



2016  
STATE OF THE  
DELAWARE  
INLAND BAYS

Presented by  
The Delaware Center  
for the Inland Bays

# ACKNOWLEDGEMENTS

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# TABLE OF CONTENTS

Executive Summary .....4-5  
 How We Assess the Health of the Bays..... 6

**WATERSHED CONDITION .....7-18**  
 Human Population Growth..... 8  
 Land Use Change .....10-11  
 Impervious Surface Coverage .....12-13  
 Water Quality Buffers on Croplands..... 14  
 Salt Marsh Acreage and Condition ..... 15  
 Natural Habitat Protection and Restoration .....16-17  
 Indian River Inlet Flushing ..... 18

**MANAGING NUTRIENT POLLUTION .....20-29**  
 Input of Nutrients from Point Sources ..... 22  
 Input of Nutrients from the Atmosphere ..... 23  
 Input of Nutrients from Nonpoint Sources .....24-25  
 Agricultural Nutrient Management Practices .....26-27  
 Septic System Conversion to Central Sewer ..... 28  
 Stormwater Retrofits ..... 29

**WATER QUALITY.....30-39**  
 Algae Concentration ..... 31  
 Concentrations of Nutrients .....32-33  
 Water Clarity.....34  
 Water Quality Index.....35  
 Dissolved Oxygen Concentration.....36-37  
 Seaweed Abundance .....38-39

**LIVING RESOURCES .....40-54**  
 Bay Grasses ..... 41  
 Eagle and Osprey Nesting ..... 42  
 Hard Clam Landings.....43  
 Winter Waterfowl Counts .....44-45  
 Box: Oyster Enhancement..... 46  
 Blue Crab Abundance ..... 47  
 Fish Abundance.....48-50  
 Box: Shore-Zone Fish ..... 51  
 Number of Fish Kills ..... 52  
 Recreational Fishing Statistics .....53-54

**HUMAN HEALTH RISKS .....55-60**  
 Bacteria Pollution .....56-57  
 Approved Shellfish Growing Waters.....58-59  
 Fish Consumption Advisories..... 60

**CLIMATE .....61-66**  
 Carbon Dioxide Concentration and Air Temperature ..... 62  
 Sea Level Rise.....63  
 Growing Season Length ..... 64  
 Precipitation ..... 65  
 Ocean Acidification ..... 66

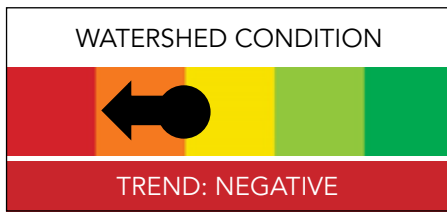
References.....68-70



## THE INLAND BAYS WATERSHED—QUICK FACTS

- The watershed of the Inland Bays is 292 square miles of land that drains to 35 square miles of bays and tidal tributaries. Located within Sussex County, Delaware on the mid-Atlantic coastal plain of the United States.
- Rehoboth Bay and Indian River Bay are tidally connected to the Atlantic Ocean by the Indian River Inlet. Little Assawoman Bay is connected by the Ocean City Inlet 10 miles to the south in Maryland.
- The Bays are shallow, generally less than 7 feet, and have an average tidal range of 3 feet.

# EXECUTIVE SUMMARY



Development driven by rapid population growth is increasing the acreage of impervious surface coverage, adding to urban pollution sources, and stressing habitats. Agricultural pollution is decreasing as land uses change. Increased flushing at the inlet has improved water quality in open Bay waters.



The remaining two point sources of nutrients should soon be removed from the Bays. Nonpoint source pollution remains above healthy limits. Septic conversions to central sewer have exceeded goals set in the Pollution Control Strategy, but other management progress has stagnated since 2011.



Water quality is improving in Little Assawoman Bay and in open waters near the Indian River Inlet. Algae and seaweed blooms have improved in some areas, but tributaries and canals are still murky and oxygen-starved.

The population in the watershed more than doubled between 1990 and 2010 when the last census was conducted. Population growth is driving many of the changes that are impacting the Inland Bays.

After a slowdown brought about by the recession that began in 2008, intense development is underway again, much of it near waterways where water quality impacts can be the greatest. With development comes impervious surfaces. Parking lots, roadways and roofs now cover over 10% of the watershed's land area—a point at which studies show detrimental impacts to water quality in estuaries.

Nutrient pollution from nitrogen and phosphorus remains the greatest threat to water quality in the Bays, but actions taken to reduce nutrient inputs give reason for optimism.

The volume of tidal water passing through the inlet has increased over time. This helps flush out nutrients, but has also contributed to degradation of marshes in the Bays.

Overall, water quality in the Inland Bays remains fair to poor, though Little Assawoman Bay and open waters near the inlet are showing some improvements.

More than 6,800 homes on septic systems were connected to central sewer since 2011, and discharges from point sources are down more

than 80% since the 1990s with only two 'point sources' of pollution to the Bays remaining out of thirteen.

Voluntary actions to reduce nutrient pollution, prescribed by the Pollution Control Strategy for agriculture and stormwater, show little progress, highlighting the need for dedicated funding.

Human health risks continue for those using the Bays for recreation. Most tributaries and canals continue to have very poor water quality and are unsafe for swimming or for the harvest of shellfish.

As the watershed urbanizes, loss of wetlands and natural shorelines impact both migrating and resident animal populations. Blue Crab populations remain low, and recreational fishing and its local economic benefits have not yet rebounded from losses brought about by the recession. Bald Eagles and Ospreys are thriving in the Inland Bays, and hard clam populations have been stable since the 1970s. Bay grasses, a signature species of healthy coastal bays, are still largely absent from the Inland Bays due to nutrient pollution.

Global emissions of carbon dioxide are bringing higher air temperatures, a longer growing season, and warmer Bays. Sea level in Delaware is now rising at a rate of 1.1 feet per century and is projected to increase to nearly five feet by 2100.



**Restoring the Bays will require proactive planning and new environmental policies that implement the Inland Bays Comprehensive Conservation and Management Plan.**

**Of greatest need:**

- **Legislation that provides funding for the clean water projects that Delawareans say they want.**
- **Improved coordination between partners responsible for actions outlined in the Inland Bays Pollution Control Strategy.**
- **Public participation in the 2018 Sussex County Comprehensive Plan—to encourage land use and policies that protect the natural resources that are the bounty of healthy Inland Bays.**

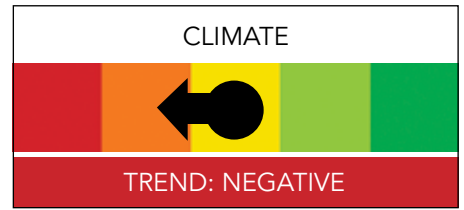
Looking down Love Creek to Rehoboth Bay Photo:



Eagles and ospreys are commonly seen around the Bays. Clams and some fish populations are stable. Other species such as Blue Crabs and waterfowl have declined. Oysters and bay grasses are rare in the Bays.



Most tributaries and canals are unsafe for swimming or for the harvest of shellfish. Consumption advisories for Striped Bass and Bluefish caught in the Bays remain in effect.



Sea level rise and warming temperatures are a growing challenge for watershed communities, residents and Bay ecosystems. Increased flooding and wetlands loss can be expected.



## DELAWARE'S INLAND BAYS ARE COASTAL LAGOONS—

bays that lie behind a narrow barrier island that separates them from the Atlantic Ocean. Traveling down Coastal Highway, through Dewey Beach, Bethany Beach and Fenwick, the Inland Bays lay to the west.

They are unique places where 'the rivers meet the sea'...where freshwater flowing from the land and down tributaries mixes with seawater that flows through inlets carved into barrier islands.

A collage of saltmarshes, tidal flats, bay grass meadows, oyster reefs and winding saltwater creeks make up this environment. For thousands of years, the Bays have supported an abundance of fish and birds that come here to feed, reproduce, and grow. The beauty and productivity of this estuary now supports a thriving human culture and economy.

The Bays are dynamic, constantly changing in response to human activities and the climate.

Fifty or sixty years ago, the Bays were thought to be generally healthy: clear waters with plentiful bay grass meadows, productive oyster reefs, and oxygen levels that supported diverse and plentiful fish populations.

But years of accumulated nutrient pollution and habitat loss have changed the Bays to generally murky waters that are dominated by algae, have very few bay grasses or oysters, and do not support healthy oxygen levels in many areas. Habitat restoration and major pollution reductions are needed to restore water quality and achieve a healthy estuary once again.

Since the adoption of the 1995 Inland Bays Comprehensive Conservation and Management Plan and its 2012 Addendum, much progress has occurred toward these goals. Now some environmental indicators suggest that accomplishments made under the Plan are bearing fruit and may be moving the Bays back in a healthy direction. But there is still much work to be done.

## HOW WE ASSESS THE HEALTH OF THE BAYS

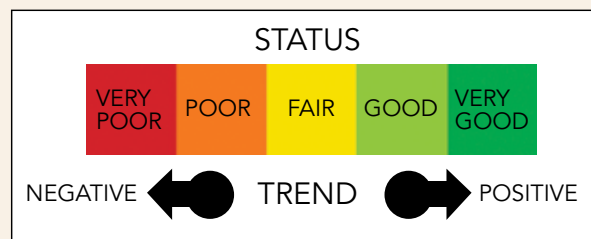
The 2016 State of the Delaware Inland Bays report is a compilation of environmental data about the Bays and their watershed. It provides communities, decision makers, and concerned citizens with robust scientific information that they can use to help restore and protect the bays and their resources.

To assess the health of the Inland Bays, a suite of environmental indicators was selected. These are specific species and conditions that are measured over time to determine how the Bays are changing and how much progress has been made toward restoration goals.

Thirty-five individual environmental indicators are grouped by subject matter and presented as the six chapters of the State of the Bays report. Each group is assigned a status and a trend by assessing its indicators together.

- The indicators are based on long-term measurements of environmental parameters and management actions
- Status and trends are assigned using best professional judgment and reviewed by scientists knowledgeable in these areas.
- For each indicator, long-term trends are addressed, as well as short-term changes that have occurred since the previous State of the Delaware Inland Bays report was published in 2011.

