lower Little Egg Harbor Bay) are listed as impaired for turbidity on the state's 2014 *List of Water Quality Limited Waters,* known as the "303(d) List" (named after a section of the Clean Water Act) due to exceedances of the turbidity standard from 2011-2014. However, in 2015, average turbidity in all segments of the bay were well below the threshold limits (Figure 1), and average secchi depth was greater than 1 meter in 2 of 3 segments (Figure 2).

Trends

Turbidity varies from year to year based on a number of factors, including the weather preceding the sample collection, freshwater flows, water temperature, other water quality parameters (*e.g.,* chlorophyll *a*), and the time of sample collection. It is therefore difficult to identify long-term trends in turbidity.

Data courtesy of NJDEP Bureau of Marine Water Monitoring.

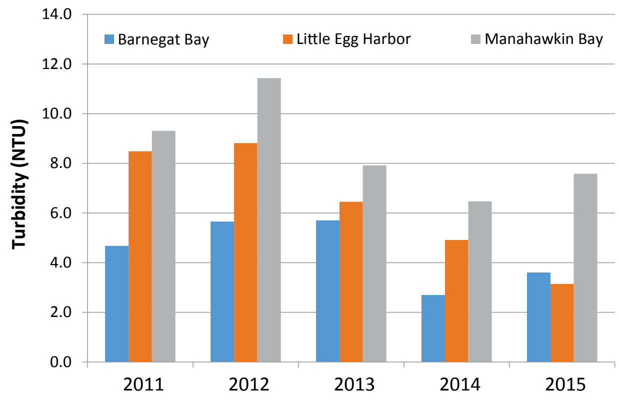


Figure 1: Average turbidity for the Barnegat Bay during the seagrass growing season (March to November) from 2011 to 2015 as recorded by the NJDEP Barnegat Bay long-term monitoring. Please see Figure 1 in the Dissolved Oxygen section for sampling locations.

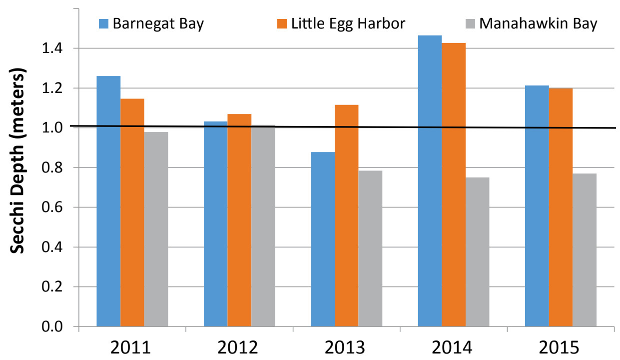
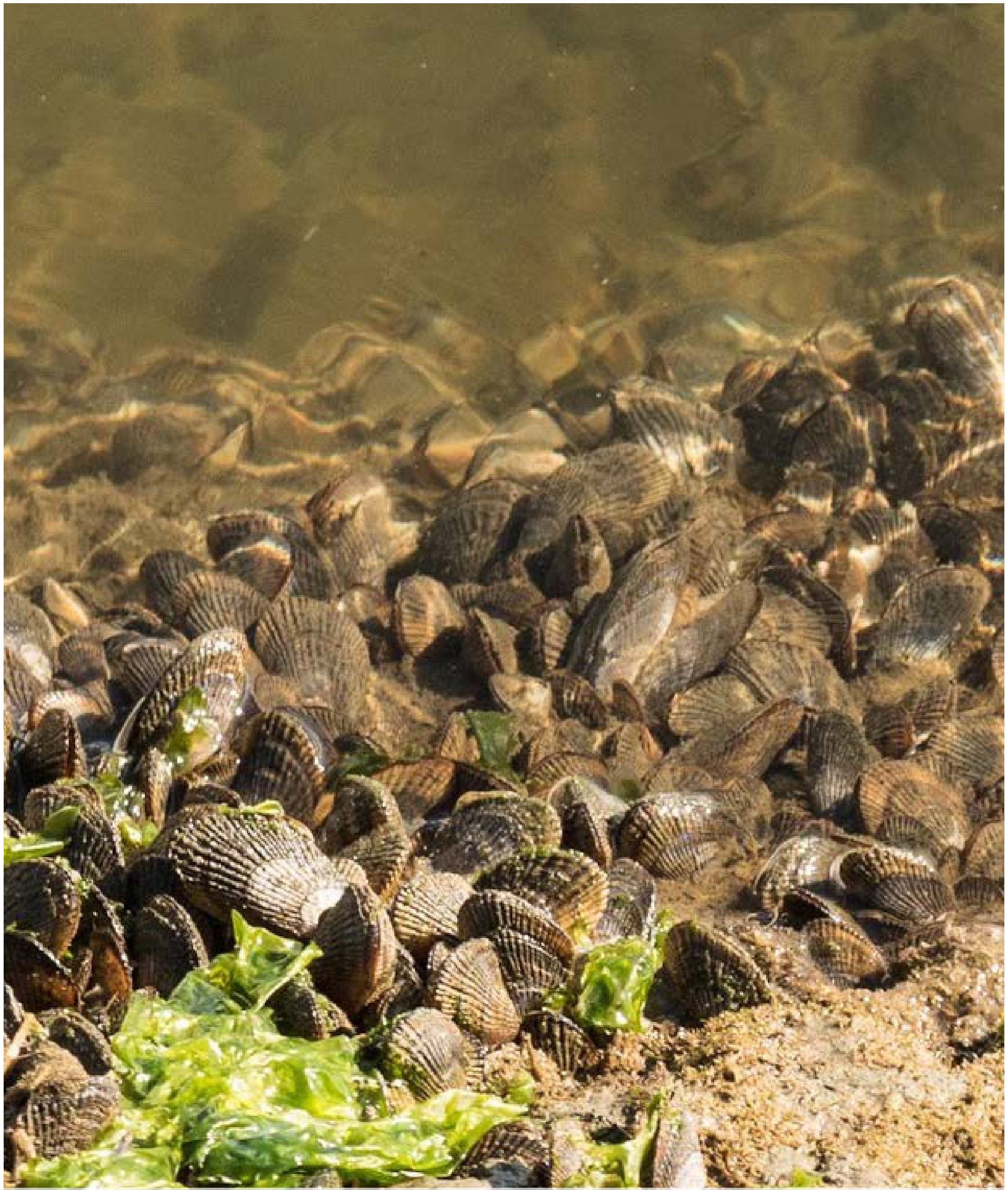


Figure 2: Average secchi depth for the Barnegat Bay during the seagrass growing season (March to November) from 2011 to 2015 as recorded by the NJDEP Barnegat Bay long-term monitoring. Please see Figure 1 in the Dissolved Oxygen section for sampling locations.



Mussels along the marsh edge help to filter particles from the water. Photo courtesy of NRCS.

Barnegat Bay salt marsh. Photo courtesy of NRCS.

Freshwater Assessment

While seemingly far from the Barnegat Bay itself, municipalities such as Plumsted, Lakehurst, Manchester, Jackson, Wall, Millstone, and Freehold contain the headwaters and tributaries that eventually join together to form the Toms River and Metedeconk River. This fresh water mixes with saltwater to create vital nursery areas for life along the entire Atlantic coast. Along with many other creeks and streams, these waterways flow through our communities, connecting all of us to Barnegat Bay.

Double Trouble State Park in the fall. Photo by New Leaf Photography.

Indicator

Temperature and pH

Indicator Status

Turtles basking on a wetland bank. Photo by New Leaf Photography.

Background

Water quality in Barnegat Bay is strongly influenced by the freshwater input from the rivers, streams, and creeks that feed into it. The major rivers and streams carry over 80% of the fresh water that enters the bay, with the remainder coming from precipitation, smaller creeks and streams, and direct groundwater discharge. This fresh water is needed to maintain an ecosystem where it mixes with saltwater to create a vital nursery area for life along the Atlantic coast. The characteristics of the incoming fresh water influence water quality in the bay, including temperature, pH, and dissolved oxygen.

Over the past five years the NJDEP and USGS have monitored temperature at 28 stations within the watershed with varying frequency (Figure 1). Stations utilized for this report had at least eight data points over the past five years.

Temperature

Temperature is an important indicator, as many fresh water and estuarine aquatic species are adapted to living within an optimal range, and departures from that range can cause stress, leading to reduced feeding, reduced reproduction, higher metabolic costs, and even mortality. Furthermore, warmer water does not hold as much dissolved oxygen, a key component for life in aquatic environments.

Status

The state's 2014 *List of Water Quality Limited Waters*, known as the "303(d) List" (named after a section of the Clean Water Act) identifies one station (Toms River at Route 528) within the Barnegat Bay watershed that exceeds the temperature standard. This listing is based on continuous temperature data collected by the NJDEP. Since only 1 station out of the 28 stations within the watershed has data that shows impairment, the overall status for temperature in the watershed is "Good."

Trends

Spring and summer temperatures in each region have been generally consistent over the past four to five years, while winter temperatures have shown a slight decrease (Figure 2). Variability between years was also highest in winter, compared to summer and spring.

Data gaps

The valid assessment of trends, seasonal changes, and comparisons of data between monitoring locations, watersheds and regions is difficult due to the short period of record. However, the development of the Barnegat Bay Long-Term Monitoring Network in 2013 should fill this data gap moving forward. In addition, the Ambient Surface Water Quality Monitoring Network (a cooperative effort between NJDEP and USGS) contains monitoring stations on the Metedeconk River, Toms River, and Cedar Creek, which have been monitored since 1998 and will continue to be monitored on a quarterly basis. These stations should be evaluated for long-term trends for temperature. In terms of temperature measurements, routine monitoring typically involves making one discreet measurement during the day. This does not represent a true minimum or maximum for the day. In order to fully assess temperature variations, continuous monitors, which record measurements throughout the day, should be utilized.

pH

The acidity of a waterway (known as pH) is also an important indicator of freshwater ecosystem health. Transitions from natural landscapes to agricultural and suburban/urban uses are typically reflected in waterways by an increase in pH. This is particularly problematic in the central and southern portions of the watershed, where the headwaters of many of the waterways are in the Pinelands area and, therefore, have naturally low pH. The unique aquatic species endemic to the Pinelands have evolved to survive in these acidic waters, and raising the pH may have adverse consequences. The New Jersey Surface Water Quality Standards (SWQS) identifies a pH range of 3.5-5.5 for Pinelands waters and 4.5-7.5 for Inner Coastal Plain waters, which are those waters outside of official Pinelands boundaries but which still may be influenced by similar natural conditions. The SWQS in the remaining waters of the state for pH is 6.5-8.5.

Status

During the 2011-2015 time frame, one station (Ridgeway Brook at Route 70) had a violation of the pH standard. Since only 1 station out of 28 stations within the watershed has data that shows impairment, the overall status for pH in the watershed is "Good."

Trends

Throughout the time series in question, pH in the central segment was lower than the north and south (Figure 3).

Data gaps

As with temperature, valid assessment of trends, seasonal changes, and comparisons of data between monitoring locations, watersheds, and regions is difficult due to the short period of record. The Barnegat Bay Long-Term Monitoring Network in 2013 should fill this data gap moving forward. In addition, the Ambient Surface Water Quality Monitoring Network (a cooperative effort between NJDEP and USGS) contains monitoring stations on the Metedeconk River, Toms River, and Cedar Creek which have been monitored since 1998 and will continue to be monitored on a quarterly basis. These stations should be evaluated for long-term trends for pH.

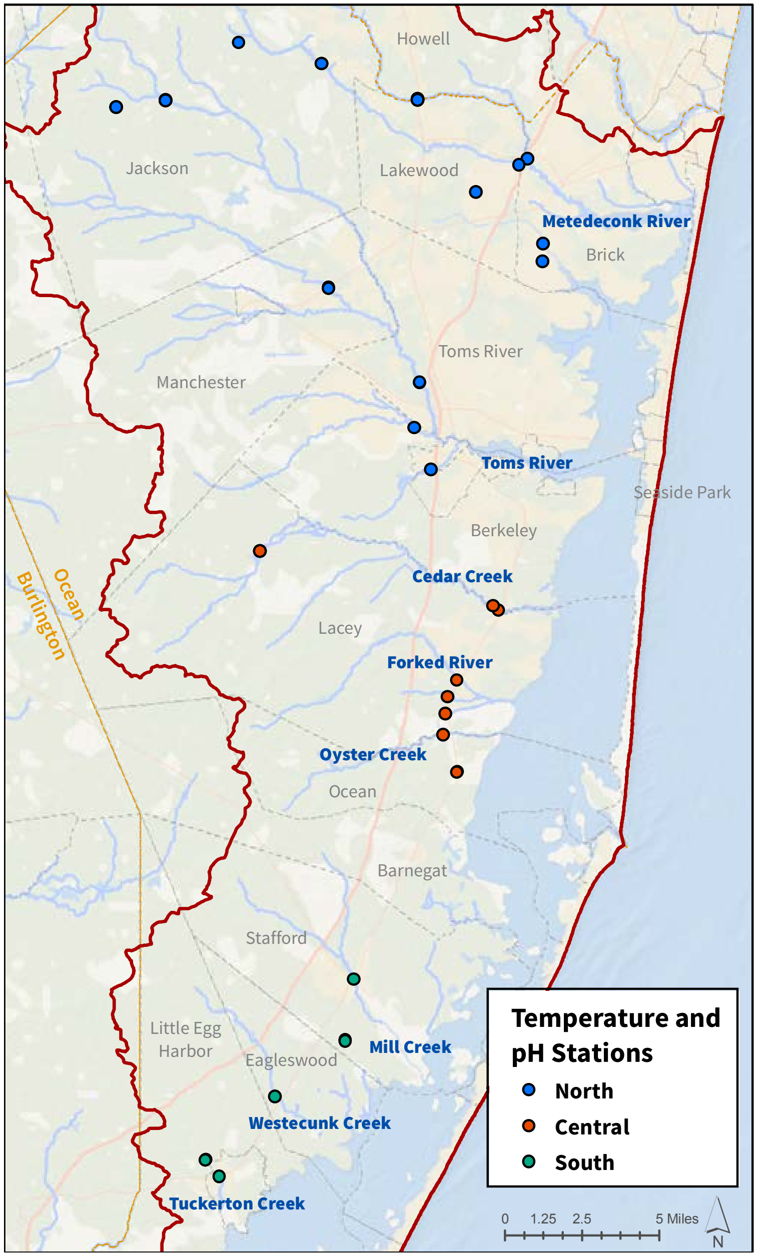
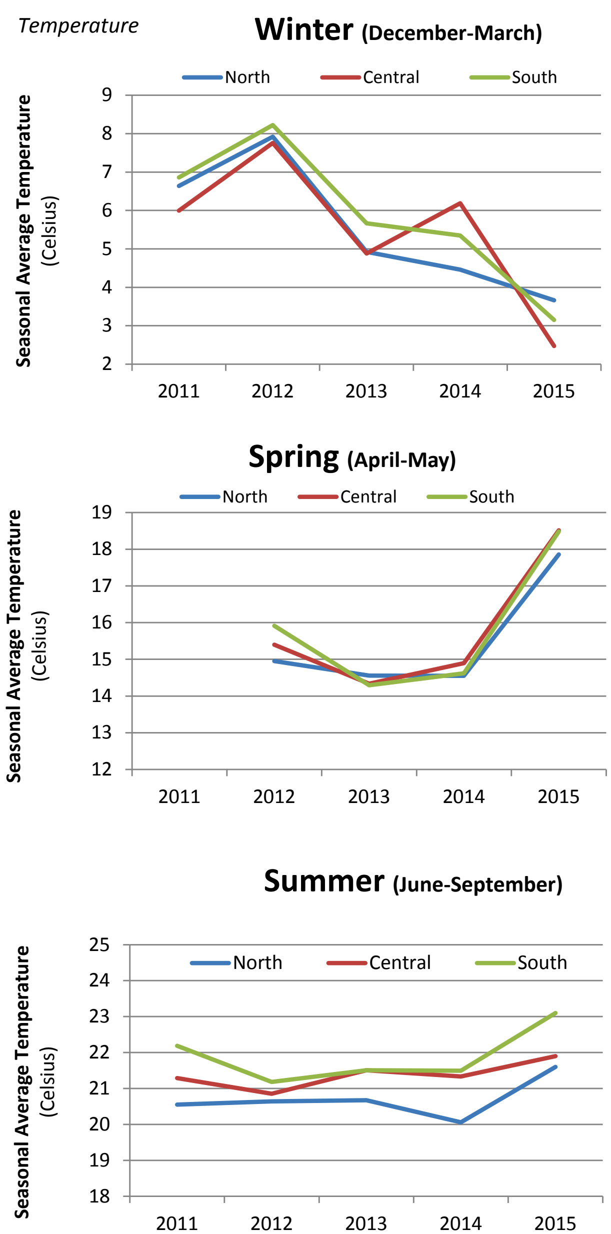


Figure 1: Temperature and pH sampling station locations within the watershed utilized in this report. Data provided by the NJDEP and USGS.

Data courtesy of NJDEP and USGS through the USEPA STORET data warehouse.

Temperature and pH

continued



◀ Figure 2: Stream and river temperatures throughout Barnegat Bay. Winter samples were collected December-March, spring samples April-May, and summer samples June-September. See map for the locations of the sampling stations. Data provided by the NJDEP and USGS.