The State of the Delaware Inland Bays report is updated and published every five years. Most of the indicators used in developing this latest report are the same as those presented in the 2011 document. This allows us to continue to track trends and progress over the years. A few new indicators have been added in 2016, as new monitoring data have become available.



### How to Read the Status Bar

Status is indicated by a dot on the status bar. The farther to the left of the center the dot is, the more negative is the status of the group of indicators. The farther to the right of the center the dot is, the more positive the status. If the dot is in the center, the status is fair.

A trend arrow pointing to the left indicates a negative trend. A trend arrow pointing to the right indicates a positive trend. No trend arrow indicates a neutral or unknown trend.

## WATERSHED CONDITION

The population of the Inland Bays watershed is growing, and the landscape is rapidly changing from farms and forests to residential and commercial development. Much of the development is concentrated around waterways where its potential impact on water quality is greatest.

Since the last report, development increased another 7.8 square miles (11%), replacing agricultural lands, upland forests, and wetlands.

With development comes more roads, parking lots and rooftops that generate polluted runoff to the Bays. The watershed as a whole has now exceeded 10% coverage by these impervious surfaces—a tipping point at which water quality has been found to degrade in estuaries. Balancing this is a reduction in the application of fertilizers that occurs when cropland is converted to other land uses.

Activities to protect natural habitats in the watershed have nearly stalled since the previous report was published. Salt marshes are disappearing at higher rates. Funding and incentives for conservation, enhancement of forested buffers, and wetlands protection are needed.

The estimated volume of water moving in and out of the Bays through the Indian River Inlet increased by at least 11% since 1988, likely contributing to observed improvements in water quality in open Bay waters.

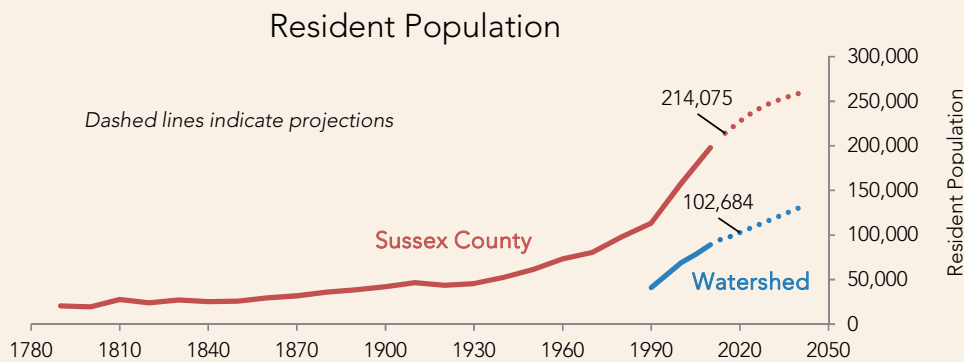
What these changes mean long-term for the watershed is uncertain. What is certain as population growth and urbanization continues is that the most effective technology for controlling storm water runoff and treating wastewater will be needed to protect the Bays.



## HUMAN POPULATION GROWTH

Rapid population growth is changing the face of our watershed. This growth brings development, traffic, more wastewater, and pressure on natural resources. The success of protection and restoration of the Inland Bays and surrounding land is dependent on how we plan for population growth and its impacts.

The 2010 census revealed that 197,897 year-round residents lives in Sussex County, with 89,121 (or 45%) residing in the Inland Bays watershed. A method of estimating seasonal and visitor population by measuring wastewater flows found that the watershed's population more than doubles in summer.



### LONG-TERM TREND

Before 1970, population growth in Sussex County increased gradually. The land around the bays was mostly agricultural, and the beach communities hosted primarily seasonal visitors. In the early 1990s, the growth greatly accelerated.

### CHANGE SINCE PREVIOUS REPORT

From 1990 to 2010, the population of the Inland Bays watershed more than doubled.

### LOOKING AHEAD

By 2020, an estimated 102,684 year-round residents are expected in Inland Bays watershed.



**The watershed population is expected to increase 15% between 2010 and 2020 and 46% between 2010 and 2040.**





WATERSHED CONDITION

NUTRIENT POLLUTION

WATER QUALITY

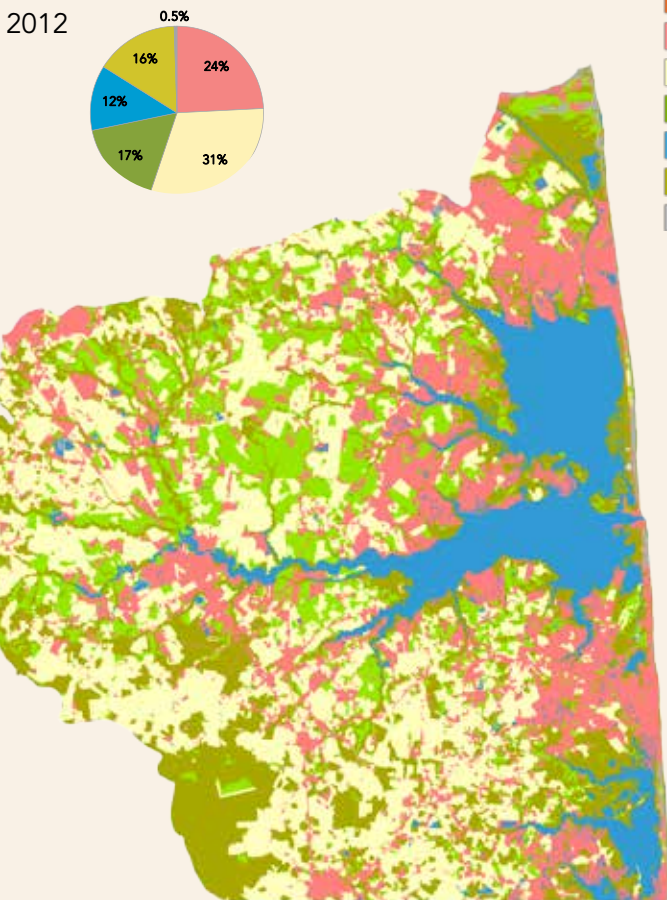
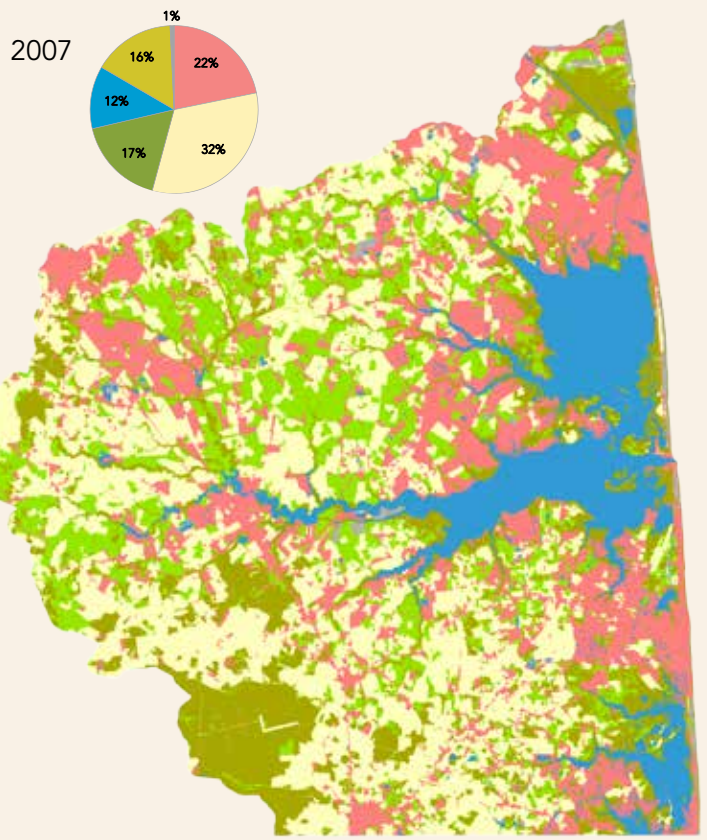
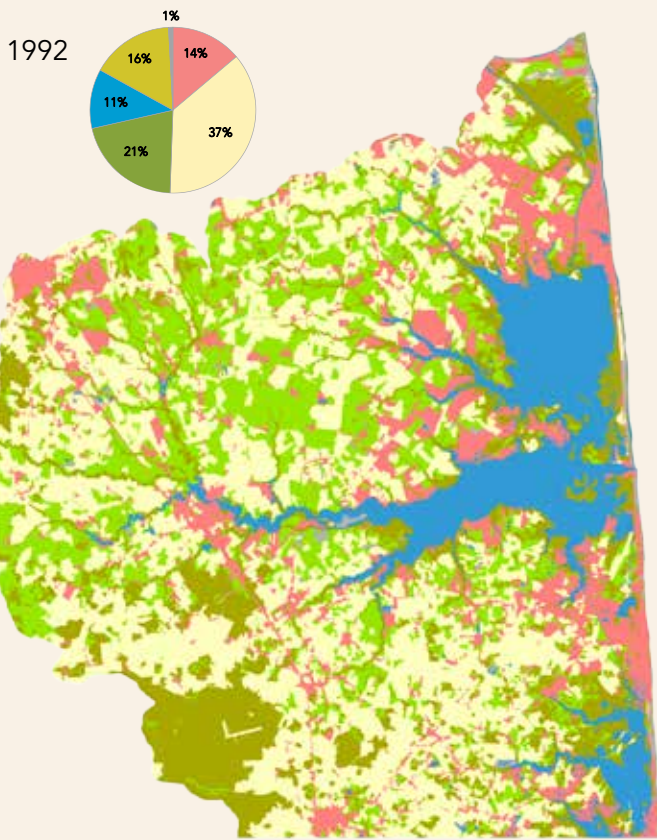
LIVING RESOURCES

HUMAN HEALTH RISKS

CLIMATE

Looking south from Jungle Jim's in Rehoboth Photo: TJ Redefer, Sky Jack Pics

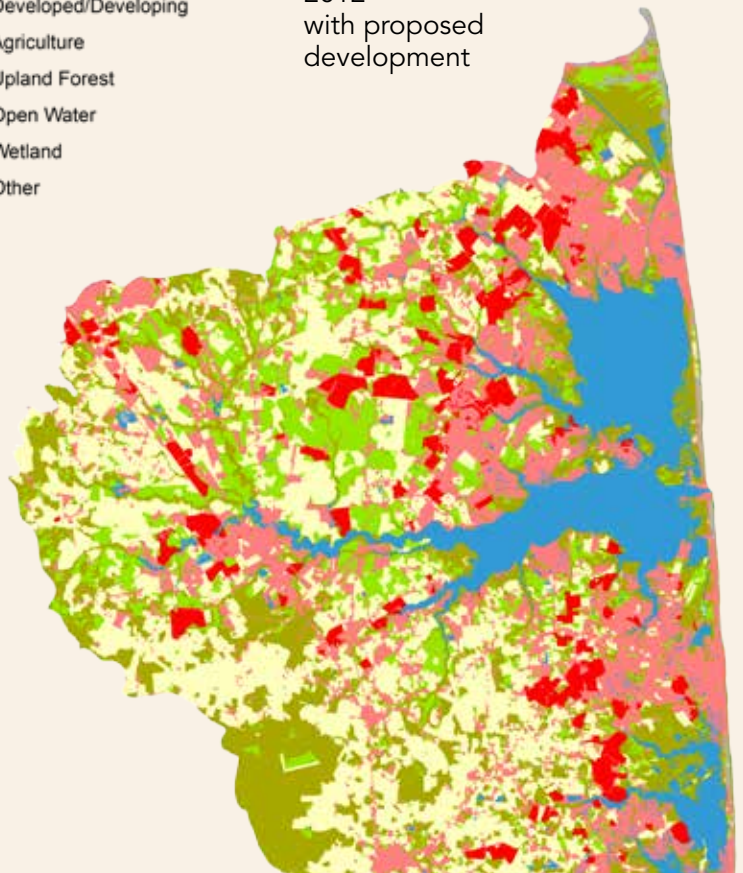
# WATERSHED CONDITION



## Land Use

- Proposed Development Projects
- Developed/Developing
- Agriculture
- Upland Forest
- Open Water
- Wetland
- Other

2012  
with proposed  
development

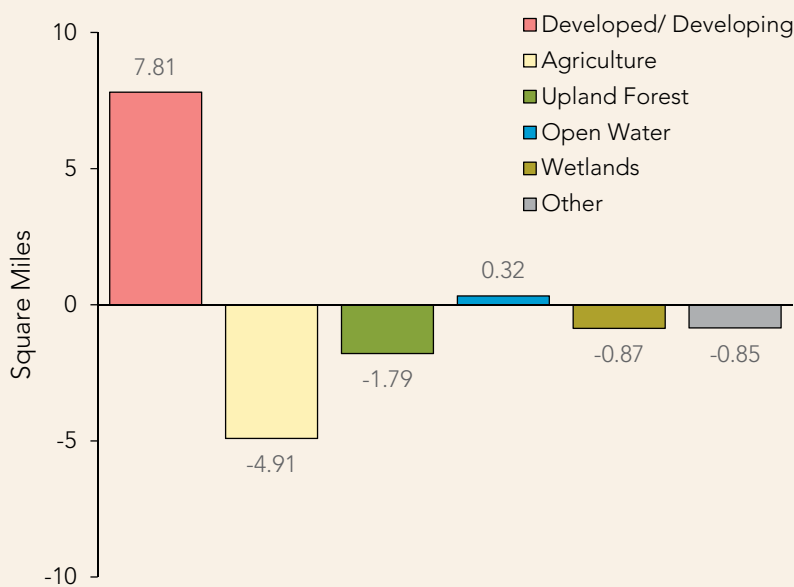


# LAND USE CHANGE

How we use the land directly affects water quality in the Bays, since various land uses result in different types and amounts of pollutants entering waterways. For example, a dense residential area without stormwater management contributes four times as much nitrogen pollution to the Bays as a forest of the same size. Agricultural lands also contribute high levels of nutrient pollution due to unintentional loss of fertilizers to ground and surface waters.

In 2012, agriculture was the largest land use (31%), followed by developed/developing lands (24%), forested lands (17%), wetlands (16%), and water (12%).

Changes in Land Use from 2007 to 2012



Aerial view of Longneck near Mariners Cove Photo: TJ Redefier, Sky Jack Pics

## LONG-TERM TREND

Between 1992 to 2012, land use in the watershed changed significantly. Developed lands increased by 33.9 square miles, agricultural lands decreased by 18.2 square miles, and upland forests decreased by 14 square miles.

## CHANGE SINCE PREVIOUS REPORT

Since the previous report, developed lands increased by 7.8 square miles (11%), with continuing declines in agricultural lands, upland forests, and wetlands.

## LOOKING AHEAD

All indications are that extensive development will continue. The 2018 Sussex County Comprehensive Plan offers the opportunity to plan for growth, open space and protection of natural resources which could have a significant positive impact on the health of the Bays.

**From 1992 through 2012, agriculture remained the largest land use of the watershed, but the land area decreased by 18.7mi (15.6% change over time). Developed land increased by 33.9mi (75% change).**

## IMPERVIOUS SURFACE COVERAGE

The creation of new roads, parking lots, driveways, and rooftops increases the amount of polluted stormwater runoff entering streams and the Bays. These impervious surfaces reduce infiltration of rainwater into the ground and contribute to flooding. Stormwater control practices such as retention ponds, raingardens, infiltration areas, and permeable pavements reduce these impacts.

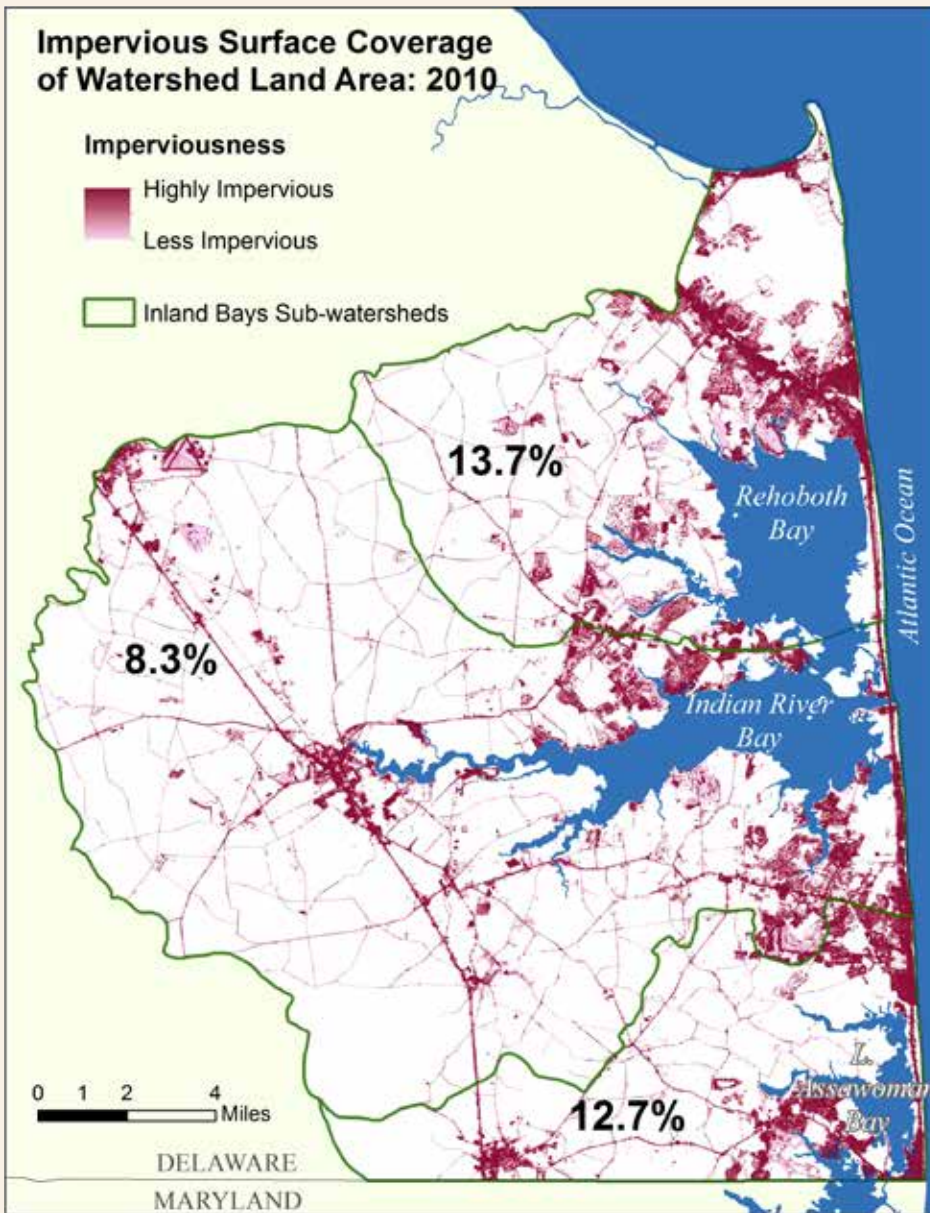
Studies have shown that noticeable degradation to the water quality of estuaries begins when their watershed exceeds 10% imperviousness.

The Inland Bays watershed as a whole has reached 10.4% impervious cover. Rehoboth and Little Assawoman Bay watersheds are even higher—13.7% and 12.7%, respectively. The most densely developed communities may exceed 50% imperviousness.



Rehoboth Bay comes to Dewey Beach September 1, 2016





#### LONG-TERM TREND

Since 1992, the percentage of land in the watershed covered with impervious surface increased by 22%. The largest increase occurred between 2001 and 2006.