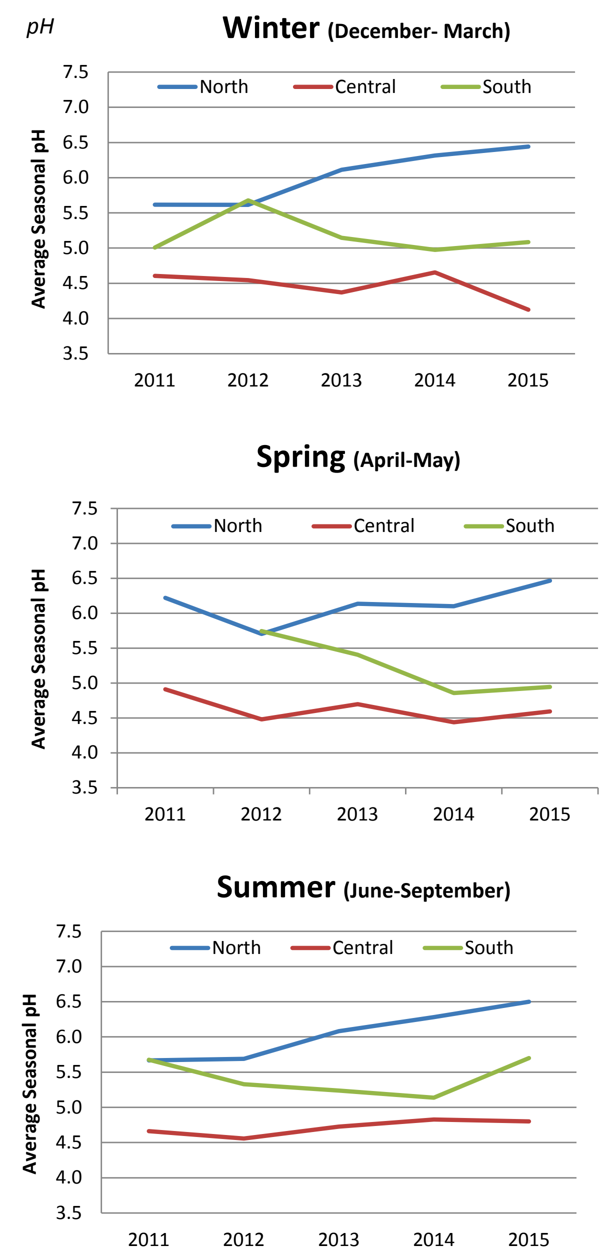
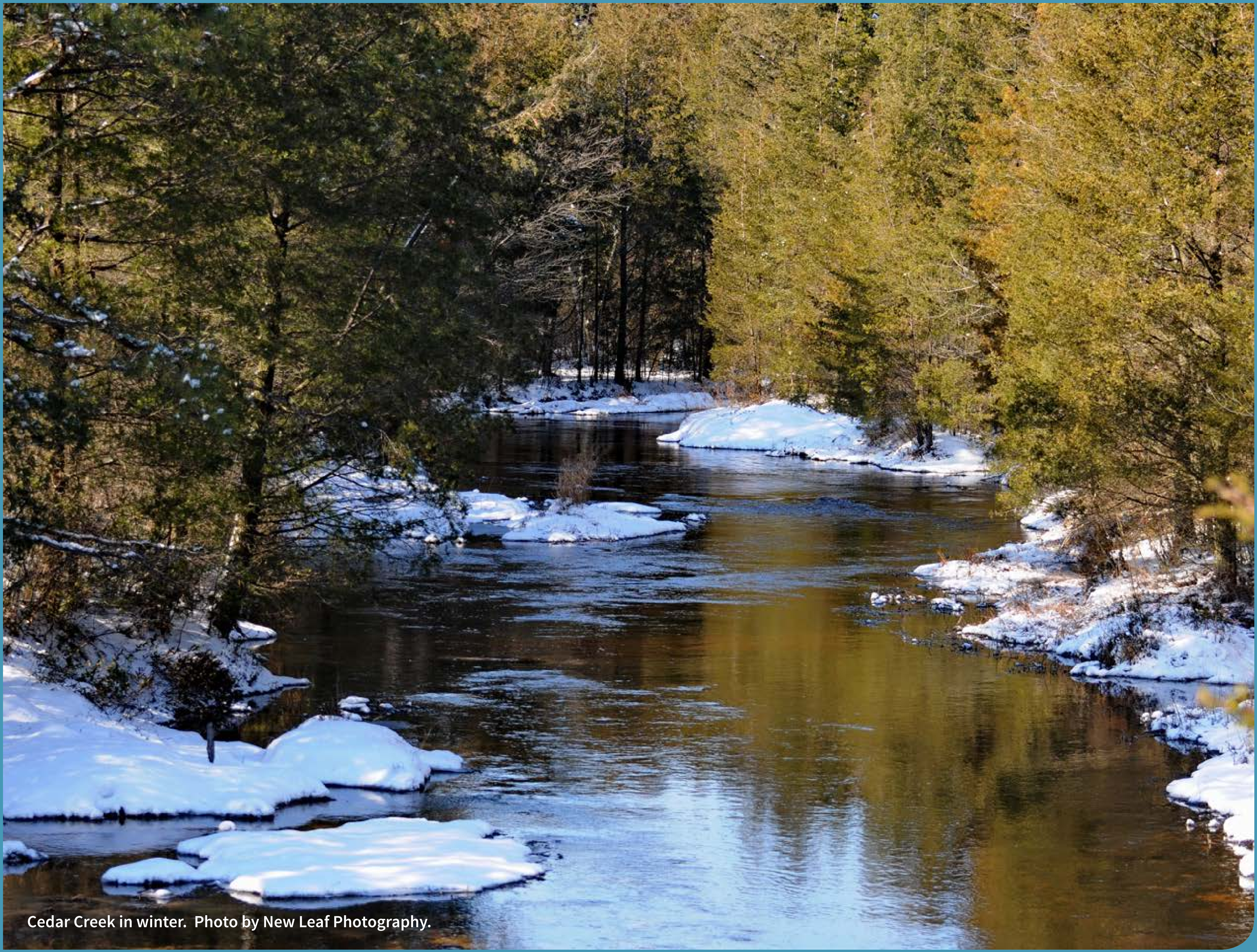


Figure 3 ▶ Stream and river pH throughout Barnegat Bay. Winter samples were collected December-March, spring samples April-May, and summer samples June-September. See map for the locations of the sampling stations. Data provided by the NJDEP and USGS.



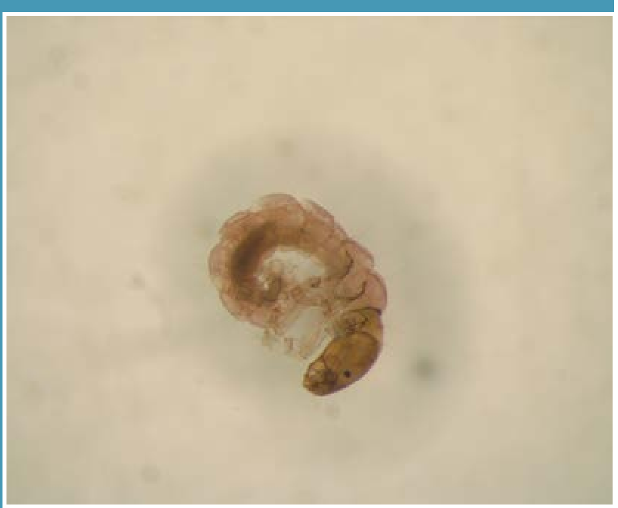
Cedar Creek in winter. Photo by New Leaf Photography.

Indicator

Freshwater Macroinvertebrates

Indicator Status

Caddisfly larvae. Photo courtesy of NJDEP Bureau of Freshwater and Biological Monitoring.



Background

Fresh water biological monitoring refers to the use of in-stream populations of benthic macroinvertebrates as indicators of water quality. Benthic macroinvertebrates are bottom-dwelling, "larger than microscopic" invertebrate animals inhabiting aquatic habitats. In freshwater rivers and streams, common forms are aquatic insects, worms, snails, and crustaceans. Macroinvertebrates are commonly found throughout the watershed's streams, fulfilling an important role in the aquatic food web. Species comprising the in-stream macroinvertebrate community occupy distinct niches (living spaces) governed by environmental conditions and their tolerance to pollution. Changes in environmental conditions, water quality, and/or habitat quality, may be reflected in changes in the macroinvertebrate community structure. Assessments of ambient water quality can then be based upon standardized measures of said changes in community structure.

There are a number of advantages to using benthic macroinvertebrates as indicators of fresh water quality: 1) they are good indicators of localized conditions of water quality due to their limited mobility, which makes them well-suited for the assessment of site-specific pollution impacts; 2) they are sensitive to environmental impacts from both point and nonpoint sources of pollution; and 3) they can be used to assess non-chemical impacts to the benthic habitat, such as by thermal pollution or excessive sediment loading (siltation).

The NJDEP's Bureau of Freshwater and Biological Monitoring conducts macroinvertebrate sampling through its statewide, rotating basin **A**mbient **M**acroinvertebrate **Net**work (**AMNET**; Figure 1). This network is designed to evaluate the health of in-stream benthic macroinvertebrate communities using a monitoring and assessment methodology (USEPA Rapid Bioassessment Protocol) that produces an index of water quality with categories of: "excellent," "good," "fair," and "poor." As part of the AMNET monitoring, 64 freshwater stream sites within the Barnegat Bay watershed were most recently sampled in 2010-2011 (Round 4). Previous sampling rounds in the watershed were conducted in 2004-2005 (Round 3), 1999-2000 (Round 2) and Round 1 (1994-1995). Sampling protocols were modified slightly between Rounds 2 and 3 in that the sampling period was restricted from year-round, to April through November, taking macroinvertebrate life histories into account. Some sites, primarily the central and southern watershed segments, were sampled in the winter during Rounds 1 and 2.

Status

Based on 2010-2011 sampling, 17% of the stream sites monitored in the watershed are classified as "excellent," 30% are classified as "good," 45% are classified as "fair," and 8% are classified as "poor" (Figure 2). In regard to meeting the Aquatic Life Use criteria of New Jersey's Surface Water Quality Standards (SWQS), 37 of the 64 sites (58%) are considered attaining and 42% are considered non-attaining.

Trends

For the 2010-2011 sampling round, the percentage of sites rated as "excellent" has declined compared to the 2004-2005 sampling, going from 35% to 17%, with the percentage in the "poor" category remaining virtually unchanged between the two rounds of sampling, and increases in percentages in both the "good" and "fair" categories. The trends for each of the bay segments can be seen in Figure 3.

When the benthic macroinvertebrate index scores for sites sampled in all four sampling periods (1994-1995 through 2010-2011) is evaluated, 54 sites (95%) had no discernible trend through time and 3 sites (5%) declined.

Data gaps

As per the AMNET rotating basin schedule, samples were collected again in the Barnegat Bay watershed during the 2015 sampling season, with results expected in 2016.

For more information on the benthic macroinvertebrate monitoring and indices, see the NJDEP Bureau of Freshwater and Biological Monitoring website, www.nj.gov/dep/wms/bfbm. For more information on the SWQS and the application of benthic macroinvertebrate data in assessing Aquatic Life Use attainment, see the NJDEP Bureau of Environmental Analysis, Restoration, and Standards website, www.nj.gov/dep/wms/bears.

Data courtesy of the NJDEP through the AMNET database.

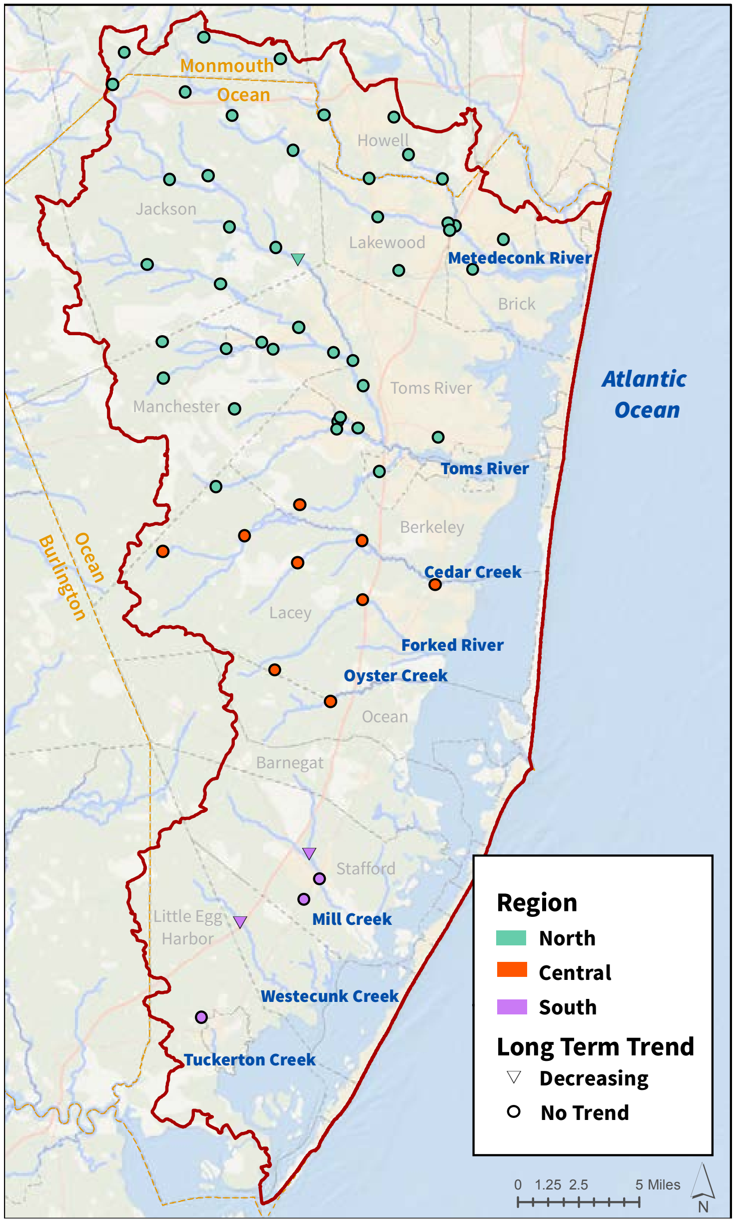


Figure 1: Location of the NJDEP AMNET sampling stations in the Barnegat Bay watershed utilized in this study. Sites denoted by a circle showed no discernible long-term trends, while those denoted by a triangle had a declining trend through time.

Freshwater Macroinvertebrates

continued

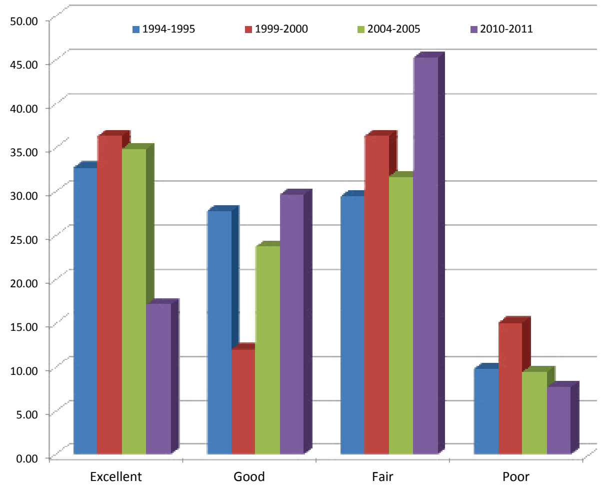
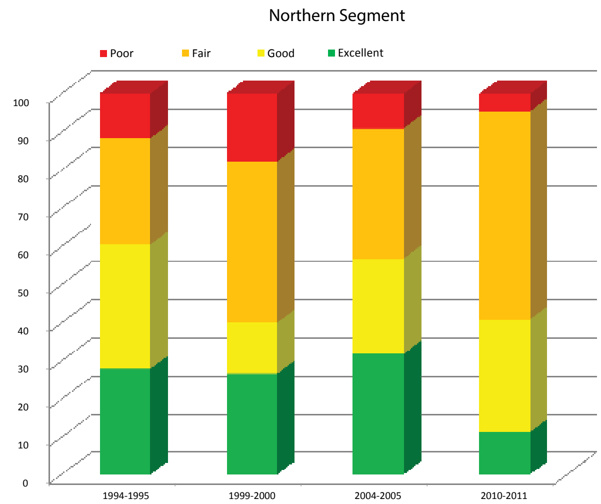
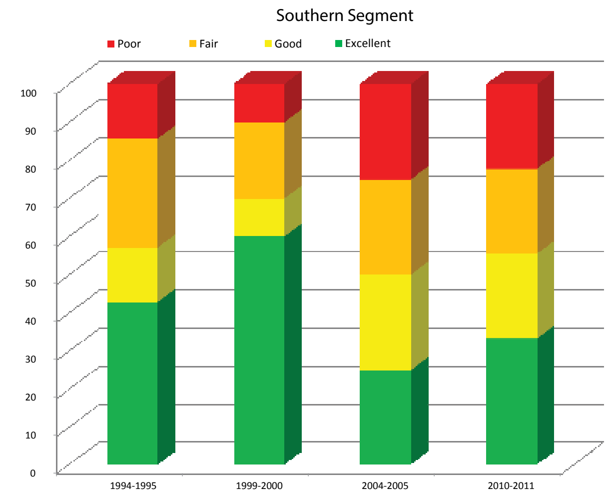


Figure 2: Percentage of sampled streams within the Barnegat Bay watershed that obtained each of the AMNET index rating categories for the four sampling rounds.





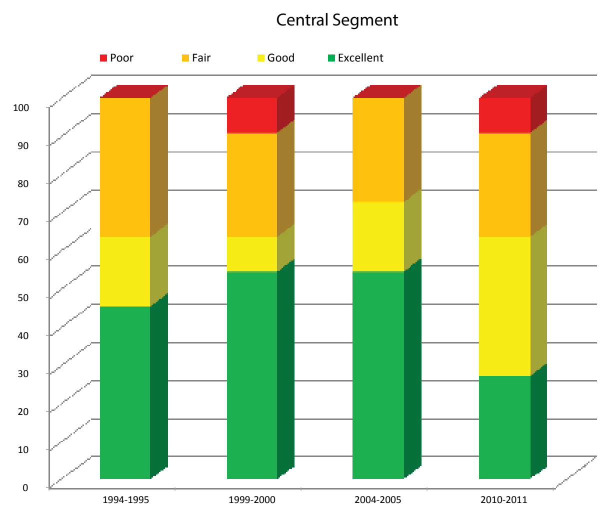


Figure 3: Percentage of sampled streams within the northern, central, and southern portions of the Barnegat Bay watershed that obtained each of the AMNET index rating categories for the four sampling rounds.

Human Use Impairments

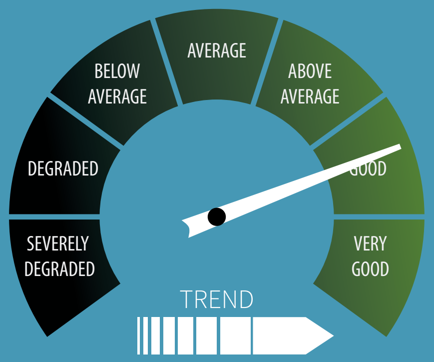
The Barnegat Bay has long been a favorite spot for recreational activities like boating, swimming, fishing, and clamming. Unfortunately, our enjoyment of the bay can be disrupted by the presence of pollutants which force us to limit our interaction with the water in order to avoid exposure. The reasons for closing a bathing beach are often similar to those for closing waters to shellfish harvesting – the presence of pathogens like viruses, some bacteria, and parasites. These pathogens mainly originate from stormwater runoff and animal wastes.

Garrison Grant, Andrew Hassall, and Kira Dacanay of NJ Bureau of Shellfisheries collect hard clams using a hydraulic hard clam dredge during the 2012 stock assessment of Barnegat Bay. Photo by Kira Dacanay, NJ Bureau of Shellfisheries.

Indicator

Bathing Beach Closures

Indicator Status



Children at Barnegat Bay beach. Photo by Barnegat Bay Partnership.