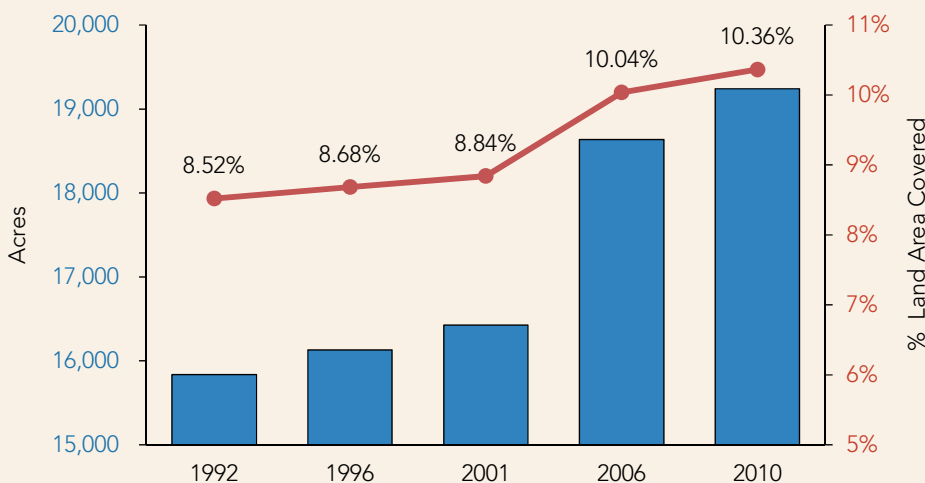
#### CHANGE SINCE PREVIOUS REPORT

Development slowed during the recession that began in 2008, as did the rate of increase in impervious surface coverage. Data for years more recent than 2010 are not yet available.

#### LOOKING AHEAD

Improving economic conditions have revived development activities postponed due to the recession, so impervious surface coverage will continue to increase. Limitations on the amount of impervious surface in new developments potentially could be incorporated into Sussex County's 2018 Comprehensive Plan.

Land Area Covered By Impervious Surfaces



**Studies have shown that noticeable degradation to the water quality of estuaries begins when their watershed exceeds 10% imperviousness. The Inland Bays watershed as a whole has reached 10.4% impervious cover.**

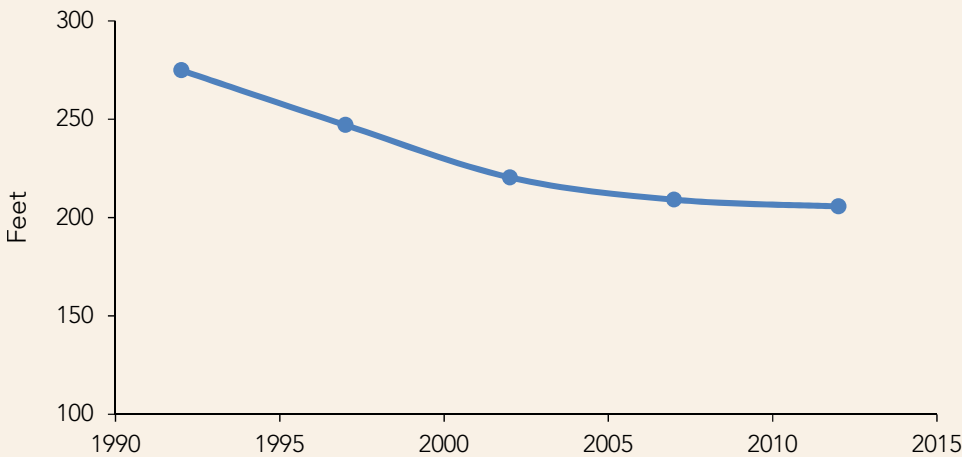
## WATER QUALITY BUFFERS ON CROPLANDS

Agriculture is still the largest land use in the watershed and contributes more nutrient pollution to the Bays than any other major land use. Buffers of natural vegetation between croplands and waterways can intercept and remove many of these nutrients.

Buffers vary in their effectiveness based partly on their width and type of vegetation. Wider buffers and forested buffers are more effective in removing nutrients from runoff and groundwater.

A geographic analysis was used to estimate how the average width of forested buffers between cropland and waterways has changed overtime. Only forested buffers wider than 50 feet were detected, which underestimates the actual acreage of functioning buffers. Still, this allows tracking of major changes.

Average Width of Forested Buffers Between Waterways and Croplands



### LONG-TERM TREND

From 1992 to 2012, the average buffer width decreased from 274 feet to 206 feet (or 25%).

### CHANGE SINCE PREVIOUS REPORT

Mean buffer width continued to decrease since the previous report, down 1.6% since 2007.

### LOOKING AHEAD

The outlook for changes in buffer width is uncertain. Due to long term declines in government incentives to establish and maintain buffers, their width is expected to continue to decrease.



Love Creek at Mulberry Knoll looking downstream to Arnell Creek and Rehoboth Bay  
Photo: TJ Redefier, Sky Jack Pics

**Forested buffers can remove over 80% of nutrient pollution from waters on their way to the Bays.**

# SALT MARSH ACREAGE AND CONDITION

Saltmarshes provide highly valuable services to people. They reduce flooding and erosion from storms, filter pollutants, trap and store carbon, and provide critical habitat for fish and wildlife.

Nearshore development and sea level rise are contributing to the loss of salt marshes. A significant feature of many Inland Bays salt marshes is the appearance of open water pools in the interior of the marsh. These areas are drowning due to sea level rise and because old ditches dug to control mosquitos are now causing water to be trapped on the marsh surface.

The total acreage of salt marshes fringing the Bays was 7,300 when last inventoried in 2007—a net loss of over 3,500 acres since 1938. The loss of marshes is particularly harmful to the water quality and living resources of the Bays.



Salt Marsh Cordgrass *Spartina alterniflora*

## LONG-TERM TREND

22% of the Bays' salt marshes were lost between 1938 and 1968 mostly to excavation and filling for development. The decline has continued, but at a slower pace due to Delaware's 1973 Wetlands Act that legally protected saltmarshes.

## CHANGE SINCE PREVIOUS REPORT

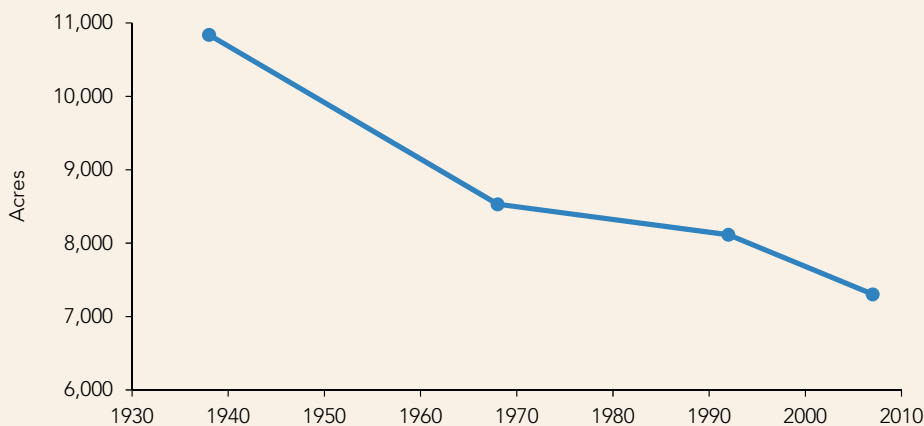
There has been a marked increase in the amount of interior open water in salt marshes since 1992, indicating accelerating degradation and loss.

## LOOKING AHEAD

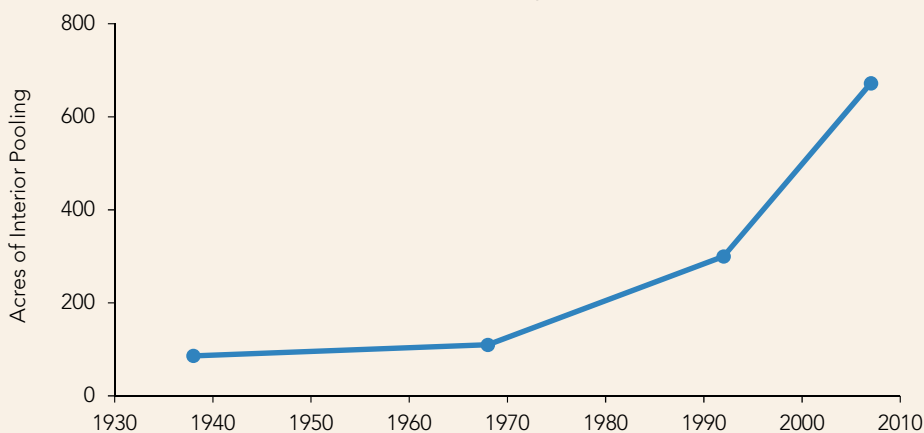
Most direct destruction of salt marsh by human impacts has been halted. Now the major cause of tidal marsh loss is erosion and 'drowning' of wetlands due to land subsidence and sea level rise. With rising sea levels and nearshore development, the important services of this resource will continue to disappear.

**Salt marshes reduce flooding and erosion from storms, filter pollutants, trap and store carbon, and provide critical habitat for fish and wildlife.**

Acres of Salt Marsh in the Inland Bays



Salt Marsh Degradation



### NATURAL HABITAT PROTECTION AND RESTORATION

Many types of natural habitats exist in the watershed, including forests, wetlands, meadows and beaches. They support a diversity of plants and animals, some of them rare. They also provide scenic beauty and recreational opportunities that are valued by visitors and residents.

Habitats are being lost due to changes in land use. Natural areas have become increasingly fragmented, stressing or eliminating some sensitive species that require large tracts of wetlands or forests.

Protecting the remaining high-quality natural areas and restoring degraded habitats are priorities for the CIB and its conservation partners. Protection is accomplished through purchase of land or conservation easements that restrict development. Restoration seeks to reestablish the natural ecosystems by reintroducing species and removing stressors.



James Farm Ecological Preserve on Indian River Bay

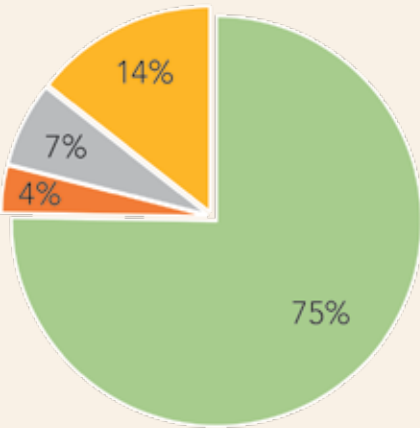
Planting trees at Angola Neck Preserve



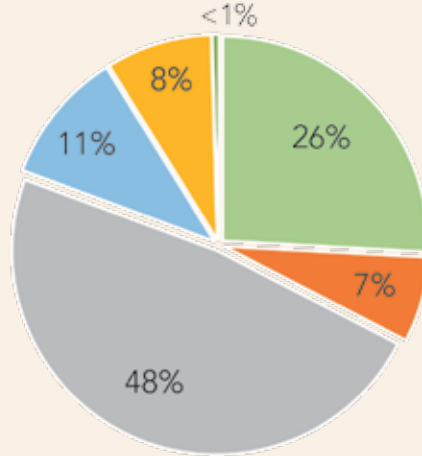




Protected

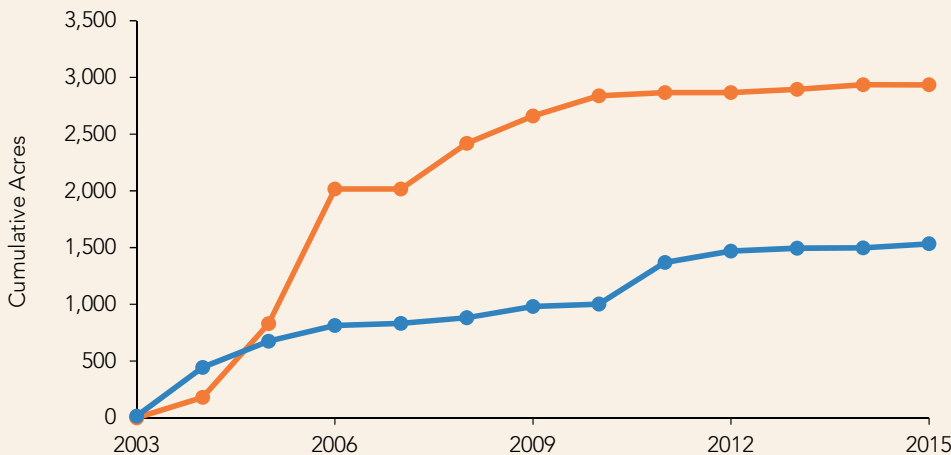


Restored or Enhanced



- Upland Forest
- Freshwater Wetland
- Open Field/Cropland
- Freshwater
- Saltmarsh

Natural Habitat Protection & Restoration



### LONG-TERM TREND

Since tracking began in 2003, nearly \$12 million has been spent to protect 3,000 acres and restore over 1,500 acres of natural habitat. Most of that progress occurred before 2010.

### CHANGE SINCE PREVIOUS REPORT

Since our previous report, progress on protection of natural habitat has nearly stalled and restoration has slowed. Since 2011, only 97 acres were protected and 530 acres restored. This slowdown is attributable to reductions in funding programs for public conservation programs and high land values for development.

### LOOKING AHEAD

Progress in habitat protection and restoration will be closely tied to availability of funding and incentives. New and innovative approaches to land conservation in the Inland Bays are needed if natural habitats are continued to be protected.

**Protecting remaining high-quality natural areas and restoring degraded habitats are priorities for the CIB and its conservation partners.**

## INDIAN RIVER INLET FLUSHING

Twice each day, the tides carry billions of cubic feet of salty ocean water into Indian River Bay where it mixes with freshwater entering from streams and groundwater.

Years ago, the inlet to Indian River Bay was shallow and moved around; it cut through the barrier island at various locations, blown out by one storm, closed up by another.

The inlet as we know it today was stabilized in the late 1930s by the construction of rock jetties. Since then the inlet has deepened over time, passing greater volumes of water and increasing the tidal range of the Bays. This has led to a long-term increase in the salinity of the Bays and contributed to degradation of marshes.

Increasing flushing also results in the flushing out of nutrient pollution from the Bays to the ocean. This likely contributes to improved water quality seen in the open bay waters that are most influenced by the tide.



The location of the inlet naturally shifted locations, as it was opened and closed by storms, until the early 20<sup>th</sup> century when it was secured in place by the Army Corps of Engineers. Photo: Delaware Seashore State Park

### LONG-TERM TREND

In the late 1960s, the increase in tidal flushing accelerated, such that 20 years later the amount of water passing through during one tide cycle had increased by over four times.

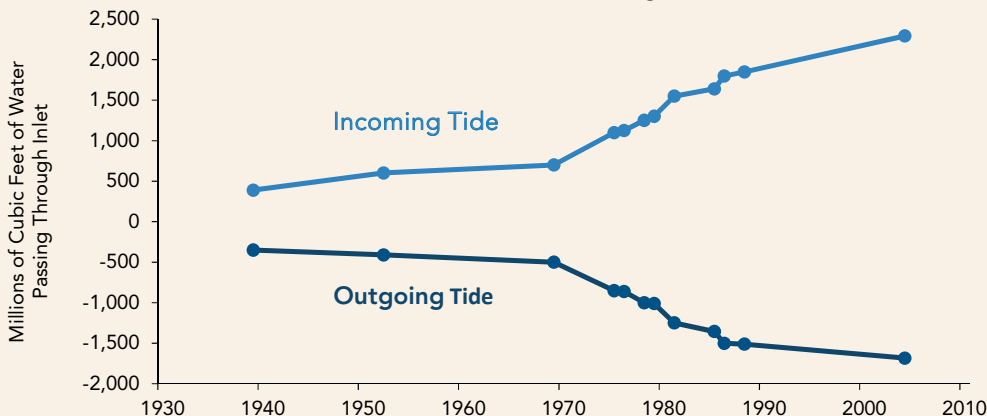
### CHANGE SINCE PREVIOUS REPORT

A 2004 estimate indicated the volume of tidal flushing continued to increase by 11–24% compared to the previous measurement in 1988.

### LOOKING AHEAD

The future rate of change in tidal flushing is uncertain. However, exchange through the inlet will continue to benefit water quality in the Bays.

Indian River Inlet Flushing Over Time



Years ago, the inlet to Indian River Bay was shallow and opened and closed by storms. The inlet as we know it today was deepened and stabilized in the late 1930s by the construction of rock jetties.

Indian River Inlet looking northwest to Rehoboth Bay  
Photo by Gordon Campbell / At Altitude Gallery



WATERSHED CONDITION

NUTRIENT POLLUTION

WATER QUALITY

LIVING RESOURCES

HUMAN HEALTH RISKS

CLIMATE

## MANAGING NUTRIENT POLLUTION

**Nutrient pollution is the largest problem facing the Inland Bays.**

**Point source pollution** originates from a pipe, such as discharge from a wastewater treatment plant.

**Nonpoint source pollution** originates from diffuse sources and enters the Bays through groundwater and surface runoff. Sources include fertilizers, septic systems, land application of wastewater, and stormwater runoff.

**Atmospheric sources** originate from the emissions of power plants, automobiles, and agriculture that later deposit directly onto the surface of the Bays.

The maximum amount of nutrient pollution that a water body can receive and still support healthy environmental conditions is called its Total Maximum Daily Load (TMDL). In 1998, state regulations established target loads for the Inland Bays. The regulations require elimination of all point sources, a 40 to 85% reduction of nonpoint source loads, and a 20% reduction of loads from atmospheric deposition. In 2008, the Delaware Department of Natural Resources and Environmental Control enacted a Pollution Control Strategy (PCS) that laid out a series of regulatory and voluntary actions needed to meet the TMDL.

After decreasing by over 80% since the 1990s, point source pollution decreased only slightly since the last report, and two point sources remain in the Bays.

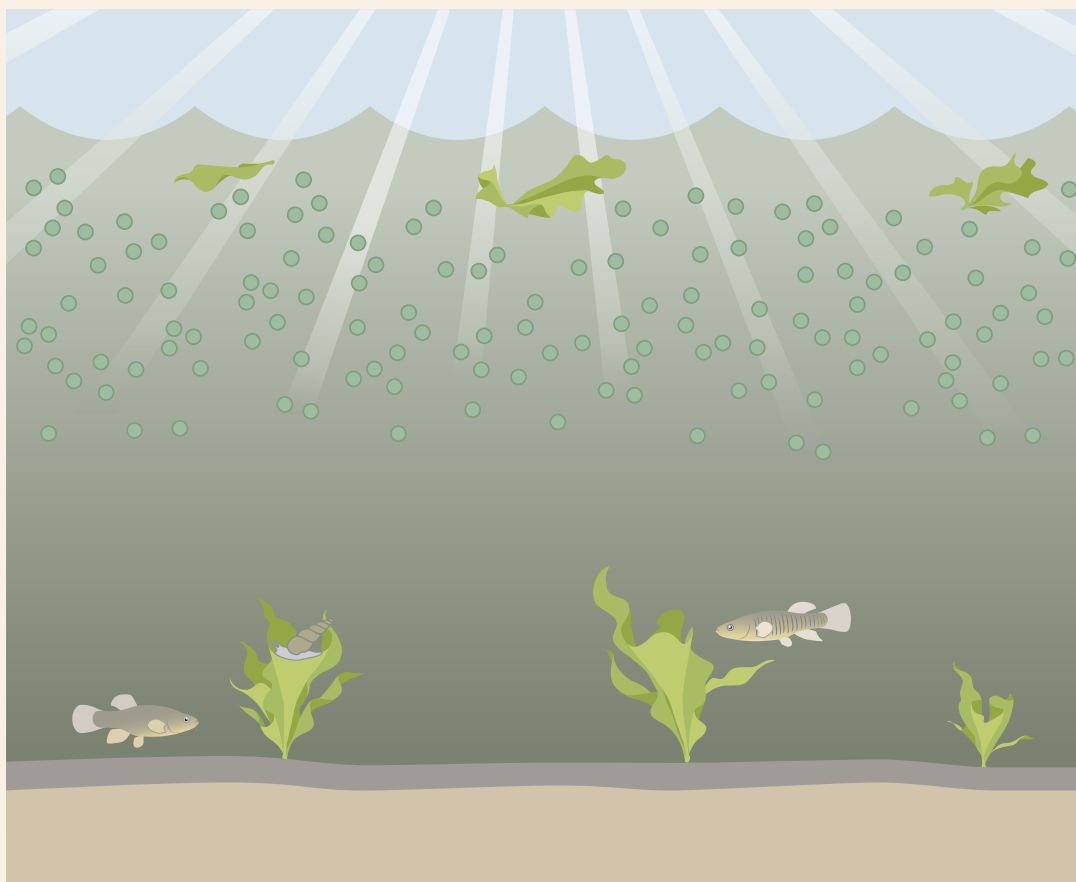
Nonpoint source nitrogen loads remained far in excess of healthy limits in all bays, but loads to Little Assawoman Bay may now be decreasing. Phosphorus loads on average were within healthy limits for Rehoboth and Little Assawoman Bays, but continue to exceed healthy limits for Indian River Bay.