Background

For more than 30 years the Ocean County Health Department (OCHD) has obtained and analyzed water samples from all public bathing beaches in the county on a weekly basis between Memorial Day and Labor Day. Results of bathing beach monitoring provide an indication of the levels of pathogenic bacteria in the waters utilized for recreational bathing. These findings are used by the OCHD to determine whether beaches are to remain open for bathing. Closure statistics for beaches on the bay, freshwater lakes, and rivers provide an indication of the amount of bacteria from various sources being flushed from the watershed into the waterways that eventually flow into the bay. Closure statistics also provide a general indication of the nonpoint source loadings of contaminants and pathogens other than bacteria. Stormwater typically contains suspended solids, nutrients, organic carbon, petroleum hydrocarbons, heavy metals, and pesticides, in addition to bacteria.

Freshwater samples are analyzed for fecal coliform, which is a group of coliforms present in the digestive tract of warm-blooded animals. In 2004, the NJDEP (at the suggestion of the USEPA) changed the required indicator organisms for brackish and saltwater beaches from fecal coliform to *Enterococcus*, a bacterium found in the digestive tracts of warm-blooded animals.

Status

Lakes

The OCHD sampled ten public recreational bathing lake sites during the 2010-2015 bathing seasons (Figure 1). The bathing areas at the lakes represented approximately 79% of all beach closings during that six-year span. Two factors, stormwater runoff and waterfowl waste, influence the occurrence of elevated bacterial counts in lakes of the BB-LEH watershed.

Without external factors such as waterfowl, the lakes appear to recover to pre-storm coliform levels within approximately 24-36 hours after a rainfall event. With an abundance of waterfowl, the lake may require several days to recover. The severity of the initial influx of bacteria is proportional to the density of development in the area serviced by the storm drain system that empties into a given lake. Lakes (such as Harry Wright Lake in Manchester) that are surrounded by a lower density of housing, recover fairly quickly in comparison to Lake Barnegat and Deerhead Lake in Lacey Township, which receive stormwater from a relatively higher population density.

Creeks

The OCHD sampled two public recreational bathing creek sites during the 2010-2015 bathing seasons on the freshwater portions of Cedar Creek (Figure 1). Cedar Creek is an example of how bacteria-free a water body can be without the influence of storm drains. The stream has very few storm drains, and as a result seldom has an elevated bacteria count (four total closures from 2010-2015; two at each beach).

Bays and Rivers

The OCHD and Long Beach Island Health Department (LBIHD) sampled 14 public recreational bathing bay-beach sites and 9 public recreational bathing brackish-river sites (Figure 1) throughout the 2010-2015 recreational bathing beach seasons. The river sites are along the Toms, Metedeconk, and Manasquan rivers, while the bay sites are located throughout the eastern and western sides of the bay. Four bay beaches accounted for a total of seven closures over the six-year period. Of the 49 closures at river beaches during 2010-2015, 11 were at Windward Beach on the Metedeconk River in Brick Township and 24 were at Beachwood Beach on the Toms River in Beachwood Township (see sidebar). Non-point source pollution delivered via stormwater is the primary source of contamination at these beaches.

Trends

When the data from county public recreational bathing beaches that have been sampled routinely for 15 years are analyzed, there is a general decrease in the number of bathing beaches closed due to poor water quality (Figure 2). The number of closures at bay and river beaches has decreased through the early part of the time frame and have remained relatively low over the past five years. The number of freshwater closures (predominantly lakes) has fluctuated throughout the past 15 years, though the highest number of closures occurred in 2013, before dropping over the past 2 years. The fluctuation in the number of closures is attributable primarily to the number, duration, and intensity of rainfall events occurring immediately before and during the recreational bathing season.

Data Gaps

The results of rain-provisional sampling preliminarily indicate that many of the beach closures are rain-event driven; however, the amount of rain required to instigate a closing was not quantified. This information could be used to further refine future sampling schemes to answer questions regarding bacterial sources and pathways.

For additional information regarding beach closings and water-quality updates during the recreational bathing season, please visit the Ocean County Health Department online at http://www.ochd.org/Resources/Page/43.

Data were provided courtesy of the Ocean County Health Department.

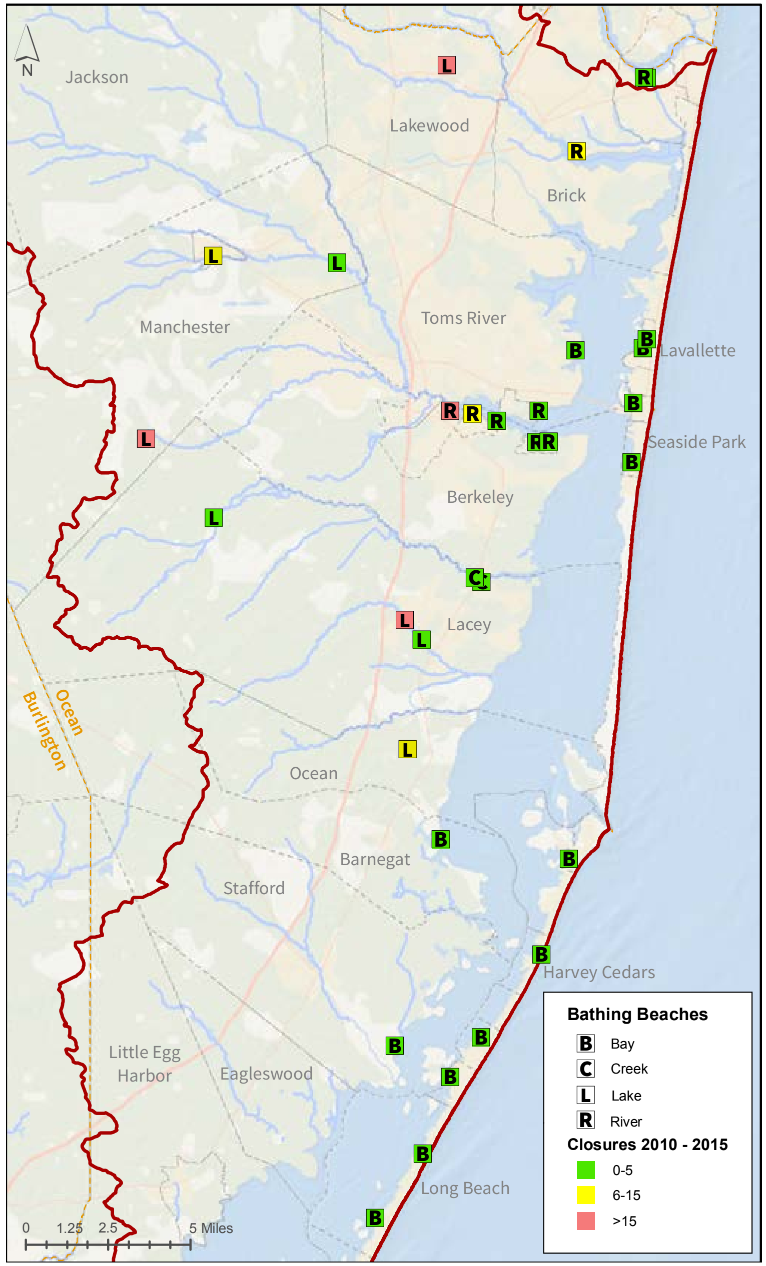


Figure 1: Location of bay, creek, lake, and river bathing beaches in the Barnegat Bay monitored for pathogens and included in this study.

A bay beach in Island Beach State Park. Photo by New Leaf Photography.

Bathing Beach Closures

continued

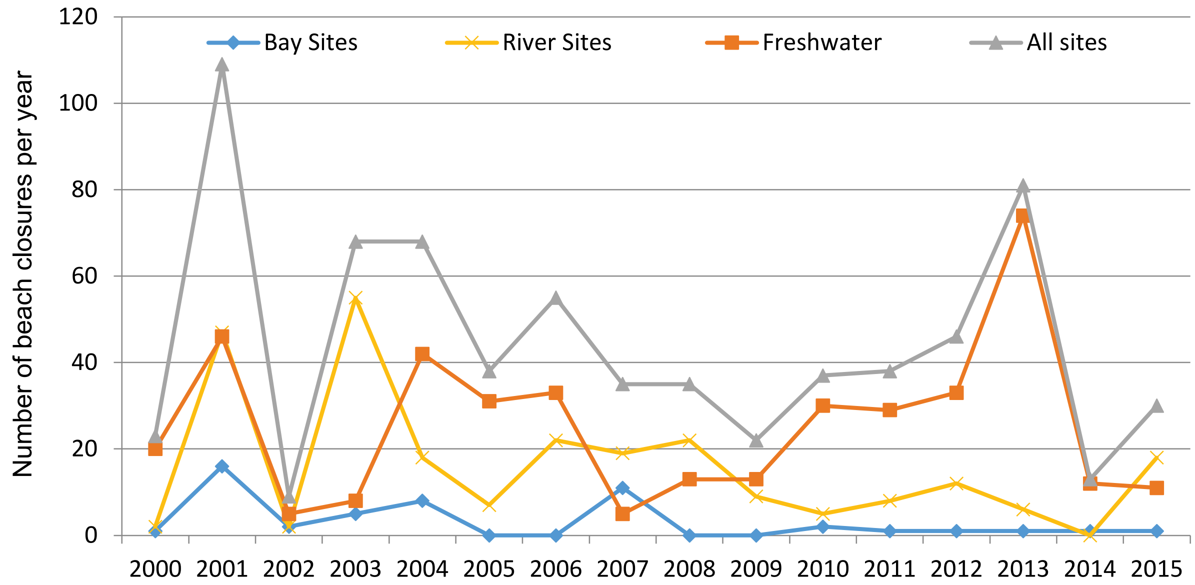


Figure 2: The annual number of bay, river, and freshwater beach closings over the last 15 years. Only those beaches (bay=14, river=9, freshwater=10) which have data for the entire time-series are included.

Newly planted beachgrass. Photo by Barnegat Bay Partnership.

State of the Bay Extra:

Beachwood Beach Project

While many river and bay bathing beaches face challenges from pathogen influx from stormwater systems in the Barnegat Bay watershed, Beachwood Beach historically experienced the most failures and elevated bacteria counts when compared to other beaches in Ocean County. In order to combat this problem, the Ocean County Health Department reviewed archived data sets and performed some basic flow and infrastructure investigations. Armed with this initial information, the NJDEP Bureau of Marine Water Monitoring then organized efforts to leverage municipal, county, and state assets to address local stormwater issues in an attempt to improve water quality at this bathing beach. Experts from the NJDEP, Ocean County, Beachwood Borough, and other agencies coordinated a targeted pollution source trackdown effort to identify local sources of pathogens near the beach. The Borough and County were granted monies from the NJDEP Environmental Infrastructure Trust, and re-engineered several key stormwater collection and discharge pipes, ultimately removing the main stormwater discharge location downstream of the bathing beach. Assistance for this project came in many forms, from the Ocean County Road Department cleaning out stormwater pipes before and during the bathing season, to the NJDEP and US Food and Drug Administration's aid in modeling both the existing water circulation patterns and the impacts of the proposed new outfall. All of this work was done in support of ultimately reducing pathogenic discharges at the beach.

At this time not all of the problem areas and sources of pathogens have been addressed, and there is a great deal of work still being conducted. But the work completed so far demonstrates that a project of this size and scope can be successful when all involved focus on a single goal. Under the coordination of the NJDEP, the overwhelmingly positive actions taken at all levels of government to address this issue make the Beachwood Beach stormwater discharge improvement project a success story for others to use as a model in the future.

Stormwater pipe replacements undertaken as part of the Beachwood Beach Improvement Project. Photos by T&M Associates.

Indicator

Shellfish Bed Closures

Indicator Status

Shellfish aquaculture in Barnegat Bay. Photo by Christian Palmisano, Forty North Oyster Farms.

Background

The NJDEP's Bureau of Marine Water Monitoring (Bureau) monitors the shellfish-growing waters contained within the Barnegat Bay. To ensure that shellfish within these waters are safe for consumption, the waters are analyzed using coliform bacteria as an indicator of human and animal waste. Based on the National Shellfish Sanitation Program requirements, the bay waters are classified as "approved," "seasonal," "special restricted," and "prohibited." Updates to the classification of shellfish waters are completed annually and are based on the latest 30 data points for each station over multiple years.

Status

Currently, the waters of the Barnegat Bay consist of approximately 75% "approved," 6% "prohibited," and 19% "seasonal and special restricted" for shellfish harvest (Figure 1). Poor water quality around shellfish beds is generally attributable to contamination from stormwater runoff and other nonpoint sources rather than single, point source discharges. This can be seen in the northern portion of the bay, which represents a majority of the prohibited and special restricted waters. Red prohibited classifications in the Atlantic Ocean in Figure 1, are a result of administrative buffers around wastewater discharges or known potential sources of bacterial pollution, and not due to degraded water quality.

Trends

There have been no substantial changes in the percentages of classified waters over the past five years. From 2010-2014, an average of 3,506 samples were collected and analyzed for fecal coliform bacteria each year as part of the Bureau's monitoring program. When looked at bay-wide, there is no clear trend in the average overall coliform bacteria levels by year (Figure 2). Because bacterial concentrations can be influenced by rainfall and other meteorological conditions, this year-to-year fluctuation is not surprising. Overall, the estuary has low bacteria concentrations, less than the shellfish water standard of 14 CFU/100ml (Figure 2). High concentrations do sometimes occur in localized areas and subsequently result in different classifications (Figure 1).

For additional information on the NJDEP Bureau of Marine Water Monitoring Shellfish Sanitation Program and the latest classification maps, please visit their webpage at http://www.state.nj.us/dep/wms//bmw/index.html.

Data courtesy of the NJDEP Bureau of Marine Water Monitoring.

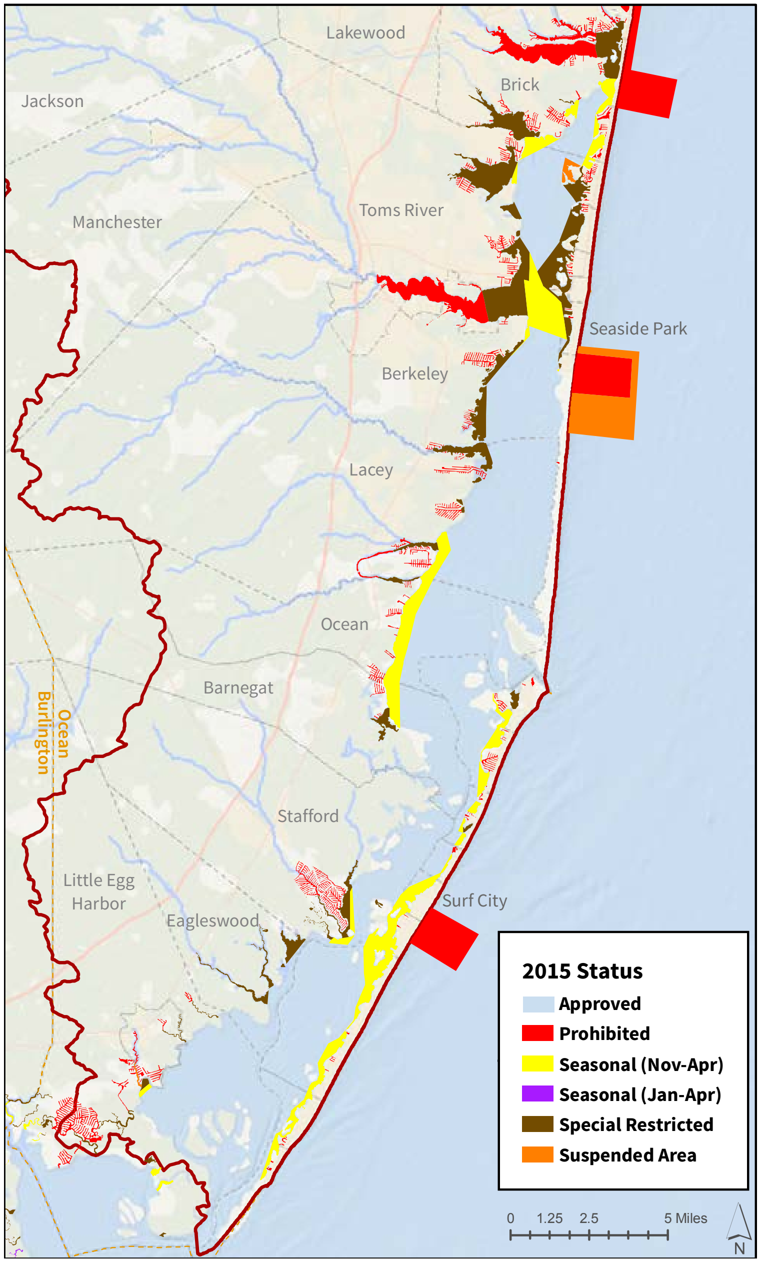


Figure 1: 2015 shellfish growing water classifications for the Barnegat Bay.

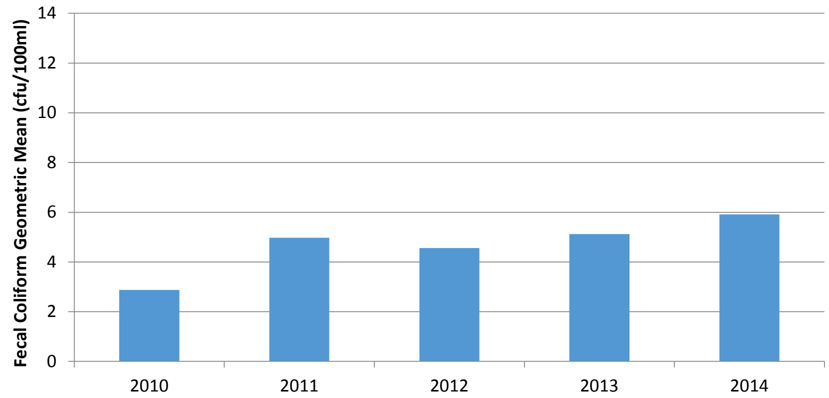


Figure 2: Bay-wide annual mean fecal coliform counts for 2010-2014.

An American oystercatcher working the mudflats.
Photo by New Leaf Photography.

State of the Bay Extra:

Trash Free Waters

Trash that enters inland waterways, coastal waters, and oceans has become a significant challenge to water quality, habitat, complex food webs, and potentially human health. If land-based trash is not disposed of and managed correctly, it can enter freshwater and marine ecosystems.

Land-based aquatic trash consists of many different types of products and materials, especially plastics and packaging, such as bags, bottles, food containers, wrappers, and plastic utensils. In the aquatic environment, plastic trash is associated with direct impacts on aquatic life via strangulation, ingestion, or other physical harm. Additionally, there is a growing concern regarding the potential for microplastic particles, and their associated toxic chemicals, to adversely impact human health as the microplastics and toxins are consumed through the fresh- and marine-water food webs.

Various activities are held throughout the Barnegat Bay watershed by the BBP and its partners to help clean up the trash before it enters the water:

A Canada goose investigating a plastic bag from a local waterway. Photo by New Leaf Photography.

Clean Ocean Action Beach Sweeps are held twice per year (once in the spring and once in the fall) in Ocean County towns. In April 2015, over 789 people participated in the cleanup. Approximately 3,806 pounds of trash was collected (394.5 trash bags) from an estimated distance of 145.9 miles (http://cleanoceanaction.org/index.php?id=153).

The New Jersey Department of Environmental Protection hosts the annual "Barnegat Bay Blitz," consisting of cleanups at 100 locations through the Barnegat Bay watershed. The June 3, 2015 Blitz attracted over 4,000 volunteers. Approximately 1,200 bags of garbage/recycling were collected, in addition to 250 cubic yards of trash. Over the past six years, the Barnegat Bay Blitz has attracted 22,161 volunteers and resulted in the cleanup of approximately 3,037 cubic yards of trash (http://www.nj.gov/dep/barnegatbay/bbblitz.htm).

As a result of the Blitz, the NJDEP began its illegal dumping campaign known as "Don't Waste Our Open Space." While this campaign is not just focused in Barnegat Bay, it can help keep debris out of our waterways (http://www.stopdumping.nj.gov).

EPA Region 2 has initiated a Trash Free Waters (TFW) Program, seeking to help states, municipalities, academia, nonprofits, citizens, and businesses work together to develop innovative land-based aquatic trash management strategies and projects, with the ultimate goal of zero-trash loading within 10 years.

What can we do to make our marine waters safer and healthier? Properly dispose of all litter, including cigarette butts, and securely cover trash cans. Keep streets, sidewalks, parking lots, and storm drains clear of trash and debris – what goes down the storm drains can end up in the bay and ocean. Reduce, reuse, recycle – avoid purchasing products with excessive packaging; bring reusable bags for your purchases; recycle. Tie it down, secure it, or stow it – keep equipment and possessions on the boat and out of the water. Collect and recycle your monofilament fishing line – there are recycling bins located throughout the state. Keep outdoor furniture, decorations, trash cans, and other objects secured or stored inside during windy or stormy weather. Make a difference through prevention!

Water Supplies for People and Wildlife

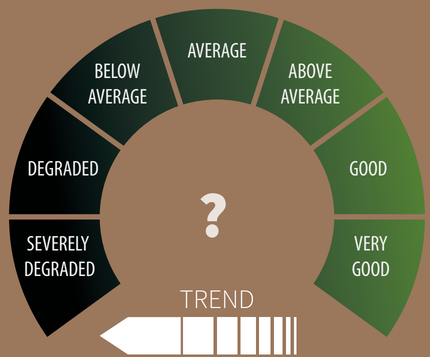
Fresh water plays a crucial role in estuarine health. Not only does the mixing of fresh water with ocean water produce the salinities required by estuarine inhabitants, the rate and continuity of freshwater flow into the estuary also affects many water-quality and ecological processes. Maintaining an adequate rate of freshwater flow while addressing the needs of an ever-increasing human population will be critical in meeting estuarine water-quality and habitat goals.

Canada geese on a winter pond. Photo by BTMUA.

Indicator

Streamflow

Indicator Status



A tributary to the Metedeconk River. Photo by New Leaf Photography.

Background

Approximately 590 million gallons per day of fresh water enter the Barnegat Bay through more than 15 rivers, streams, and creeks. The water in these streams and creeks can be split into two components: base flow and runoff. Base flow is the sustained flow of a stream that comes largely from groundwater entering the waterway. Runoff is the portion of streamflow that comes from precipitation, snow melt, or irrigation water flowing across the land surface (or piped) before entering the waterway. In undeveloped watersheds, runoff is a small part of the total flow, and as development occurs (*i.e.,* an increase in impervious surfaces, groundwater withdrawals for irrigation and consumption), the fraction of total flow from base flow decreases. Reductions in base flow can have serious ecological repercussions, as changes in the timing and amount of fresh water entering the streams and eventually reaching the estuary can affect water quality and habitat for many of the bay's species, including humans!

The United States Geological Survey maintains a network of stream gauging stations that measure the rate of flow in some of the major streams in the watershed on a continuous basis, including the North Branch of the Metedeconk River, Toms River, Cedar Creek, and Westecunk Creek (Figure 1).

Status

Base flow accounted for 67%-94% of total streamflow at the monitored streams in 2014 (Figure 2). The Westecunk Creek had the highest percentage of base flow (94%), followed by Cedar Creek (90%), Toms River (83%), and the North Branch of the Metedeconk (67%). The pattern in the percentage of base flow reflects the north to south urbanization gradient in the Barnegat Bay watershed. The status of streamflow within the watershed is classified as "unknown" because there is currently no minimum base flow criteria to judge the results against.

Trends

From 2010-2014, there has been a high degree of variability in base flow in all four streams, with no overall trend present. However, over the last 40 years, the percentage of base flow in the total flow has significantly declined in the North Branch of the Metedeconk River and Toms River.

Data Gaps

Continued monitoring is needed to determine if the long-term declining trend continues. Furthermore, a criteria for minimum base flow levels to support ecological health should be developed.

For additional streamflow data, including in near real-time for the continuously operated gauging stations, please visit the USGS New Jersey Water Science Center's website (http://nj.usgs.gov).

Data courtesy of the U.S. Geological Survey.

Figure 1: Location of continuously operating streamflow gauging stations in the Barnegat Bay watershed used in this analysis.

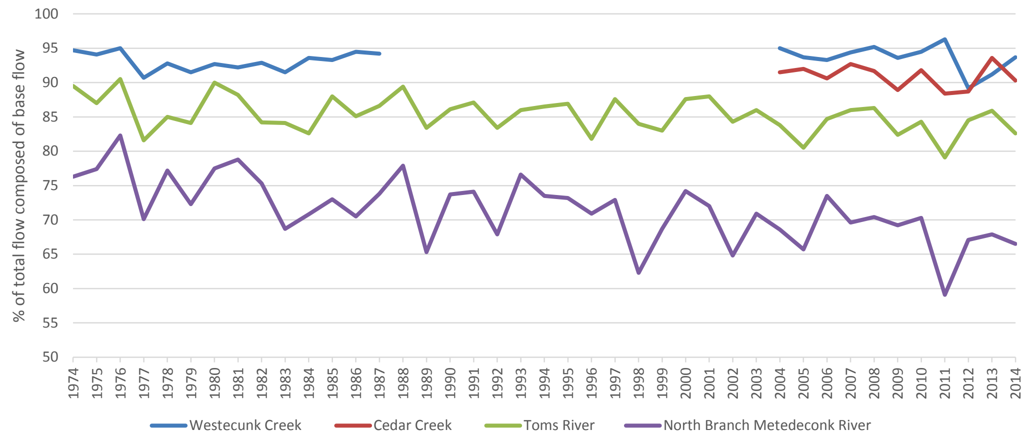


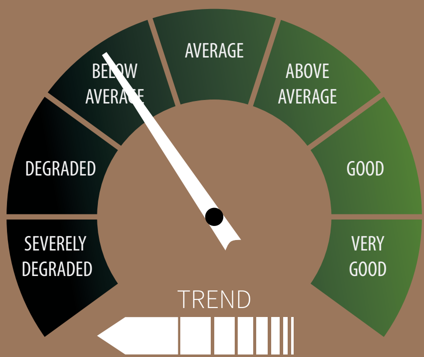
Figure 2: The percentage of total flow composed of base flow for the Westecunk Creek (blue), Cedar Creek (red), Toms River (green), and North Branch Metedeconk River (purple) from 1974-2014.

The Long Swamp Creek at Brown's Woods. Photo by Barnegat Bay Partnership.

Indicator

Water Withdrawals

Indicator Status



Irrigation taps spraying over lawn. Stock photo by Paul Wishart.

Background

Fresh water is important for a variety of human activities, including public supply, agriculture, landscape irrigation, commercial and industrial uses, mining, and power generation. Sources of fresh water include both surface waterways and groundwater from aquifers. Due to their proximity to the surface, unconfined aquifers are generally the easiest to access. The Kirkwood-Cohansey Aquifer system is the most used aquifer in Ocean County for this reason. Unconfined aquifers are also the most impacted by drought and pollution. Deeper, confined groundwater sources are isolated beneath the Barnegat Bay watershed. Withdrawals from these confined aquifers do not typically affect surface waterways. The Barnegat Bay watershed has several underlying confined aquifers. The Potomac-Raritan-Magothy Aquifer System is the most heavily used confined aquifer.

In a natural setting, fresh water from streams and rivers and groundwater discharge would make its way to Barnegat Bay unimpeded, but a significant amount of fresh water is withdrawn and removed from the system before it ever makes it to the bay. In 2014, public supply and industrial use were the two largest withdrawal use categories within the Barnegat Bay watershed.

Public supplies are provided for domestic, commercial, and industrial water needs in many areas of the watershed, particularly in the northern and coastal regions. In 2010, 479,365 Ocean County residents were served by public water utilities, while 97,202 were self-supplied via private wells. Most areas with public water service also have public sewer service, with wastewater being directed to one of three centralized wastewater treatment facilities and, ultimately, the Atlantic Ocean. Where public supplies are drawn from surface water or shallow aquifers, water that would otherwise make its way to the Barnegat Bay is intercepted, utilized, treated and discharged offshore. It is important to recognize that the existing centralized wastewater treatment system was developed to address water quality problems that resulted from many small discharges of questionable-quality wastewater throughout the watershed. Returning high-quality treated wastewater to its point of origin in the watershed would be ideal, though it would require a higher level of wastewater treatment, commonly known as tertiary treatment, which would only be possible with significant infrastructure upgrades. Small-scale pilot projects would be useful to move this concept forward.

Status

USGS estimates that in 2010, Ocean County's freshwater withdrawals averaged approximately 85.56 million gallons per day. Discharge of treated wastewater to the Atlantic Ocean from centralized wastewater treatment facilities in 2014 averaged approximately 50 million gallons per day (Figure 1). The top two withdrawal categories were drinking water and industrial use. Table 1 details water withdrawals within the Barnegat Bay watershed.

Trends

Freshwater withdrawals in the Barnegat Bay watershed and centralized wastewater treatment discharges have increased over the past several decades, and are closely linked to population growth. From 2000-2010, Ocean County added the most residents of any New Jersey county and was the second fastest growing county by percent increase. As the population increases, so will water withdrawals and treated wastewater discharges. While total water withdrawals and wastewater discharges have increased over the last 20 years, per capita wastewater discharges and per capita water withdrawals have decreased. This may be due to a shift towards higher-density housing and the success of water efficiency programs.

Data gaps

Currently, it is impossible to determine the amount of water withdrawn from small wells (withdrawals of <100,000 gal/day) as they are not regulated or specifically tracked. These wells would be used for household supply or landscape irrigation where water is lost to evapotranspiration and not returned to the watershed. USGS estimates how much water is withdrawn from these smaller wells, but exact figures are not known. Available NJDEP data only reflect larger reported withdrawals, leaving billions of gallons of water unaccounted for every year. Most of these wells are drawing water from the Kirkwood-Cohansey aquifer system, which is linked to streamflow within the Barnegat Bay watershed.

Data were provided courtesy of the NJDEP Office of Water Allocation, NJDEP Division of Water Quality, USGS, and US Census Bureau, Population Division.

	Total Withdrawals (Millions of gallons)	Withdrawals per day (Millions of gallons)	Percent of total use
Surface			
Agriculture & Irrigation	1710.4	4.686	1.73
Dewatering	105.2	0.288	0.44
Drinking Water	1900.6	5.207	7.93
Industrial	2908.5	7.969	12.13
Confined Aquifer			
Agriculture & Irrigation	21.7	0.06	0.09
Domestic	10.0	0.027	0.04
Drinking Water	10844.9	29.712	45.24
Industrial	12.9	0.035	0.05
Other	162.3	0.445	0.68
Unconfined Aquifer			
Agriculture & Irrigation	745.9	2.044	3.11
Domestic	32.3	0.088	0.13
Drinking Water	4859.0	13.312	20.27
Industrial	260.4	0.713	1.09
Other	397	1.087	1.65

Table 1: NJDEP-reported water withdrawals in 2014. Note that small wells withdrawals of <100,000 gal/day) are not reported. Other categories include recovery wells, test wells, and unspecified wells.

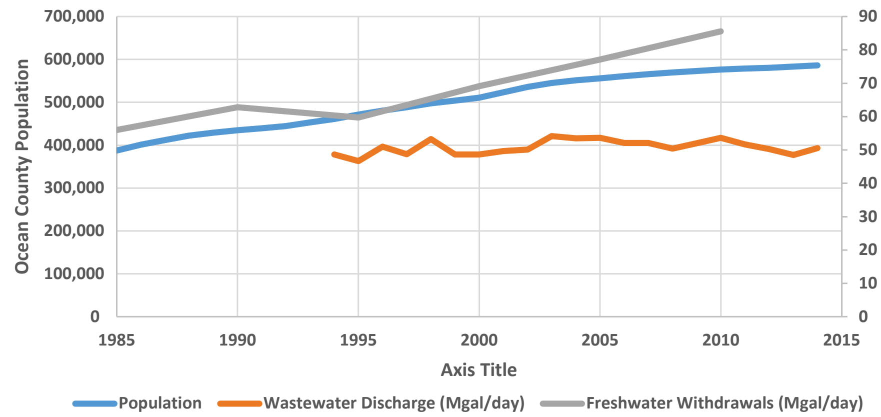


Figure 1: Freshwater withdrawal, wastewater discharges, and population growth in Ocean County for 1985-2014.

The Brick Township Municipal Utilities Authority reservoir. Photo by BTMUA.

State of the Bay Extra:

Green Infrastructure

Stormwater runoff is a major cause of water pollution in developed areas. When rain falls on our roofs, streets, and parking lots, the water cannot soak into the ground as it should. Stormwater drains through gutters, storm sewers, and other engineered collection systems and is discharged into nearby water bodies. The stormwater runoff carries trash, bacteria, heavy metals, and other pollutants from the urban landscape. Higher flows resulting from heavy rains also can cause erosion and flooding in urban streams, damaging habitat, property, and infrastructure.

Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts and provides many community benefits. While single-purpose gray stormwater infrastructure—conventional piped drainage and water treatment systems—is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits.

Several practices fall into the category of green infrastructure and are briefly described here. Further information on each of these practices is available on EPA's green infrastructure website (https://www.epa.gov/green-infrastructure).

A bioswale in a parking lot in Island Heights. Photo by Bryce Bennett.

Rainwater harvesting in a commercial setting. Photo courtesy of US EPA.

Porous Pavement: Permeable pavements infiltrate, treat, and/or store rainwater where it falls. They can be made of pervious concrete, porous asphalt, or permeable interlocking pavers. This practice could be particularly effective where land values are high and flooding or icing is a problem.

Bioswales: Bioswales are vegetated, mulched, or xeriscaped channels which provide treatment and retention. Vegetated swales slow, infiltrate, and filter stormwater flows. As linear features, they are particularly well suited to being placed along streets and parking lots.

Rain gardens: Rain gardens are versatile features that can be installed in almost any unpaved space. Also known as bioretention, or bioinfiltration cells, they are shallow, vegetated basins that collect and absorb runoff from rooftops, sidewalks, and streets. This practice mimics natural hydrology by infiltrating, and evaporating and transpiring—or "evapotranspiring"—stormwater runoff.

Green Roofs: Green roofs are covered with growing media and vegetation that enable rainfall infiltration and evapotranspiration of stored water. Green roofs can be extensive or intensive. Extensive green roofs are characterized by vegetation needing little maintenance, no permanent irrigation system and a shallow growing depth. An intensive green roof system is characterized by a variety of vegetation, advanced irrigation systems, and a deeper growing medium. These can include rooftop farms and buildings in public parks.

Rainwater Harvesting: Rainwater harvesting systems collect and store rainfall for later reuse on-site. Individual rain barrels that generally hold 55 gallons are typically used by homeowners while larger cisterns can be installed in commercial/municipal settings.

A rain barrel collecting roof runoff in Island Beach State Park. Photo courtesy of NJDEP.

Protecting Land and Water

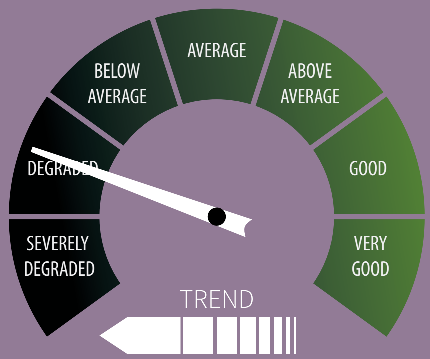
While seemingly far from the Barnegat Bay itself, municipalities such as Plumsted, Lakehurst, Manchester, Jackson, Wall, Millstone, and Freehold contain the headwaters and tributaries that eventually join together to form the Toms River and Metedeconk River. This fresh water mixes with saltwater to create vital nursery areas for life along the entire Atlantic coast. Along with many other creeks and streams, these waterways flow through our communities, connecting all of us to Barnegat Bay.

Fall leaf on water. Photo by New Leaf Photography.

Indicator

Land Use – Land Cover

Indicator Status



Aerial photo of Toms River.
Photo by Wallace "Smitty" Smith.

Introduction

Changes in land use can have dramatic and far-reaching impacts on the environment. The conversion of forested areas and wetlands into **urban** settings directly reduces the amount of habitat available for plant and animal species not adapted to living in close proximity to humans. Further, this alteration not only disrupts hydrologic and other natural cycles, but has been linked to the degradation of estuarine habitat quality far removed from the site of disturbance through sediment contamination, increased nutrient levels in surface waters, and increased incidences of hypoxia, or low dissolved oxygen levels in water.

The NJ Department of Environmental Protection has contracted the mapping of land use/land cover across the watershed based on the visual interpretation of aerial photography since 1986. The Rutgers University Center for Remote Sensing & Spatial Analysis (CRSSA) has analyzed the mapped data for the years 1986, 1995, 2002, 2007, and 2012.

Status

Updated mapping reveals that urban land use occupied approximately 110,665 acres (32%) of the Barnegat Bay watershed in 2012, excluding water. Including all altered land uses (*i.e.*, urban + barren + agriculture lands), the total altered land area is 121,347 acres, or nearly 35% (Figure 1).

The data used for this analysis can be found on the NJDEP Bureau of GIS website at http://www.nj.gov/dep/gis/lulc12.html.

Trends

Urban land use in the watershed has continued to increase, from approximately 22% of the Barnegat Bay watershed in 1986, to approximately 32% in 2012 (Figure 2). However, the rate of conversion of forest, farm, and wetland to urban land use slowed from approximately 1,590 acres per year between 1995 and 2002, to 514 acres per year between 2007 and 2012. This recent time period closely corresp onds to the Great Recession and a major slump in New Jersey's housing market. Despite this slowing, the watershed is continuing to experience a significant conversion of forested and wetland habitats to urban land cover, thereby exacerbating nutrient loading to the BB-LEH estuary.

Data Gaps

As newer imagery becomes available, similar analysis will need to be conducted to determine if the rate of land conversion continues to slow.

Urban:
Defined here to include all land covered with structures, including but not limited to houses, buildings, and parking lots.