Atmospheric nitrogen loads are now within healthy limits.

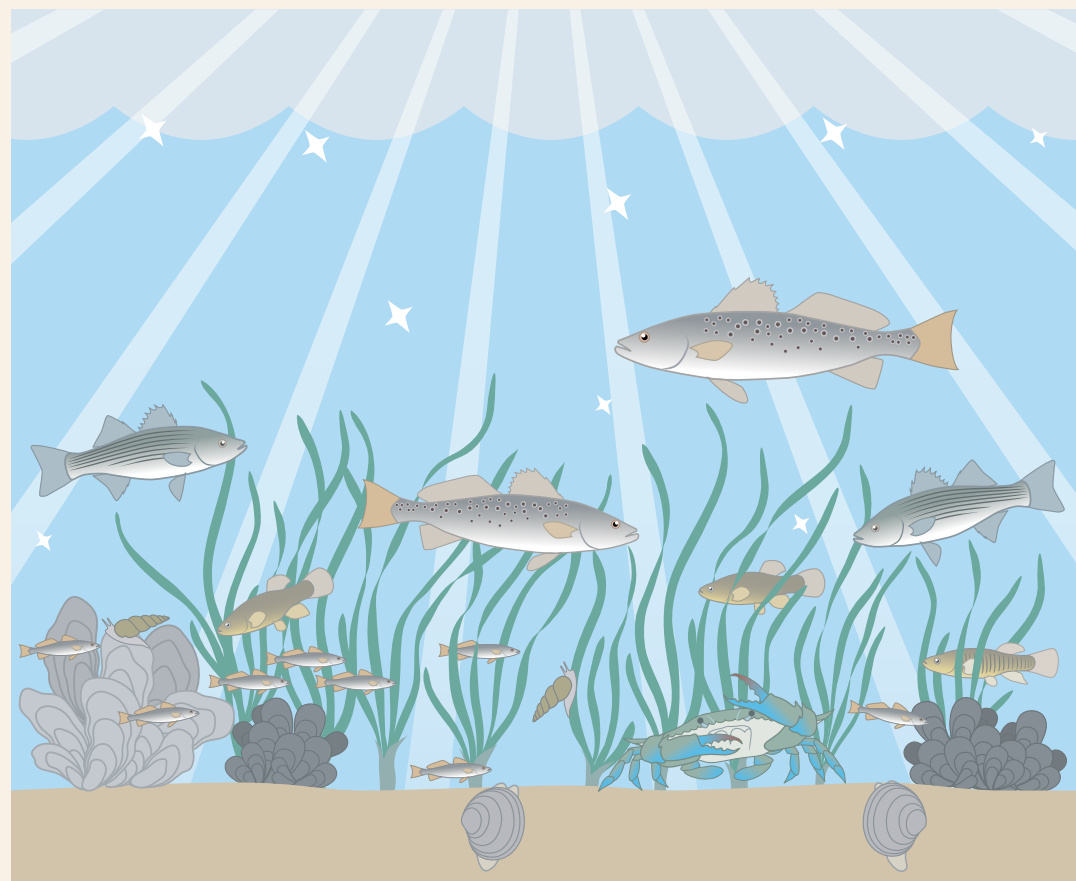
Substantial progress was made on conversions of septic systems to central sewer, far surpassing the pollution reduction goal.

Voluntary agricultural and stormwater nutrient management practices yielded very little progress, highlighting the need for dedicated funding for these most important bay restoration actions.





**Excess nutrients** from fertilizers, wastewater, and runoff cause blooms of microscopic algae. These, along with sediments in runoff, reduce water clarity which inhibits growth of bay grasses. Oxygen levels fluctuate naturally on a daily cycle in our shallow Bays. But when nutrient pollution is high, the cycles become extreme, and very low oxygen harms fish and invertebrates.

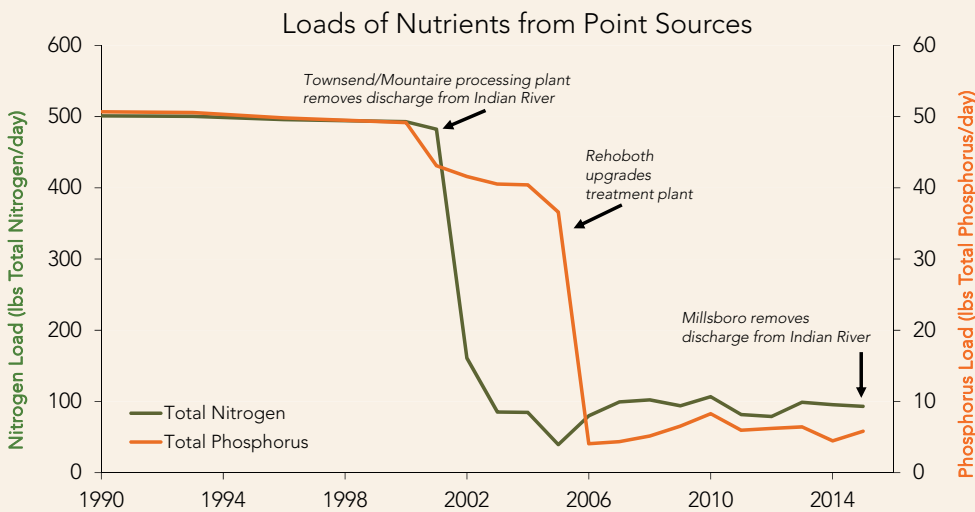


In a **healthy bay**, there is little algae, light reaches the bottom allowing bay grasses to grow, a greater diversity of fish and shellfish are present, and oxygen is plentiful and relatively stable.

## INPUT OF NUTRIENTS FROM POINT SOURCES

In 1990, thirteen point sources of pollution discharged to the Bays. Now only two remain: the City of Rehoboth Beach, and the Allen Harim facility near Indian River.

Since the last report, the removal of Rehoboth Beach’s wastewater discharge from Rehoboth Bay was again delayed, while the Town of Millsboro removed its discharge from the Indian River in August of 2015. Lewes is permitted to maintain its discharge to the Lewes & Rehoboth Canal, and makes up for the small amount of pollution that reaches the Bays by funding manure relocation from the watershed.



### LONG-TERM TREND

As wastewater facilities have improved treatment or removed their discharges, pollution to the Bays has decreased dramatically. From 1990 to 2009, pollution loads from point sources decreased by 407 lbs. per day of nitrogen (82%) and 44 lbs. per day of phosphorus (87%).

### CHANGE SINCE PREVIOUS REPORT

From 2009 to 2015, pollution continued to decrease slightly by 0.83 lbs. per day of nitrogen and 0.71 lbs. per day of phosphorus.

### LOOKING AHEAD

Pollution from point sources is anticipated to continue to decrease to zero, as required by the Total Maximum Daily Load regulation. Rehoboth plans to divert its discharge to an ocean outfall by 2018. Allen Harim is in discussions with DNREC about how to address its point source. The reduction in pollution from the removal of Millsboro’s discharge will be realized in the next report.



**In 1990, thirteen point sources of pollution discharged to the Bays. Now only three remain.**

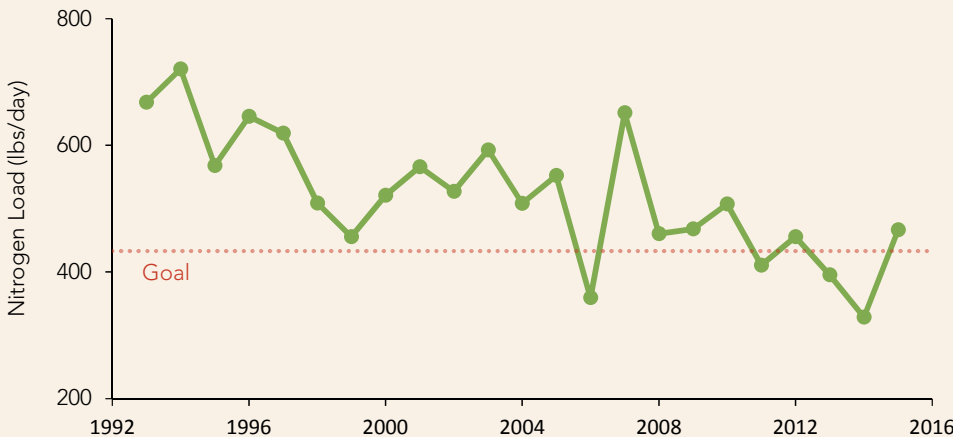
# INPUT OF NUTRIENTS FROM THE ATMOSPHERE

Nutrients are deposited from the atmosphere directly into the Bays during both wet and dry weather. Excess nitrogen in the atmosphere comes from coal-burning power plants, automobiles, and agriculture. Phosphorus in the atmosphere may originate from combustion, natural vegetation, blown soil particles, sea spray, and herbicide application.