Intensive rooftop farm. Photo courtesy EPA.

Land Cover Description	Acres	% of Land Area
Urban	110,665	31.8
Agriculture/Grassland	3,876	1.1
Barren	6,806	2.0
Upland Forest	138,650	39.8
Wetlands	88,018	25.3
Land Area Total	348,015	

Table 1: Year 2012 land cover as acres and as % of the Barnegat Bay watershed's land area.

	1986	1995	2002	2007	2012
URBAN LAND					
Area (acres)	78,781	90,044	101,078	108,094	110,665
% of watershed	23%	26%	29%	31%	32%
ALTERED LAND					
Area (acres)	96,992	105,564	115,159	119,794	121,347
% of watershed	28%	30%	33%	34%	35%

Table 2: Urban and altered (urban + barren + agriculture) land totals and % of the watershed land area by year.

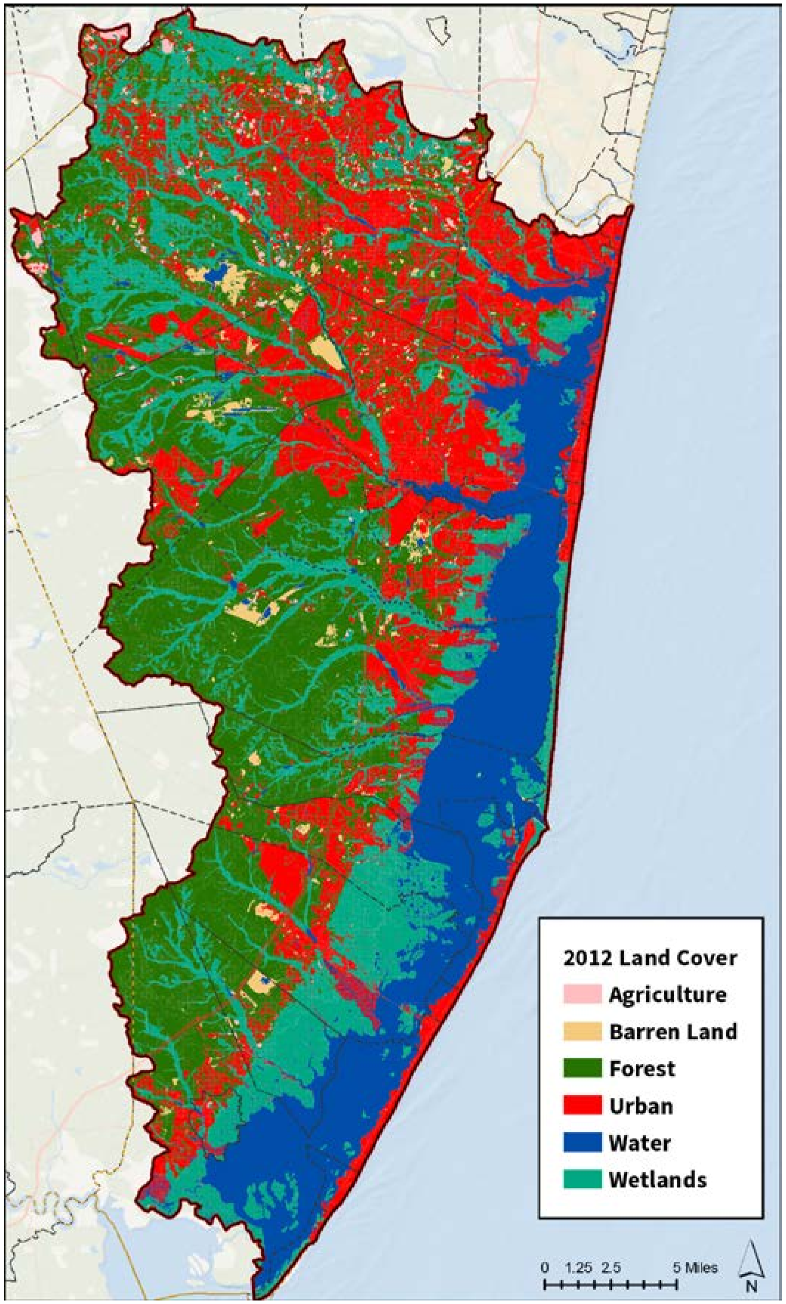
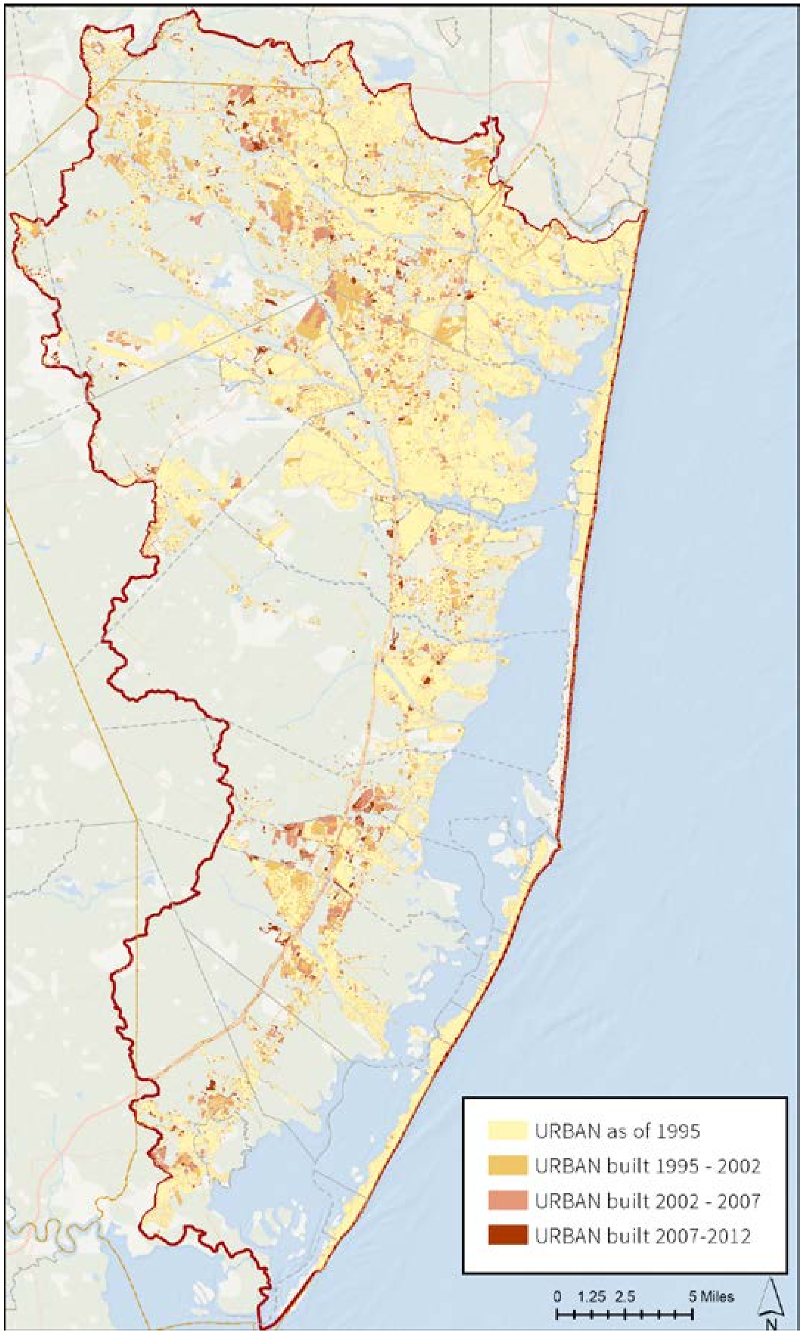


Figure 1: Map of the Barnegat Bay watershed's land use/land cover for 2012.

Land Use – Land Cover

continued

Figure 2: Urban land increases from 1985-2012 within the Barnegat Bay watershed.

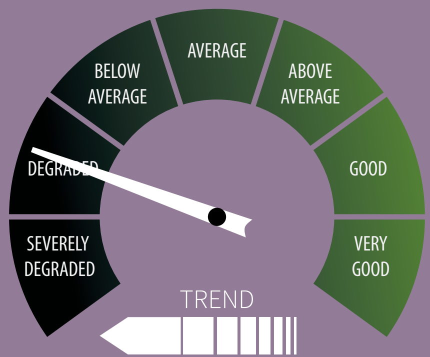


The "Judge's Shack" at Island Beach State Park. Photo by New Leaf Photography.

Indicator

Wetland Area

Indicator Status



Residential development along the edge of a salt marsh. Photo by Barnegat Bay Partnership.

Background

The Barnegat Bay estuary is home to many diverse species of plants and wildlife. The wetlands surrounding the area are an integral part of this sensitive ecosystem, providing habitat and a nursery for various fish, shellfish, and wildlife. In the latter half of the 20th century, Ocean County has experienced an exponential growth in population which has stressed the bay waters, as well as the wetlands and wildlife. Increased boat traffic wake has added to the erosion of salt marshes along the waterfront, and development along the mainland and barrier islands has changed the land cover in many places, and resulted in losses of wetlands.

The Stockton University Coastal Research Center (CRC) completed tidal- and freshwater- wetlands trends analyses using Geographic Information System (GIS) Land Use/Land Cover datasets available from the New Jersey Department of Environmental Protection (NJDEP) for the years 1995, 2002, 2007, and 2012 (conditions prior to Hurricane Sandy).

Status

There were approximately 22,795 acres of tidal wetlands and 67,034 acres of freshwater wetlands within the Barnegat Bay watershed in 2012.

Trends

The Barnegat Bay watershed has continued to lose tidal wetlands over the past 20 years, with losses apparent throughout the entire bay (Figure 1). The area of tidal wetland area lost between each study period has ranged from a low of 144 acres between 2002 to 2007 to a high of 295 acres between 1995 to 2002. The 238 acres of tidal wetlands lost during the most recent study period (2007-2012) was substantially higher than the previous study period, suggesting that the pace of loss is accelerating.

Tidal wetlands open to large wind fetches along the Barnegat Bay shoreline have experienced the brunt of wetlands loss. Possible reasons for the losses include erosion from boat traffic, wind-generated wave energy, sea level rise, or human alteration of the landscape that was originally delineated as wetlands. Sheltered tidal waterways and lagoons were the only areas where small gains occurred.

While the amount of freshwater wetlands within the Barnegat Bay watershed continues to decrease, the rate of the decline has slowed (Figure 2). Between 1995 and 2002, approximately 1,107 acres of the freshwater wetlands within the county were lost, while the most recent assessment suggests that 284 acres of the freshwater wetlands present in 2007 were lost by 2012. The economic slow-down of the late 2000's likely played a role in slowing freshwater wetland losses, as they are typically associated with development activities.

Data were provided courtesy of the Richard Stockton College Coastal Research Center.

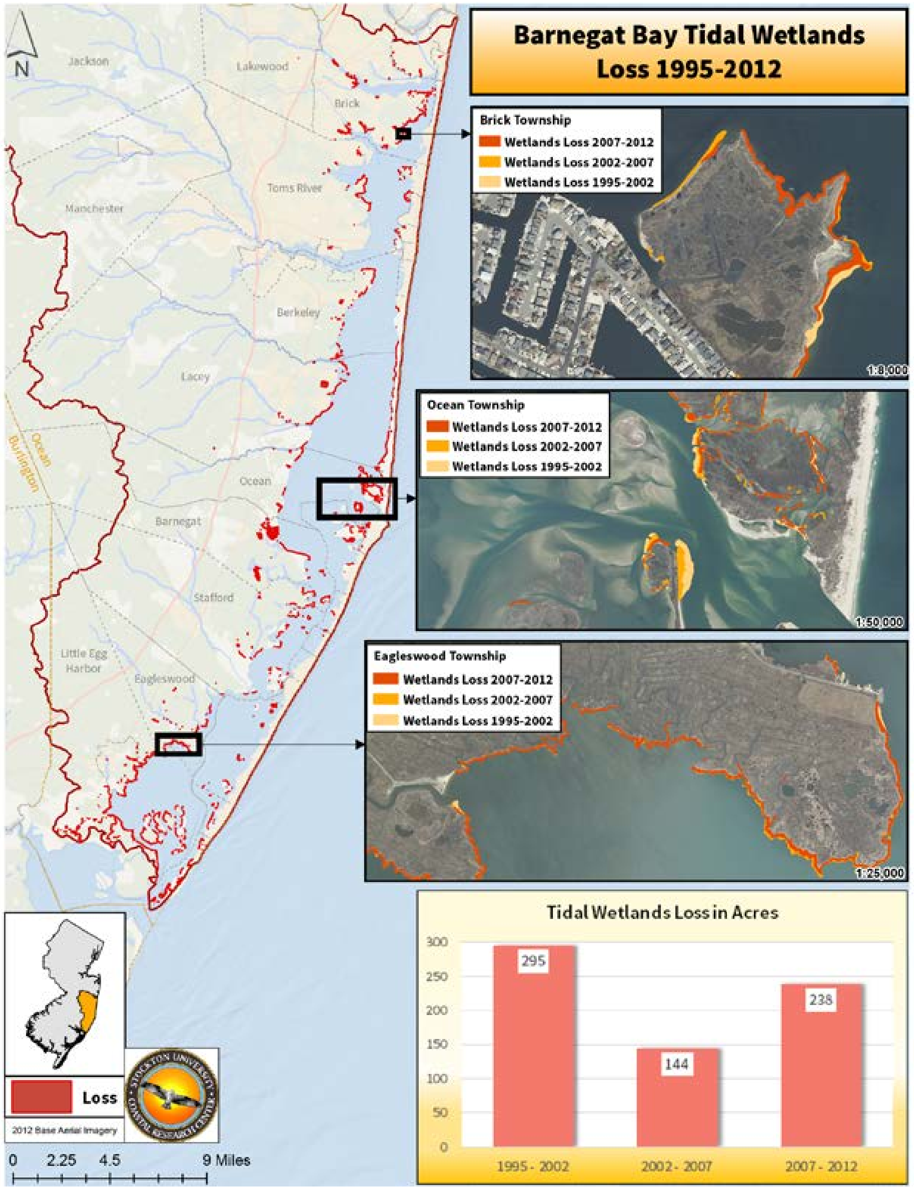


Figure 1: The areas of the main figure in red depict tidal wetlands lost in the watershed between 1995 to 2012, with close-ups of select areas in the insets. The acreage of tidal wetlands lost between study dates, as calculated from aerial photographs, are shown on the column graph.

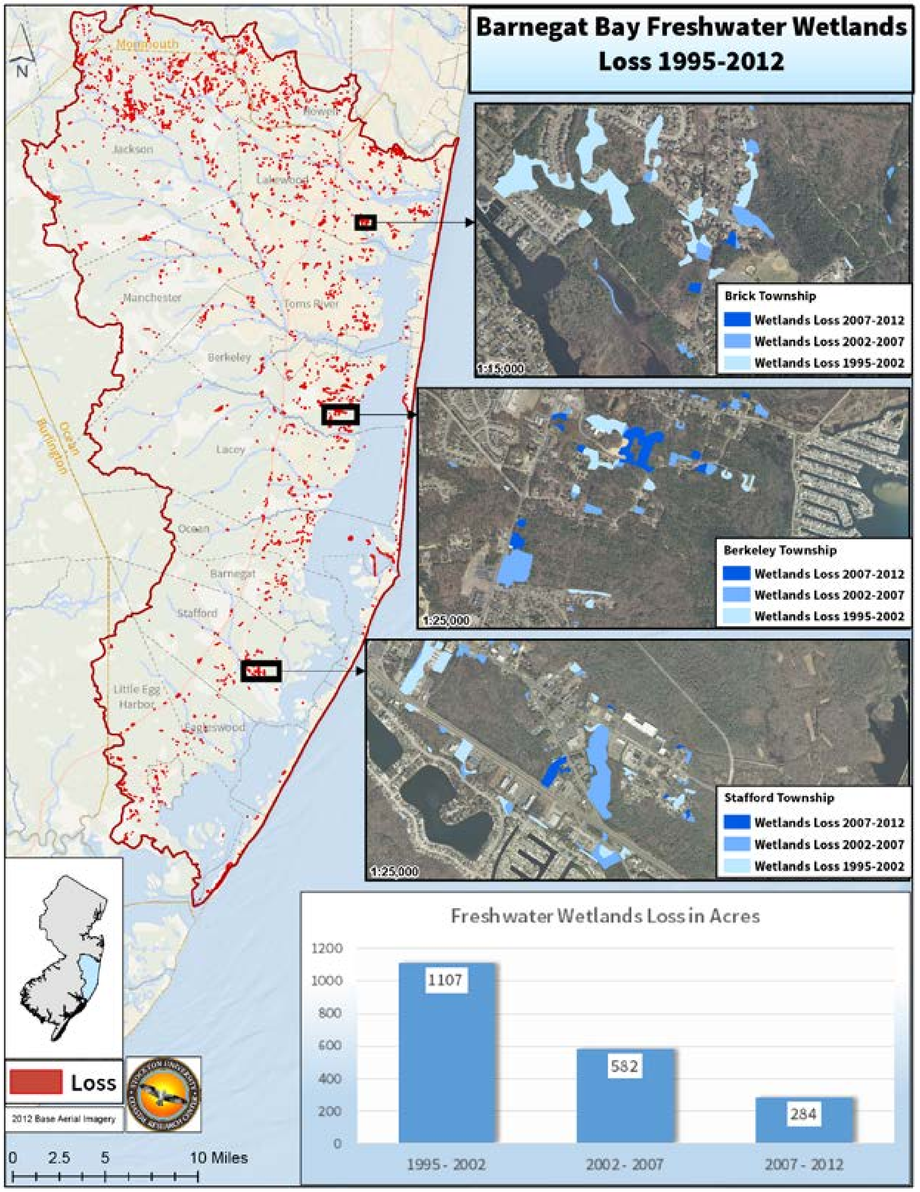


Figure 2: The areas of the main figure in red depict freshwater wetlands lost in the watershed between 1995 and 2012, with close-ups of select areas in the insets. The acreage of freshwater wetlands lost between study dates, as calculated from aerial photographs, are shown on the column graph.

Indicator

Tidal Wetland Condition

Indicator Status

A tidal wetland with extensive ditching and encroaching development. Photo by Barnegat Bay Partnership.

Background

Tidal salt marshes provide essential ecosystem services to the coastal communities of Barnegat Bay. These areas are the transition zones in estuaries, providing nursery, forage, and nesting habitat for fish and other wildlife, and display greater complexity and primary production than other nearby habitats. Tidal salt marshes also provide flood protection, water quality improvements and biogeochemical cycling, all of which benefit the surrounding communities. A 2012 study valued the ecosystem services of saltwater wetlands in Barnegat Bay at $155 million per year.

In 2010, the Mid-Atlantic Coastal Wetlands Assessment (MACWA) was established to assess and track the extent and condition of tidal wetlands across the Delaware Bay and Barnegat Bay estuaries. MACWA is a multi-tiered program that includes long-term, site-specific intensive monitoring, remote sensing analysis, special studies, and rapid assessments. To assess wetland condition and identify stressors affecting wetland health, rapid assessments were conducted at random wetland sites throughout the Barnegat Bay watershed and assessment began in the Great Bay/Mullica River system for comparison purposes. Wetland assessments were conducted using the Mid-Atlantic Tidal Rapid Assessment Method (Mid-TRAM) Version 3.0. This indicator is based on the Mid-TRAM findings.

Status

Thirty Rapid Assessment points for the Barnegat Bay north and Barnegat Bay south watersheds were completed in 2012 and 2013, which represents a complete assessment of both of the Barnegat Bay watersheds (Figure 1). Overall, the Barnegat Bay tidal wetlands are considered moderately stressed, with northern Barnegat Bay considered severely stressed and the southern bay considered moderately stressed, though there is variation within the zones (Figure 2).

Trends

Currently, there is only one data point per location, so no trend can be determined at this time. This assessment is intended to be repeated every 10 years.

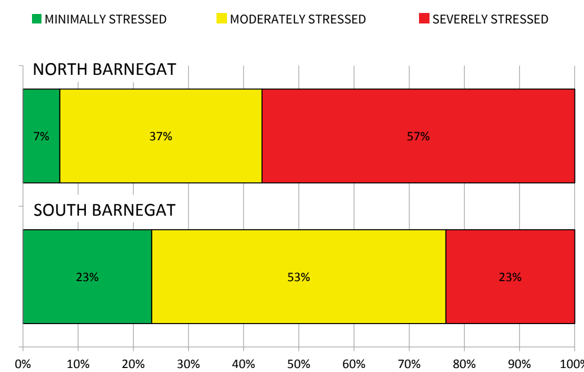


Figure 2: Tidal wetland assessment classifications for each watershed. The percentage of sites in each classification category is shown in the bar.

Data courtesy of the Barnegat Bay Partnership.

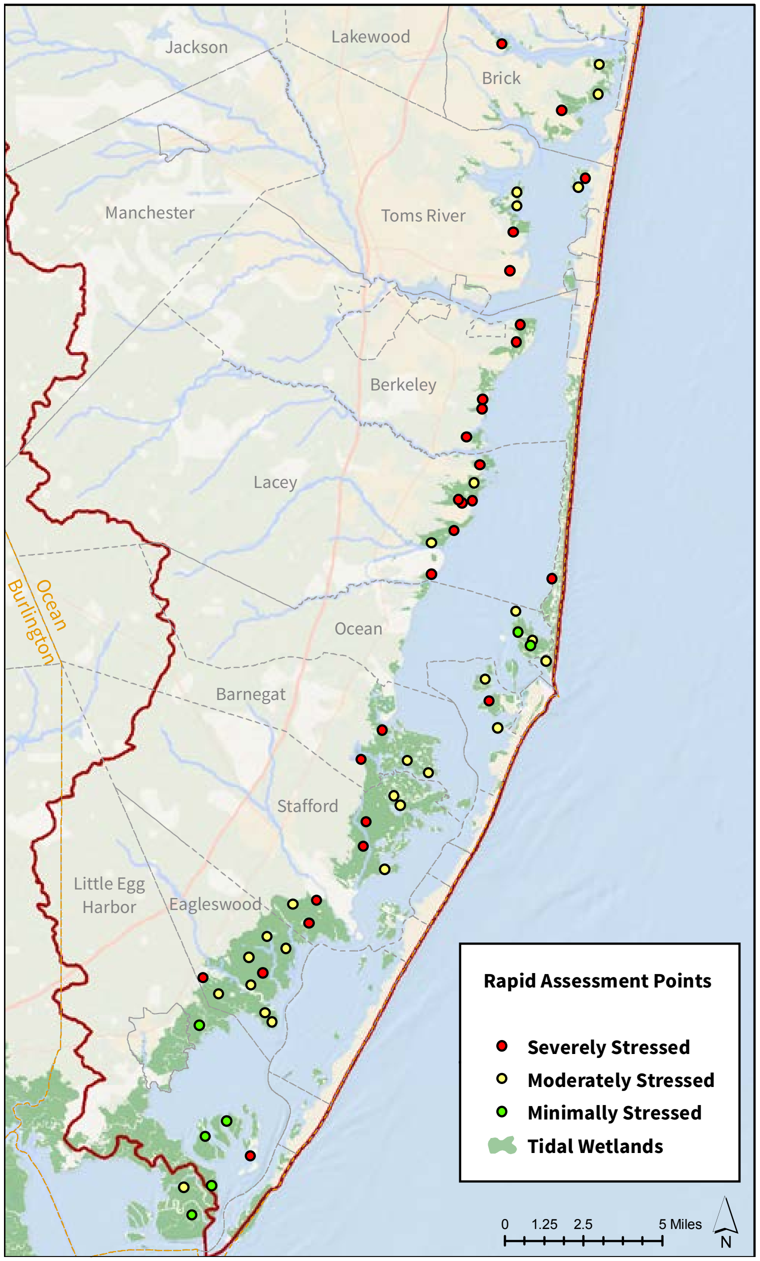


Figure 1: Location and condition of the tidal wetland assessment points in the Barnegat Bay.

State of the Bay Extra:

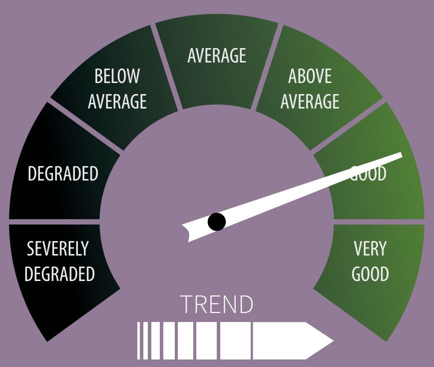
Paddle for the Edge

In 2015, the Barnegat Bay Partnership developed and piloted a citizen science project called “Paddle for the Edge.” The project used trained volunteers in kayaks, canoes, or stand-up paddle boards to paddle along 20 miles (35 km) of Barnegat Bay’s marsh shoreline. Volunteers collected information about shoreline vegetation, condition, and recreational use at more than 650 points from Point Pleasant down to Tuckerton. Shorelines are important indicators of watershed health because they are the sites where land and water processes collide and interact. The data collected by our Paddle for the Edge volunteers are being used to analyze current shoreline conditions and, as the program continues, to look at trends in how the shorelines of Barnegat Bay are changing. This dataset may contribute to the design of future marsh restoration and living shoreline projects.

Indicator

Protected Land

Indicator Status



A trail through the dunes at Island Beach State Park. Photo by New Leaf Photography.

Background

Protected lands are those areas where activities are restricted to passive recreation (such as walking, hiking, horseback riding, cross-country skiing, snowshoeing, birdwatching, nature observation, boating, picnicking, fishing, and hunting) or conservation (such as nature preserves, parks, and arboretums).

Protected lands are important because they generally have minimal human disturbances, and they also serve as important refuges for wildlife, especially for those animals that tend to avoid human interactions. A substantial amount of protected lands in Ocean County lie along rivers and streams, and can also serve as corridors for movement of wildlife between larger parcels. With low levels of impervious surfaces and other man-made development, open spaces enhance water quality and aquifer recharge by allowing rainwater to filter directly into the ground. Protected lands along the edge of the bay, usually composed of coastal wetlands and maritime forests, buffer the adjacent lands from storm surge and flooding.

Status

Between January 2010 and September 2015, approximately 11,114 acres in the Barnegat Bay watershed were acquired by federal, state, county, local, and non-governmental agencies for conservation purposes (Figure 1). These purchases bring the total acreage of publicly-owned land in the watershed to over 141,935 acres. This also includes publicly-owned lands (such as the Joint Base McGuire-Dix-Lakehurst) which are not set aside for natural resource conservation, but due to size and limited land-use, is preserved in its natural state and protected from development.

Trends

New Jersey has strong and continuing programs by federal, state, county government, and non-governmental organizations for protecting land. The newly acquired parcels raise the percentage of publicly-owned land from 37% of the watershed's land area in December 2009 to 41% in September 2015 (Figure 2).

Data gaps

None.

Data courtesy of Ocean County Natural Lands Trust, US Fish and Wildlife Service Edwin B. Forsythe Wildlife Refuge, and New Jersey Department of Environmental Protection Green Acres Program.

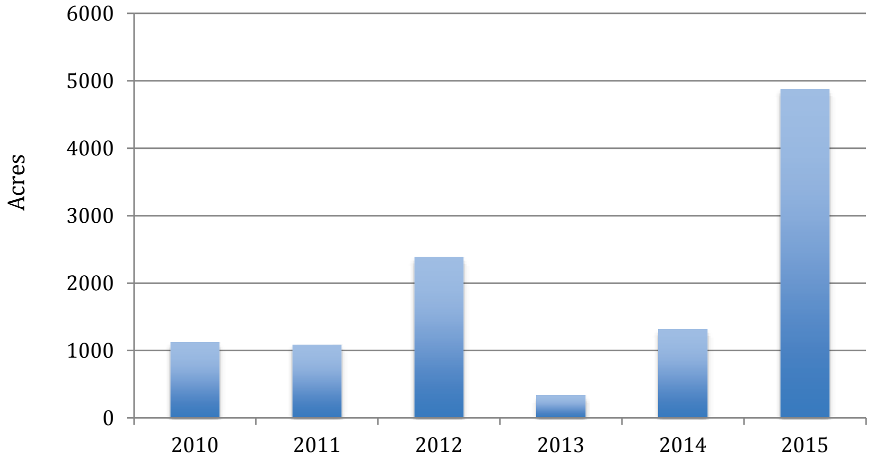


Figure 1: Acreage of protected lands acquired within the watershed from 2010-2015 by Ocean County Natural Lands Trust, US Fish and Wildlife Service, NJDEP Green Acres, and other non-governmental organizations.

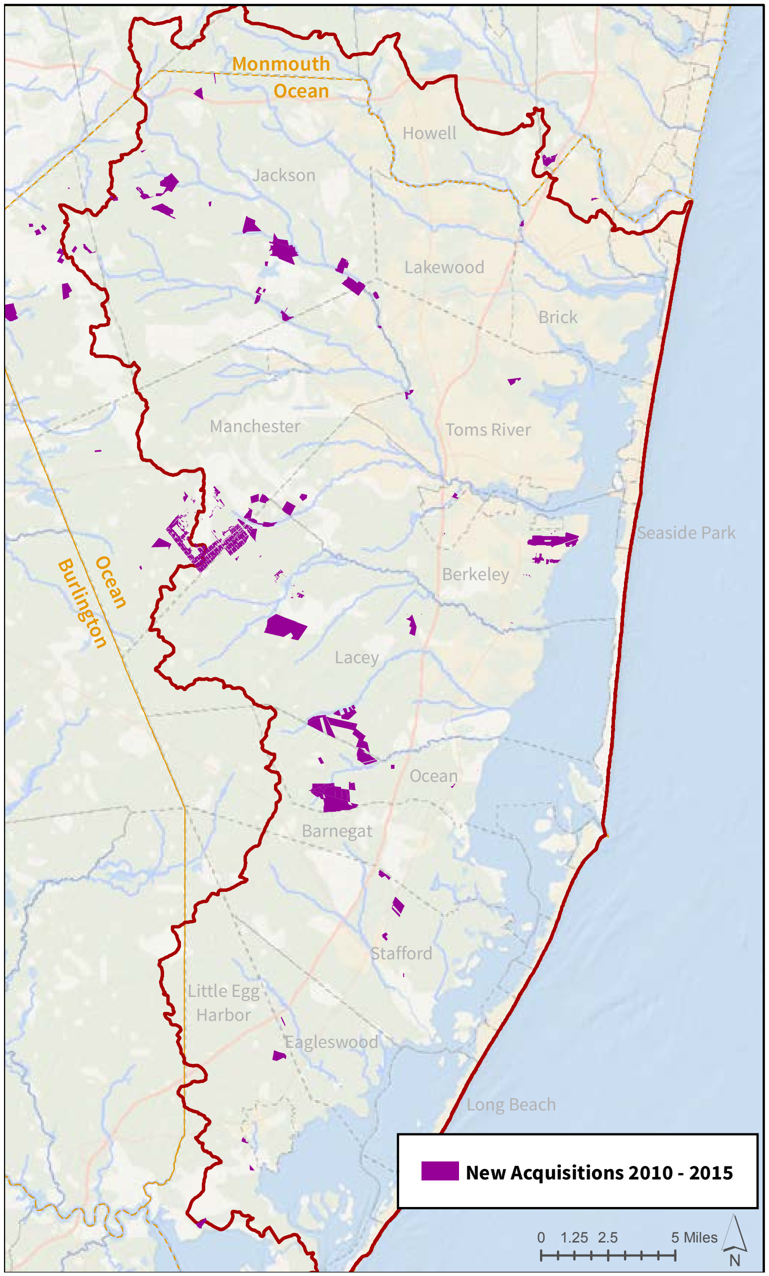


Figure 2: Map of protected areas within the Barnegat Bay watershed acquired from 2010 to 2015.

Indicator

Seagrass

Indicator Status

Eelgrass plants covered by encrusting organisms. Photo by Dr. Elizabeth Lacey.

Background

Seagrasses serve as habitat and food for many recreationally and commercially important estuarine and marine species (*e.g.,* bay scallop [*Argopecten irradians*], blue mussel [*Mytilus edulis*], blue crab [*Callinectes sapidus*], and weakfish [*Cynoscion nebulosus*]). Seagrass beds also play a significant role in nutrient cycling, carbon sequestration, filtering of essential elements, and wave dampening. In addition, seagrasses are excellent indicators of water and sediment quality as they indicate changes in water quality and benthic attributes. Seagrasses are impacted by water nutrient levels, elevated water temperatures, ice scouring, damage from boat props and anchors, disease and light intensity fluctuations caused by dredged or storm-tossed sediments, and algal blooms or overgrowth. By assessing the condition of seagrass beds over time, it is possible to establish accurate trends in estuarine condition. Within Barnegat Bay, eelgrass (*Zostera marina*) dominates the seagrass beds south of Toms River, while mixed eelgrass and widgeon grass (*Ruppia maritima*) beds are found in the central and northern portions of the bay.

Status

The area of seagrass habitat within Barnegat Bay has not been assessed since 2009, when it covered approximately 14% of the estuarine bottom. A 2015 bay-wide survey of seagrass bed demographics (Figure 1) found a significant increase in eelgrass aboveground biomass in the southern portion of the estuary in the spring compared to 2011, the last year for which data are available (Figure 2). However, due to natural fluctuations in growth throughout the growing season, by fall the eelgrass aboveground biomass was comparable to prior sampling. Bay-wide there was no difference in widgeon grass aboveground biomass between 2015 and 2011, though there was a significant increase in widgeon grass in the central region (Figure 3).

Trends

From a bay-wide perspective, eelgrass aboveground biomass reached its lowest level in 2009, and though the 2015 levels were encouraging, they do not represent a statistically significant improvement from the lows of the late 2000's. The increase in widgeon grass in the central part of Barnegat Bay is encouraging from a broad habitat perspective, though what that means for eelgrass populations and habitat use by recreationally and commercially important species is not yet clear.

Data Gaps

Without future sampling it is unclear if the increase in eelgrass biomass observed in 2015 is due to temporarily favorable water quality conditions, the result of nutrient reduction efforts over the past four years, or a combination of both factors. An assessment of the extent (size and distribution) of seagrass beds in the bay is also needed.

For additional details on seagrass distribution and abundance in the Barnegat Bay, please visit the Studies and Reports section of the BBP website at http://bbp.ocean.edu/pages/184.asp *and search the Description field for "seagrass."*

Data courtesy of Rutgers University (2004-2011), Barnegat Bay Partnership, and Stockton University (2015).

Figure 1: Sampling locations for the seagrass biomass surveys used in this analysis.

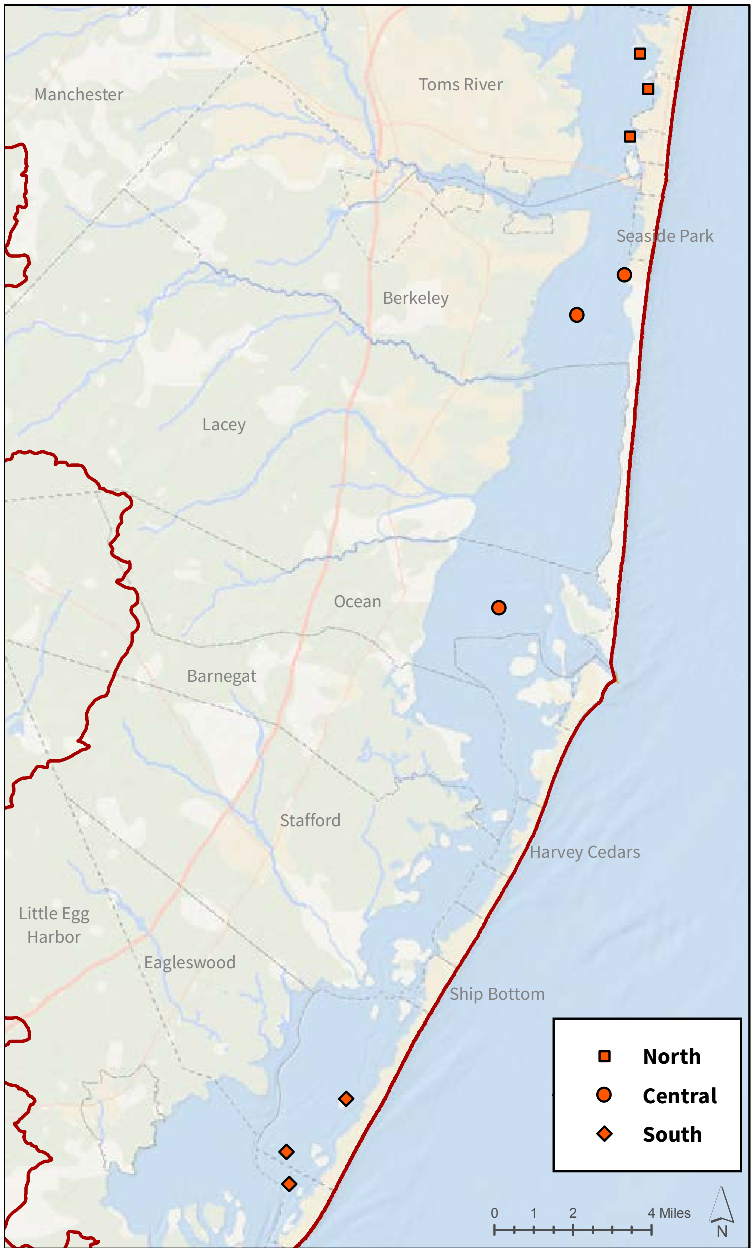


Figure 2: Annual mean above-ground biomass of eelgrass (*Zostera marina*) in the Barnegat Bay-Little Egg Harbor estuary between 2004 and 2015.