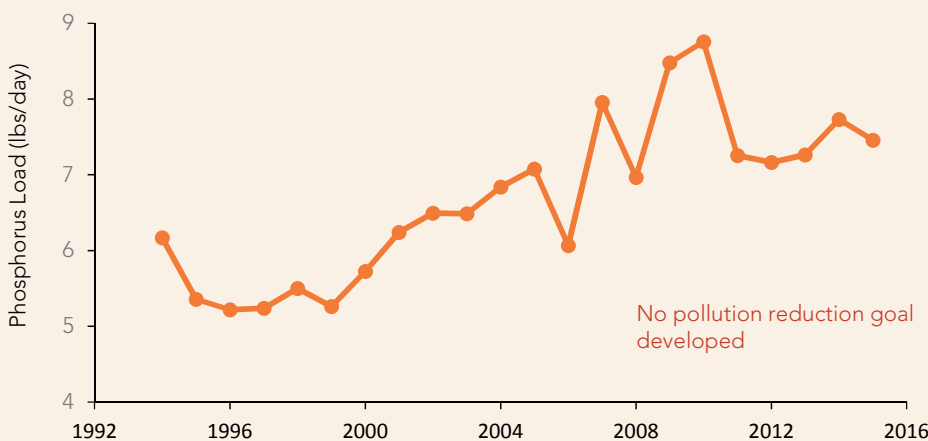
Deposition of nitrogen is of most concern for Bay health, and now atmospheric nitrogen loads meet their pollution reduction goal on average.



Nitrogen Load from the Atmosphere



Phosphorus Load from the Atmosphere



## LONG-TERM TRENDS

Since the early 1990s, atmospheric nitrogen loads have decreased due to improved federal emission standards for power plants and automobiles. Phosphorus loads have increased slightly for unknown reasons.

## CHANGE SINCE PREVIOUS REPORT

Since the previous report, atmospheric inputs of nitrogen have continued a slight decrease. Retirement of coal-fired generating units at the Indian River Power Plant may have contributed to the improvement. Phosphorus loads have continued to increase slightly.

## LOOKING AHEAD

Reductions in atmospheric nitrogen loads should continue as a result of both increasing fuel economy standards and the federal Clean Air Act and Clean Power Plan that requires reduced emissions from power plants. Should phosphorus from the atmosphere continue to increase, investigation into its specific sources may be needed.

**Atmospheric nitrogen loads meet their pollution reduction goal on average.**

## INPUT OF NUTRIENTS FROM NONPOINT SOURCES

Nonpoint source pollution comes from fertilizers, animal wastes, and human wastewater transported through runoff or groundwater. It is by far the largest source of nutrient pollution.

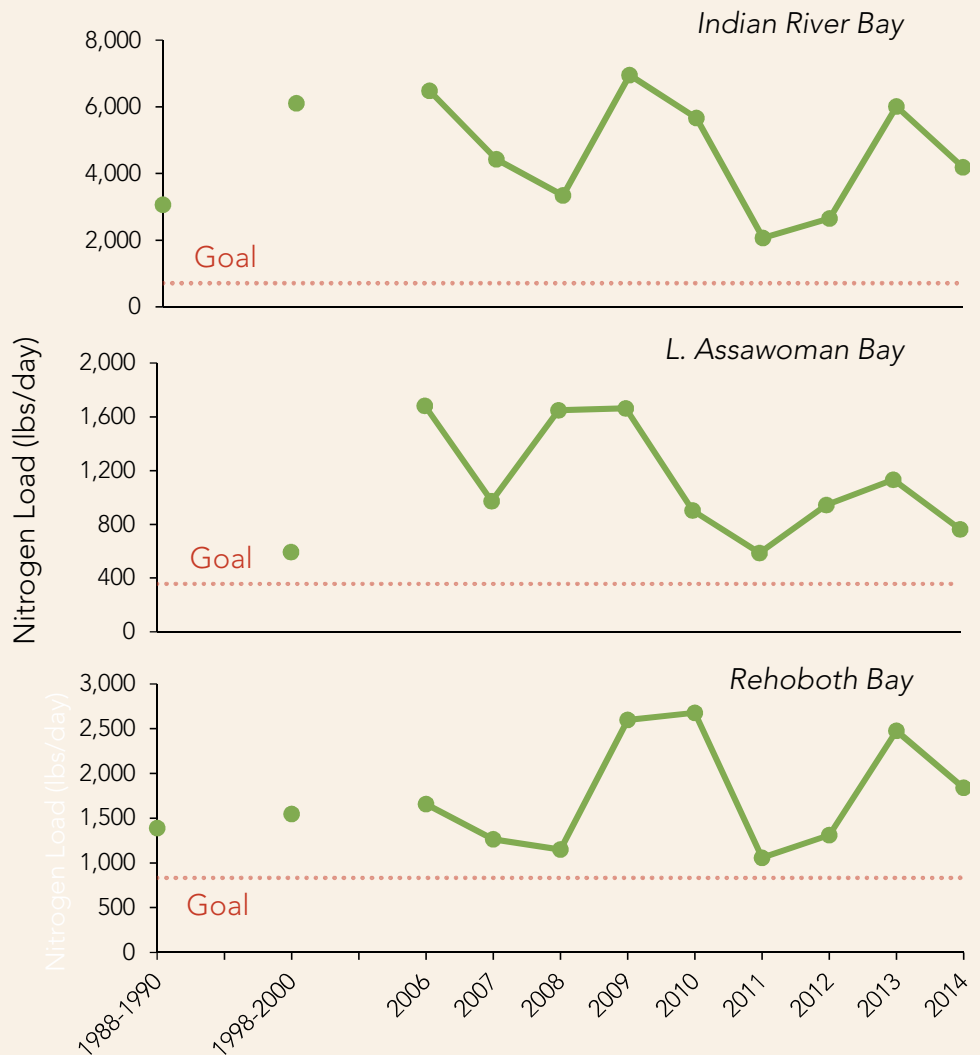
Input (or 'loads') of nutrients from nonpoint sources are estimated from monitoring the major streams that drain to the Bays. Many years are needed to detect changes, because stream flow is variable, and groundwater carrying nutrients may take decades before entering streams.

Inputs of nitrogen remained far in excess of healthy limits in all three Bays. Indian River Bay had average inputs more than six times the healthy limit.

Inputs of phosphorus, on average, remained within healthy limits in Rehoboth and Little Assawoman Bays, but some years exceeded limits. Phosphorus loads in Indian River Bay were nearly twice the healthy limit.



Loads of Nitrogen from Nonpoint Sources

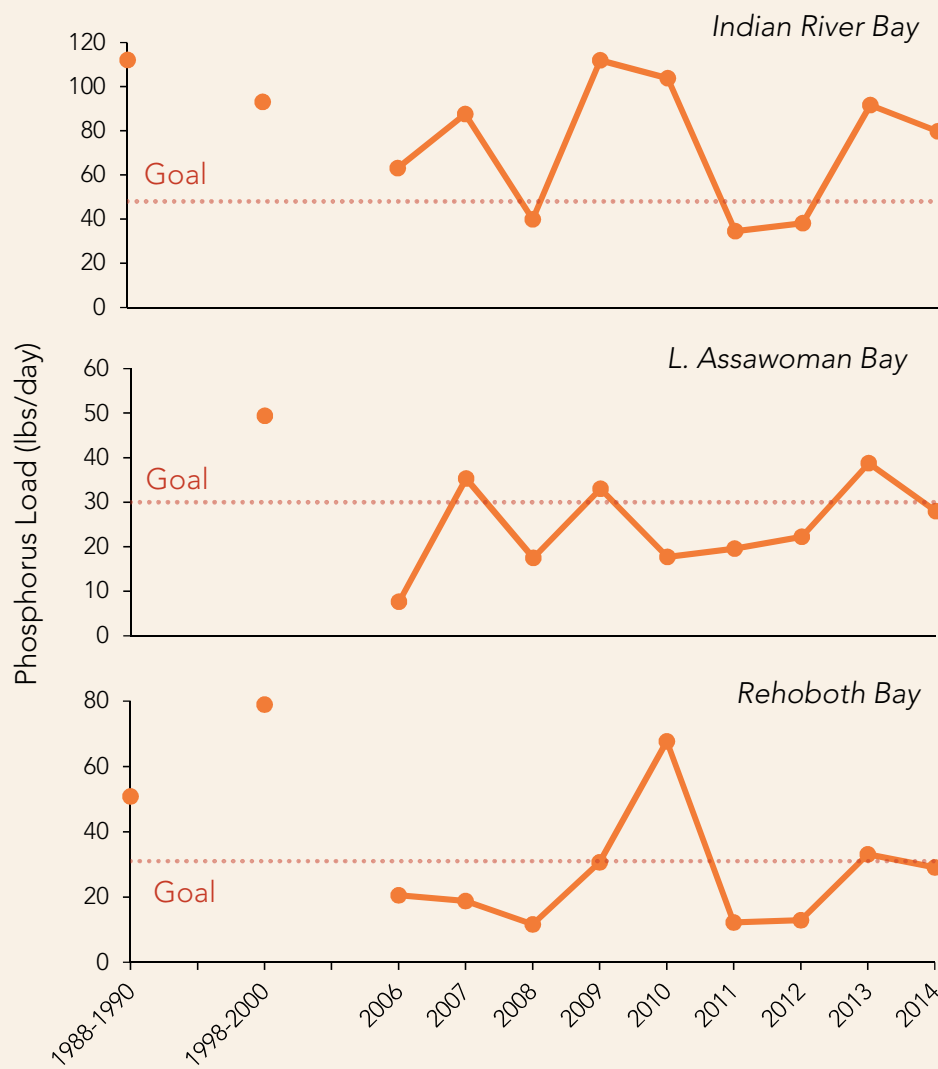






Runoff from a construction site on Dirickson Creek

### Loads of Phosphorus from Nonpoint Sources



### CHANGE SINCE PREVIOUS REPORT

Since the last report, nitrogen inputs to Little Assawoman Bay have decreased but inputs did not change to Rehoboth and Indian River Bays. No short-term trends in phosphorus inputs were observed.

### LOOKING AHEAD

Sustained phosphorus reductions are credited to improved nutrient management on farms and the conversion of cropland to development with stormwater controls. Sixteen years after Total Maximum Daily Load regulations were enacted, nitrogen loads have not decreased. This has been enough time to allow nearly half of the polluted groundwater to flush through aquifers and into streams.

Decreases are expected as cleaner water begins to enter streams over time. However, significant improvement hinges on the widespread implementation of all actions of the Pollution Control Strategies.