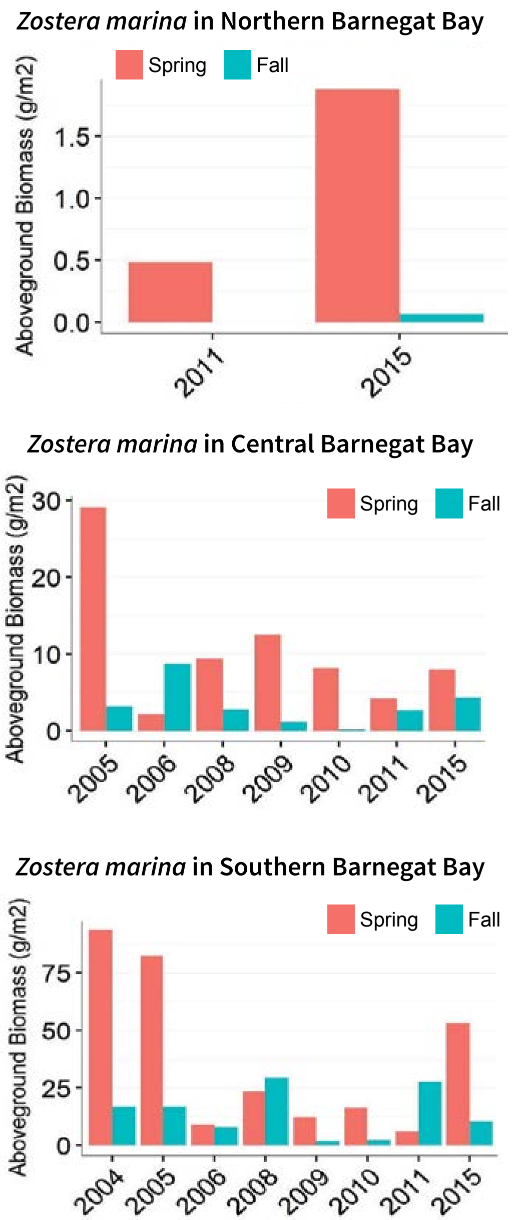
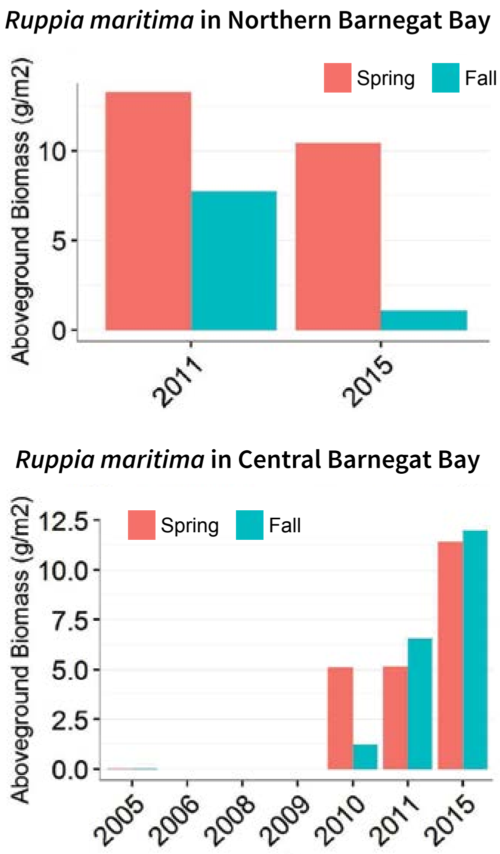


Figure 3: Annual mean above-ground biomass of widgeon grass (*Ruppia maritima*) in the Barnegat Bay-Little Egg Harbor estuary between 2004 and 2015. No widgeon grass was been recorded in southern Barnegat Bay.




Morning along the Metedeconk. Photo courtesy of BTMUA.

Conserving Fisheries and Wildlife

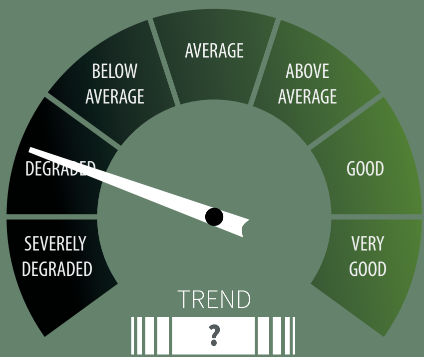
Mention the Barnegat Bay, and many people think of the fish, crabs, clams, and birds which reside in and around the bay. When combined with the other species found within the watershed, they form links in the food web which support the diversity of life that makes the Barnegat Bay a unique place.

A fishing boat returning home through the Barnegat Inlet. Photo by New Leaf Photography.

Indicator

Shellfish Resources

Indicator Status



Hard clams collected during the NJ Bureau of Shellfisheries hard clam stock assessment of Barnegat Bay, 2012. Photo by Kira Dacanay, NJ Bureau of Shellfisheries.

Background

Estuarine shellfish have limited mobility, are sensitive to environmental changes, and are a commercially and recreationally important species, making them a key indicator used to assess ecological condition/impairment of estuarine systems nationwide. Historical records note the presence of hard clams (*Mercenaria mercenaria*), Eastern oysters (*Crassostrea virginica*), and bay scallops (*Argopecten irradians*) in Barnegat Bay. For example, Barnegat Bay oyster beds were documented in *A report of the oyster industry of the United States* (Ingersoll, 1881). Native American oyster shell middens found along Barnegat Bay date back to pre-colonial time.

Status

Bay-wide surveys for hard clams conducted in 2011 (Little Egg Harbor) and 2012 (Barnegat Bay) estimated a standing stock of approximately 224 million clams (Figure 1). There is currently a limited commercial wild fishery for hard clams within the Barnegat Bay, though there is an aquaculture industry active primarily in Little Egg Harbor. Hard clams are also harvested on a recreational basis, centered mainly around the southern portion of the estuary. There is limited natural recruitment of oysters into the estuary, and scallops are occasionally found during seagrass and hard clam sampling, although there is no wild fishery for either species. There is an oyster aquaculture industry beginning to develop in the bay as well.

Trends

Overall, the abundance of hard clams in Barnegat Bay in 2012 was down approximately 23% from the last survey completed in 1985/1986. For Little Egg Harbor, the overall abundance in 2011 was down approximately 57% compared with the 1985/1986 survey. However, the abundance of hard clams in Little Egg Harbor increased 32% between 2001 and 2011. The 2001 survey in Little Egg found a 67% decline in abundance compared with 1985/1986. Regularly scheduled surveys will be needed to determine if this is the beginning of a rebound in hard clam abundance or a temporary increase associated with a single large spawning event.

Data courtesy of the New Jersey Department of Environmental Protection Bureau of Shellfish.

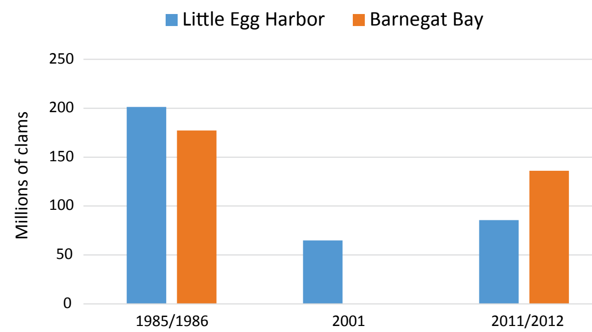


Figure 1: Hard clam abundance in Little Egg Harbor and Barnegat Bay.

Barnegat Bay oysters. Photo by Forty North Oyster Farms

Indicator

Estuarine Fish Communities

Indicator Status

A juvenile summer flounder.
Photo by Barnegat Bay Partnership.

Background

With a mosaic of diverse habitats located within close proximity to each other, estuaries are home to a variety of aquatic organisms, many of which are of commercial or recreational importance. Within temperate estuaries like the Barnegat Bay, this includes both resident and non-resident fish across all life history stages. Because of this critical habitat function, fishery production within estuaries is higher than most other marine or freshwater systems.

The Barnegat Bay Partnership has been sampling with a 50-foot seine net at six locations within the central and northern portions of the bay for juvenile fish on a regular basis from May through October since 2012 (Figure 1). These sampling sites cover a variety of habitat types (seagrass beds, muddy bottom, sandy bottom, wetland edge) and a range of salinities, and are representative of the habitats found throughout the bay. During this time, 69 fish species, 5 crab species, and 4 jellyfish species have been collected. The most common fishes encountered were schooling forage fishes (Atlantic silversides [*Menidia menidia*], bunker [*Brevoortia tyrannus*], and bay anchovy [*Anchoa mitchilli*]), followed by juveniles of black drum (*Pogonias cromis*), silver perch (*Bairdiella chrysoura*), winter flounder (*Pseudopleuronectes americanus*), and bluefish (*Pomatomus saltatrix*).

One way to assess an aquatic community is to measure its biodiversity, or the number and amount of different kinds of organisms it contains. More diverse communities are typically more resilient to disturbances, as there are multiple species that can occupy a particular role or take advantage of new or changing conditions. One metric for quantifying diversity is the Shannon-Weiner Index, which takes into account both the different number of species and their abundances. If there are many different types of fish and they are equal in abundance, the index is high. If most of the fish at a site are of one species the index will be low, even if there are lots of very rare species. Thus, changes in diversity values can indicate a change in habitat or other conditions over time.

Status

The Shannon-Weiner diversity index score at the Allen Road sampling site was, on average, higher than that of all other sites across 2012-2015. This is likely due to the presence of seagrass beds within and adjacent to the sampling site. For most sites, the 2015 diversity scores were at or near the maximum over the time frame studied, though Ocean Gate had its lowest value in 2015 (Figure 1).

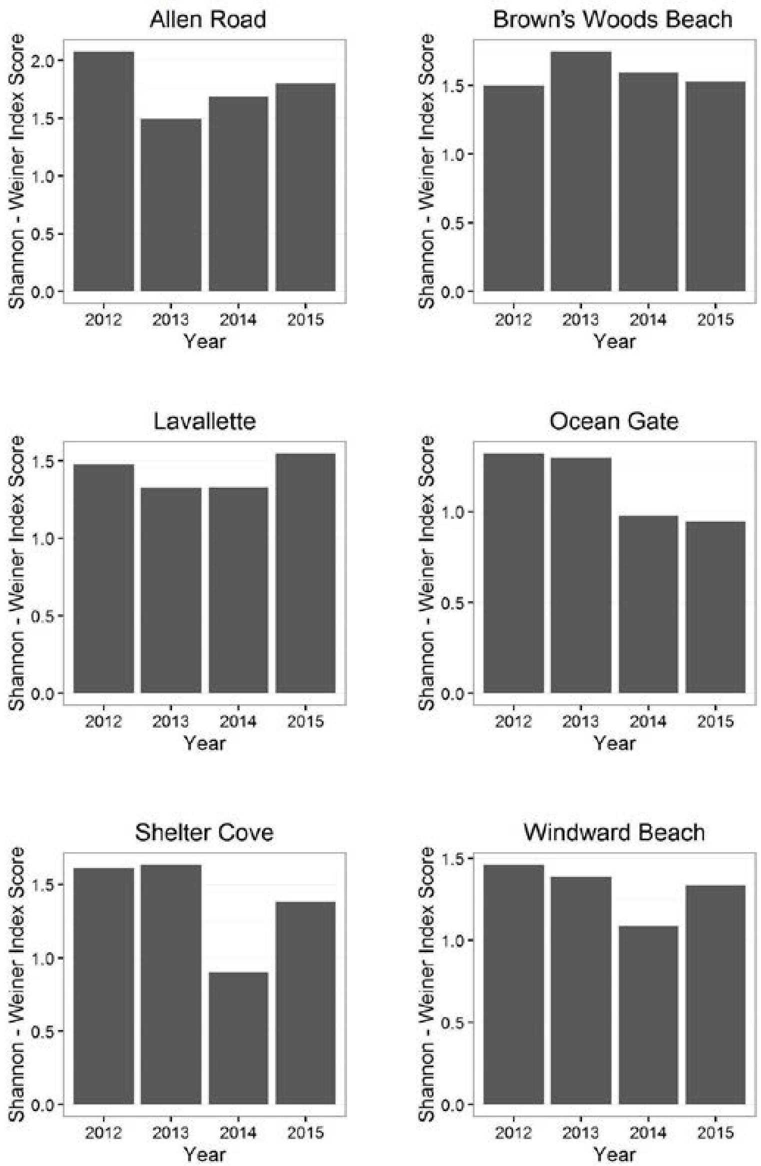
Trends

When examined bay-wide the average diversity scores were highest in 2012, declined in 2013 and 2014, and then increased in 2015. While most sites showed some variability between years, the differences were not significant.

Data gaps

The data currently cover the northern portion of the Barnegat Bay but does not extend below Cedar Creek. Monitoring at additional sites in the central and southern portions of the bay would allow for a more accurate baywide assessment of community diversity, especially with the main inlets located within these regions.

Data courtesy of the Barnegat Bay Partnership.



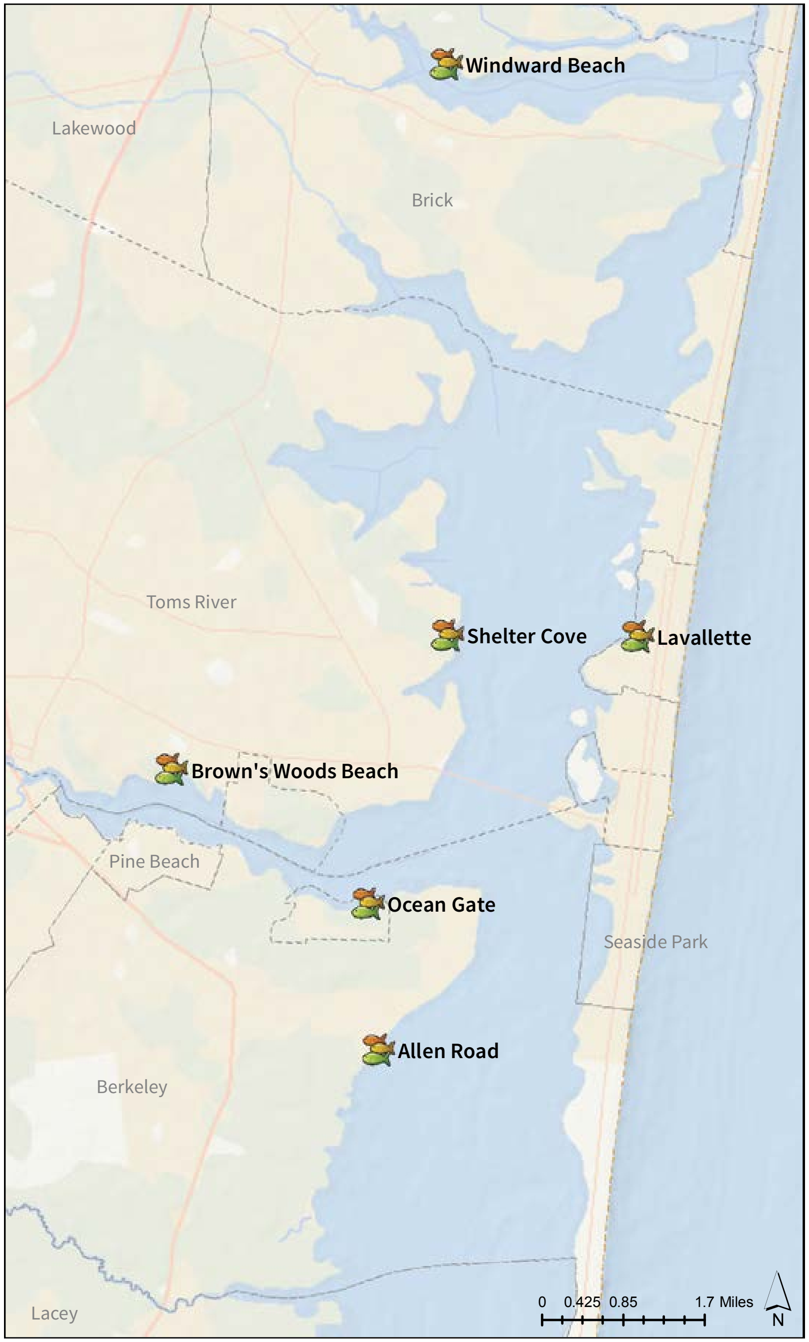


Figure 1: Location of Barnegat Bay Partnership long-term seining sites and community diversity scores.

Hurricane Sandy: Changing the Face of the Jersey Shore?

A pleasure boat washed up on the Island Heights boardwalk following Hurricane Sandy.
Photo by Barnegat Bay Partnership.

The Storm

Whether you call it a hurricane, a superstorm, "Frankenstorm," or a post- or extra-tropical cyclone, most people in New Jersey won't ever forget Sandy. Originating as a tropical wave (an elongated area of low pressure) south of Jamaica, Sandy grew in size to become the second largest hurricane ever recorded, as it moved north from the Bahamas until its final landfall as a post-tropical cyclone at Brigantine, New Jersey. When Sandy struck New Jersey, the atmospheric pressure (946 millibars, a measure of the "weight" of the atmosphere that is inversely correlated with the strength of the storm) was the second lowest ever recorded north of Cape Hatteras.

Interestingly, Sandy's path (and that of the nor'easter that followed a week later) were correctly predicted by the European Centre for Medium-Range Weather Forecasts headquartered in Reading, England nearly eight days in advance of their landfalls. Several large-scale climate-change factors have been identified as contributing to Sandy's size and path. First, sea surface temperatures off the east coast of the United States were much warmer than usual, leading to large-scale atmospheric temperature increases and higher rainfall potentials (*i.e.*, warm air holds more water). Second, sea levels off the Atlantic Coast of the U.S. were near their highest levels of the past 100 years, largely due to sea level rise but also other large-scale meteorological patterns. Lastly, melting polar ice exacerbated unusual weather patterns in the northern hemisphere (*e.g.*, North Atlantic Oscillation, a "blocking Greenland front"), which prevented the typical eastward movement of North Atlantic hurricanes. As a result, Hurricane Sandy combined with a nor'easter before turning left and slamming into coastal New Jersey as an extratropical cyclone.

Sandy's strength and path maximized the interacting forces of lunar cycle, wind and water and resulted in a record-breaking storm on the Jersey Shore. The record storm surge of 8.57 feet above normal tide level was recorded at the north end of Sandy Hook. Record waves of 32.5 feet were measured at a coastal ocean buoy near Sandy Hook. Record sustained maximum wind speeds of 80 mph were measured at landfall near Atlantic City, with record peak wind gusts of 89 mph observed in Surf City.

More than 24 states were impacted by Sandy. At least 147 deaths were directly attributed to Sandy in the United States. As of this past year, approximately $75 billion in damages makes this the second-costliest hurricane (to Katrina) in the U.S. More than 325,000 housing units were damaged, another 20,000 homes were completely destroyed, and more than 19,000 businesses suffered damages of $250,000 or more in New Jersey alone. There were more than $3 billion in damages to water and wastewater lines, and treatment plants; $3 billion in damages to NJ public transit, bridges, and roads; and $1 billion in damages to power lines and systems, and natural gas lines. More than 5 million people were without power or other utilities.

Barrier island communities in Ocean County, where the storm surge was approximately 9 feet and 15–20 foot waves pounded the islands, were among the areas in New Jersey hardest hit by the storm. Extensive areas in Pt. Pleasant Beach, including the boardwalk, were damaged severely. Storm surge damaged about 90% of the properties in Mantoloking with the largest damage occurring when a breach formed between the Barnegat Bay and the Atlantic Ocean near Herbert Street at the base of the Mantoloking Bridge. To the south, the seaside sections of Brick and Toms River, along with Lavallette, Seaside Heights, and Seaside Park, were extensively flooded. Areas bordered on the oceanfront by more complete dunes were less heavily damaged overall than areas lacking extensive dunes. Extensive portions of the oceanfront boardwalk piers and their iconic amusement parks in Seaside Heights and Seaside Park were severely damaged or destroyed. Fires fueled by broken gas lines broke out in several communities, especially Mantoloking and the Toms River community of Ortley Beach, and completely destroyed many homes. Damage on Long Beach Island was distributed unevenly throughout the island. Areas with a protective dune system, such as Harvey Cedars, Ship Bottom, Surf City, and Barnegat Light had limited damage, while areas without dunes or where dunes were breached (*e.g.*, Loveladies and the Holgate section of Long Beach Township), experienced greater destruction.

Many back-bay communities also experienced considerable storm surge and damage from the storm. Many neighborhoods in Brick and Toms River (where as many as 40% of the homes are within 2-3 feet of sea level) were inundated by the storm surge and extensively damaged. Lagoon communities and other areas built on filled wetlands throughout the watershed (*e.g.*, Shore Acres, Silver Bay, Snug Harbor, Forked River Beach, Beach Haven West, Tuckerton Beach, and Mystic and Osborne Islands) also suffered extensive damages.

Assessing the Storm's Impacts on the Bay's Ecology

Immediately following the storm, the Barnegat Bay Partnership staff and its many government and other partners were involved in emergency and first response efforts. In the weeks and months following the storm, we held regular conference calls for partners to share information and coordinate various activities.

Thanks to the tremendous investment in monitoring and research activities (some of which began before the storm), most of the short-term environmental impacts of Superstorm Sandy (*e.g.*, debris [see Trash Free Waters sidebar], poor water quality, eroded wetlands, and buried SAV beds) are now known. The NJDEP and its partners and contractors cleaned up most large debris (*e.g.*, houses, cars, boats) which washed into and was submerged in water bodies and wetlands. While service at sewage-treatment plants in Ocean County was disrupted, adverse impacts to water quality (largely from pathogens affecting shellfish resources) distributed throughout the bay were fairly short-lived. Fortunately, sewage plumes and chemical spills (*e.g.*, mostly fuels) originating within the New York Harbor and flowing into the surrounding Bight stayed well offshore.

While a majority of New Jersey's coastal wetlands were inundated several days before Sandy made landfall, tidal wetlands throughout the bay, especially those in the northern end behind the Mantoloking Breach (*e.g.*, Reedy Creek and Cattus Island County Park) suffered considerable erosion (in some places, 5–10 feet) along their

The Island Heights Yacht Club during flooding associated with Hurricane Sandy. Photo by Amanda Bottomley.

Hurricane Sandy: Changing the Face of the Jersey Shore?

continued

The Gilford Park Yacht Club during flooding associated with Hurricane Sandy. Photo by Amanda Bottomley.

edges and creek banks, as well as those interior areas exposed to wave action. These impacts to wetlands are especially worrisome because shoreline hardening (*i.e.*, bulkheading) is cutting off some supplies of sediments to the bay ecosystem that are essential for wetlands to keep pace with sea level rise. To assess these longer-term concerns, the BBP and many partners, including the EPA, NJDEP, US Fish and Wildlife Service, Partnership for the Delaware Estuary, and the Academy of Natural Sciences at Drexel University have developed and are implementing a long-term wetland monitoring and assessment program (see Wetland Condition indicator). Also, the BBP has developed and implemented a volunteer, citizen-science based monitoring program (see Paddle for the Edge sidebar) to obtain additional information about the condition of shorelines and certain other wetland resources around the bay. Lastly, the BBP is participating in statewide workgroups for living shorelines and exploring beneficial uses of dredged materials (*e.g.*, thin layer deposition), which might be used to enhance and restore some existing wetlands or possibly even create new wetlands.

Sands and coarse sediments washing over or off of the barrier islands also buried some of the bay's best eelgrass beds along the bay's eastern shores. The Barnegat Bay is home to most of the state's remaining eelgrass and other native populations of submerged aquatic vegetation (*e.g.*, widgeon grass). As noted in the *2011 State of the Bay Report*, eelgrass abundance and condition has been declining for some time. Since the storm, eelgrass abundance and condition has improved remarkably in some parts of the bay, but not in others. The abundance of widgeon grass is also increasing. The localized increases in both species is encouraging, but additional monitoring and research is needed to better understand the factors contributing to the local increases. Widgeon grass and eelgrass face ongoing and new threats to their continued existence in Barnegat Bay and New Jersey as a whole.

In the weeks and months following the storm, episodic flooding was reported throughout the watershed. Since the storm, more than 20 exceptionally high water events causing flooding have been observed in Barnegat Bay. This flooding has widely and erroneously been attributed to sand and other materials and debris having washed off of the landscape and into the bay and its tributaries as a result of Sandy. USGS studies conducted in Barnegat Bay and Great South Bay, New York have unequivocally established that the post-Hurricane Sandy high-water levels are due to high offshore sea levels caused by winter storms, not by barrier island breaching or geomorphic changes within the bays associated with the storm. In addition, dredging sands and sediments around the bay to make those areas deeper has the potential to exacerbate future flooding. This study further reinforces what scientists have been saying for years, that our climate and our lives along the shore are changing.

The Future: Good, Bad, or Ugly? It's Up to Us to Decide a New Vision for the Shore

Superstorm Sandy was a tragedy for some, a life-threatening ordeal for others and, at the very least, an eye-opening event for many, many more people who lived along the shore. Sadly, it seems we are destined to repeat Sandy's tragedies and ordeals, unless everyone opens their eyes to how our world is changing and better recognizes both the challenges and the opportunities now before us.

Over the past few years, with the transfusion of federal funds, we have cleaned up a great deal of the debris and devastation and begun rebuilding the many communities destroyed by the storm. This has not been an easy task. We've all heard horror stories of the confusing regulations, the red-tape, the confusion, the profiteering, and concerns about the wasting of money. Elected officials and policy makers have cut some corners, sometimes understandably, to get people in their homes and back to work. Our success in those efforts to date have been mixed. Some people are back in their homes and their lives have returned to "normal." But even for those people, normal now seems different. A lot of things still aren't fixed or the way they were. More streets keep flooding…

And now this year, people to our south are struggling with this year's storm, Jonas, which caused storm surges in Atlantic and Cape May Counties comparable to Sandy. Pam Bross spent January 23rd mopping up water that flooded her 24th Street Market in North Wildwood. It takes extreme flooding for her store off New Jersey Avenue to see flooding. The last time was during Sandy. "I just hope it isn't a sign of things to come," she said.

It's time to recognize that each event is just one more sign that life along the shore is changing. Everyone must prepare for more bad weather, more flooding, more tragedies, and more ordeals like Sandy and Jonas.

Or, we must find another way. What we have not done to date is develop a new vision for the future of the Shore. We have some hard decisions to make if we are to undo years of poor land-use decisions. The Jersey Shore faces huge social and economic challenges, but the region's future can be bright once our leaders and the public develop a vision for a safer, less risky future and redevelop so that the next storm doesn't put people back in the same situation. It won't happen overnight, but it can happen if we work together.

Damage on the Toms River associated with Hurricane Sandy. Photo by Amanda Bottomley.

A house knocked of its pilings by Hurricane Sandy. Photo by Barnegat Bay Partnership.

Climate Change

Flooding along the Toms River.
Photo by Barnegat Bay Partnership.

Sea level rise

The impacts of climate change have already been observed here in New Jersey, where we are experiencing rates of sea level rise well above the global average. The tide gauge at Atlantic City shows a sea level rise rate of increase of approximately 4 mm per year (about 16 inches per century) since the early 1900's (Figure 1).

Though these rates seem small and perhaps of little immediate concern, they are recognized by national and regional experts to be of sufficient magnitude to transform the character of the mid-Atlantic coast, with the potential for increased flooding episodes, large-scale loss of tidal wetlands, and possible disintegration of barrier islands. A recent report by Rutgers scientists suggests that by 2030, sea level is projected to rise by 7 to 16 inches over 2000 levels, with a best estimate of 10 inches (Miller *et al.* 2013).

Air temperatures

The statewide average temperature in 2012 was the highest since 1895, with the five warmest years all occurring since 1998 (Figure 2). Nine of the ten warmest calendar years on record have occurred since 1990, all of which is consistent with the long-term upward trend of 2.2 °F per century (Broccoli *et al.* 2013).

As temperatures have risen, temperate zones like New Jersey have seen an earlier onset of spring. This can have severe consequences for our native flora and fauna, which rely on these temperature changes as a cue for important life history events. Furthermore, an earlier spring leads to an earlier, and longer, pollen season, which will adversely affect those who suffer from allergies. Additionally, the Union of Concerned Scientists project that the seasonal average temperatures across most of New Jersey will rise 7°F to 12°F above historic levels in winter and 6°F to 14°F in summer by late century. Under these scenarios, New Jersey can expect a dramatic increase in the number of days over 100°F.

Precipitation

The Intergovernmental Panel on Climate Change (IPCC) predicts that "extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will very likely become more intense and more frequent by the end of this century, as global mean surface temperature increases" (IPCC 2013). These heavy precipitation events have occurred more than twice as frequently over the past 20 years compared to the prior century (Figure 3), and the trend is likely to continue. These heavy rainfall events can cause flooding, streambank erosion, and increases in the rate and amount of nutrients and sediments delivered into the estuary.

Data Sources

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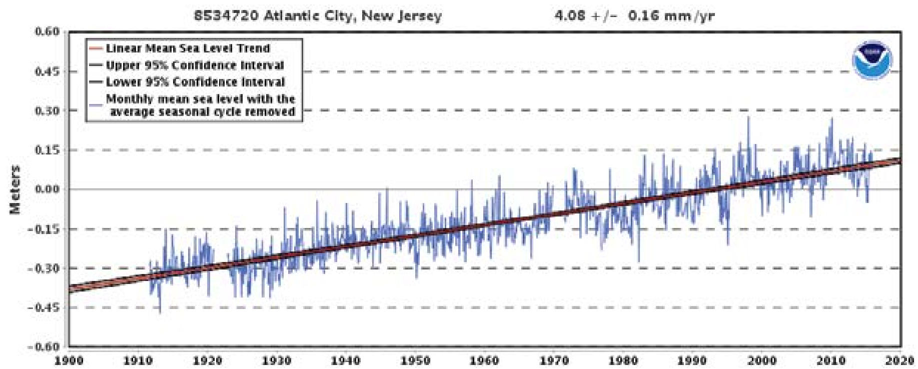

Figure 1: Tide gauge records for Atlantic City; red trend line shows steadily increasing sea level since 1912. Courtesy of NOAA.

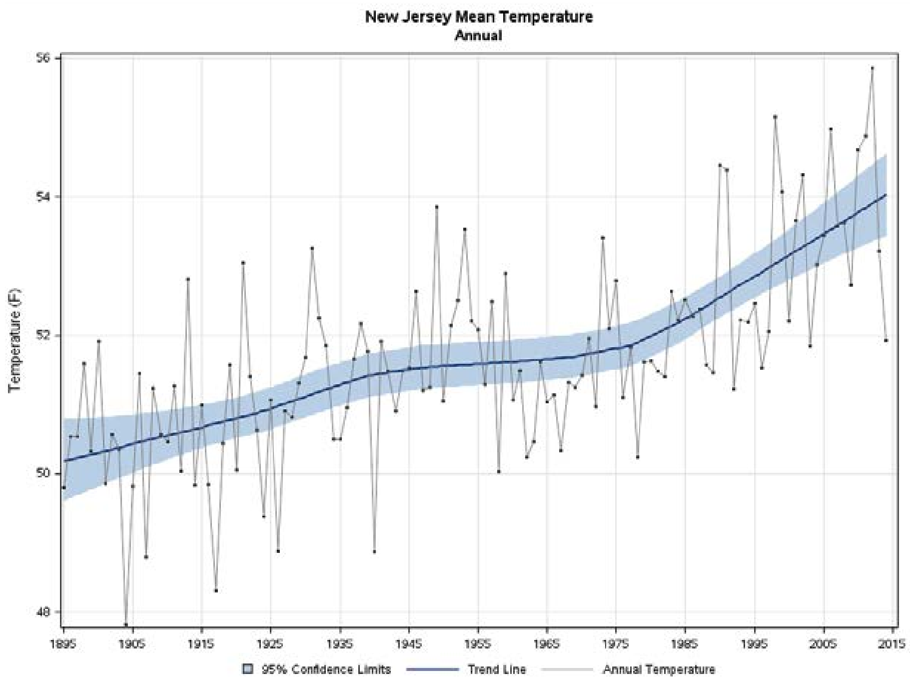

Figure 2: New Jersey statewide annual average air temperature. The gray line represents the annual temperature value. The blue line shows the overall trend in a fashion that smooths out the year-to-year variability in temperature. The light blue shaded area represents the 95% confidence interval for the trend. Courtesy of the NOAA National Climatic Data Center.

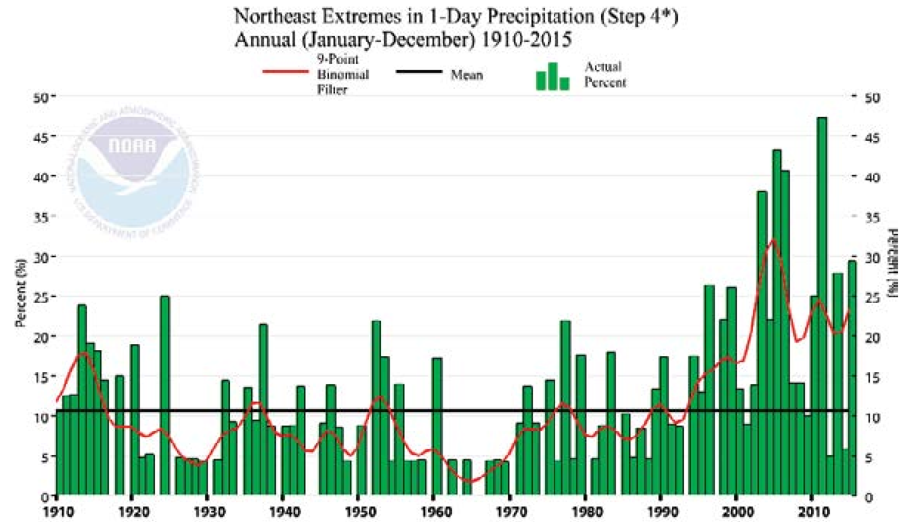

Figure 3: An index of the percentage of precipitation falling as part of a heavy precipitation event in the Northeastern United States. Courtesy of NOAA National Centers for Environmental Information.

Flooding in LBI after a nor'easter in November 2013.
Photo by Barnegat Bay Partnership.

Conclusion

The past five years in Barnegat Bay have been ones of change and upheaval. While the short-term environmental impacts of Superstorm Sandy have come into focus, we must continue to invest in monitoring and research to understand the long-term effects of Sandy and our changing climate on the bay's natural resources. What is clear from the indicators discussed in this *State of the Bay Report*, however, is that the most worrisome challenges identified in previous reports remain unchanged. Population growth within the watershed continues to drive the conversion of open space into urban land, reducing terrestrial habitats and the natural ability of the watershed to recharge groundwater and filter nutrients. Combined with unchecked withdrawals of water for human use, we are altering the amount, composition, and timing of fresh water entering the estuary. The negative effects of urbanization can be seen throughout the bay; thus, we *must* do more to reduce the bay's excessive nutrient loads and address other sources of turbidity if we are to address its dissolved oxygen and turbidity impairments, nuisance algal blooms, degraded tidal wetlands, and reduced seagrass biomass.

There is some good news in this *State of the Bay Report* as well. Open space acquisitions by Ocean County, the New Jersey Department of Environmental Protection, the US Fish and Wildlife Service, the Trust for Public Land, and other non-governmental organizations from 2010-2015 surpassed those of the previous five years, despite a slowdown as we focused on recovering from Superstorm Sandy. Closures of bathing beaches within the watershed due to pathogens and other contaminants generally declined, in large part due to a multi-agency working group which came together to tackle the recurring beach closures at Beachwood Beach. Fish communities in the northern and central parts of the bay are diverse, and hard clams, while still at very low levels, have rebounded compared to the decimated levels found in the early 2000's.

Perhaps most encouraging is the level of commitment our partners and the public have shown, both before and after Superstorm Sandy, to protecting and restoring the bay. During the past five years there has been a tremendous commitment to monitoring and research throughout the bay. Most importantly, thanks to cooperation between EPA, USGS, NJDEP, and others, we now have a working circulation model of the bay to help us better understand the movements, fluxes, and fates of nutrients throughout the ecosystem. Many people, including some of our organizational partners, have called for development of a Total Maximum Daily Load (TMDL) for nutrients in the bay. While we do not yet have the information necessary to establish such nutrient limits, we have some important tools and much needed information, and are substantially closer to having that information than we were five years ago.

In the meantime, there is still much unfinished work to be done. While we have taken some important steps to reduce the bay's nutrient load in the form of a statewide fertilizer law, we should look for ways to make the law more effective. First, the Soil Health Law, which would reduce the amount of nutrients flowing off of newly disturbed land, has not yet been fully implemented despite being passed more than five years ago. We should implement an effective soil restoration standard immediately. Second, the draft New Jersey Statewide Water Supply Plan should be shared with the public to improve the management, conservation(!), and development of water resources in the state's many watersheds, which likely will be subject to new and increasing threats with climate change. And lastly, we must make better use of two other important tools, the municipal stormwater program and watershed management planning program, to help us address the nonpoint source pollution impacting the bay.

In all of these efforts, the Barnegat Bay Partnership will continue to use the best science available to work towards understanding, protecting, and restoring this unique ecosystem that we all treasure. We need your help, so please visit our website at http://bbp.ocean.edu to learn more.

The view of Silver Bay from Ocean County Parks Headquarters. Photo by Barnegat Bay Partnership.

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A red fox on Island Beach State Park. Photo by New Leaf Photography.


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