**Inputs of nitrogen remained far in excess of their healthy limits in all three Bays. Indian River Bay had average inputs over six times its healthy limit.**

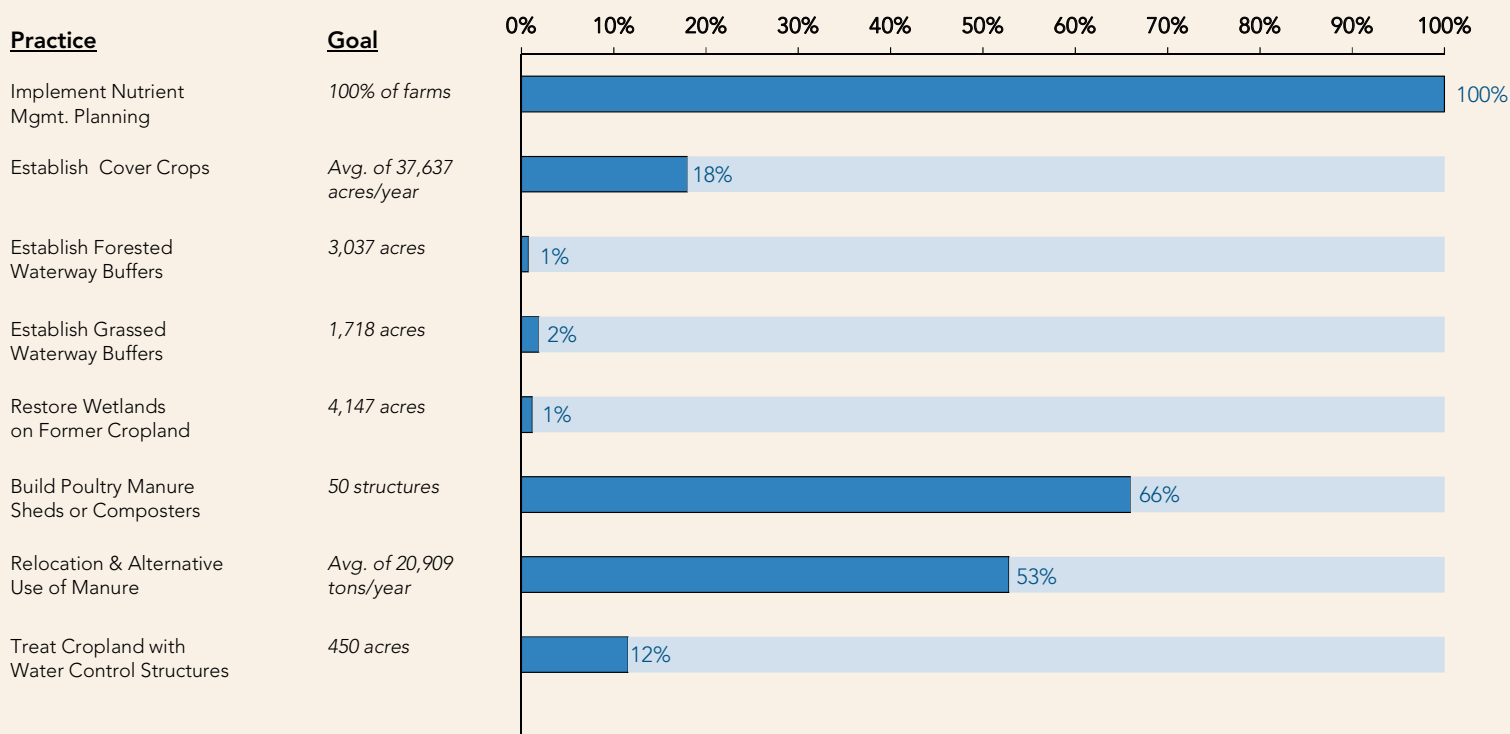
## AGRICULTURAL NUTRIENT MANAGEMENT PRACTICES

Agriculture is the largest land use in the watershed, and it contributes the most pollution through the unintentional loss of fertilizers to waters. Best management practices for nutrients significantly reduce pollution and can improve soil fertility. Agricultural practices of the Pollution Control Strategy account for over three quarters of the needed pollution reductions.

Progress since 2005, when tracking began, is mixed. Of the 8 practices, only Nutrient Management Planning (a regulatory requirement) has met its goal. Two other practices have achieved over 50% of their goals, while the remaining five practices have had little progress. Some goals are under-reported, because practices implemented without government assistance may not be tracked.



Progress Toward Pollution Control Strategy Agricultural Nutrient Management Practice Goals (since the year 2005)





Field near Love Creek Photo: TJ Redefar, Sky Jack Pics

### CHANGE SINCE PREVIOUS REPORT

Since the last report, Nutrient Management Planning increased from 95% of farms to 100% of farms. An additional 24 poultry manure sheds or composters were built, manure relocation increased slightly, and 2 water control structures were built. Since the last report, little overall progress has been made on implementing agricultural nutrient management practices, which are by far the most important for restoring the Inland Bays.

### LOOKING AHEAD

Since almost all practices are voluntary, implementation is driven by government investment in subsidies. According to the Pollution Control Strategy, for all of the remaining agricultural practices to meet their goals an estimated \$4 million investment per year would be needed. (Adjusted for inflation)

**Since the last report, little overall progress has been made on implementing agricultural nutrient management practices, which are by far the most important for restoring the Inland Bays.**

## SEPTIC SYSTEM CONVERSION TO CENTRAL SEWER

A properly maintained septic system leaches 10.6 lbs. of nitrogen and 0.7 lbs. of phosphorus to groundwater each year. When multiplied by the estimated 8,292 systems in the watershed, the total pollution contribution of septic is nearly 89,000 pounds of nitrogen yearly and more than 5,800 pounds of phosphorus.

Central sewer service allows a higher level of sewage treatment and eliminates pollution from septic systems.

Since the 1970s, Sussex County has facilitated the conversion of an estimated 50,801 septic systems to central sewer. While new septic systems are continually permitted, the total number of septic systems in the watershed has decreased with central sewer expansion.

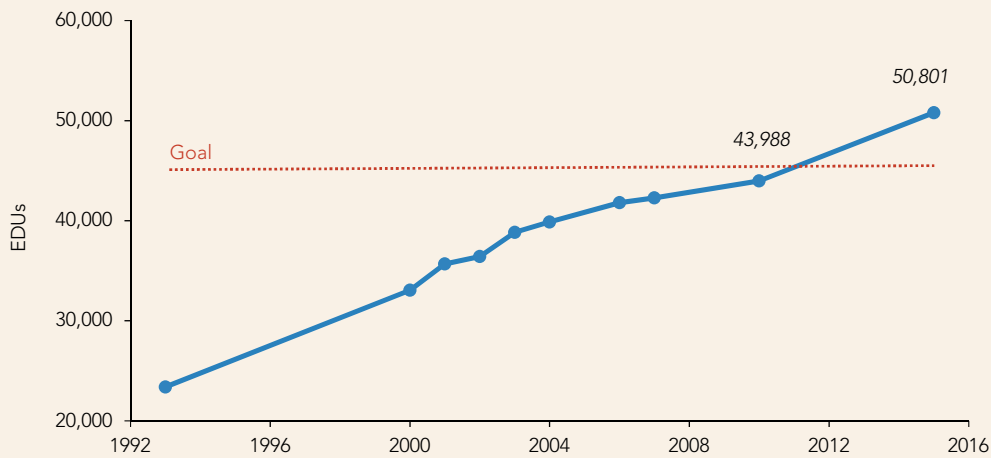
### CHANGE SINCE PREVIOUS REPORT

Since 2011, the equivalent of 6,813 single family homes were connected to central sewer. Johnson's Corner, Angola, and Oak Orchard sewer districts received the most new connections. During this time, the Pollution Control Strategy goal for septic conversion was far surpassed.

### LOOKING AHEAD

In 2016, property owners voted to include 713 homes on septic into the new Herring Creek Sewer District. Regulations requiring a greater pollution removal for new septic systems were implemented in 2014. These positive developments will continue to keep nutrients and bacteria out of the Bays.

Cumulative Number of Equivalent Dwelling Units (EDUs) Converted from Septic to Central Sewer



Dirickson Creek Team paddling up the Creek

**While new septic systems are continually permitted, the total number of septic systems in the watershed has decreased thanks to central sewer expansion.**

# STORMWATER RETROFITS

As stormwater moves overland, it picks up and carries pollutants from lawns, streets, and industrial facilities into streams and the Bays. Developments in Delaware constructed prior to 1990 were not required to control stormwater, so they contribute high levels of stormwater pollution.

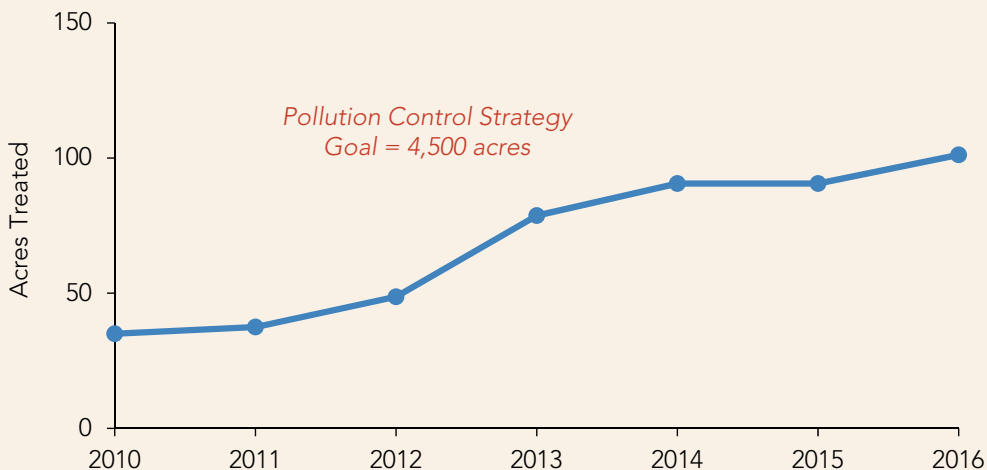
Stormwater retrofits are stormwater management facilities in locations where controls did not previously exist or were ineffective. The Inland Bays Pollution Control Strategies call for the creation of stormwater retrofits to treat 4,500 acres of lands developed prior to 1990.

Currently, 101 acres of the watershed have received stormwater retrofits. The Town of South Bethany contributed the most to this goal with the completion of the Anchorage Canal Stormwater Retrofit Project. The CLB, working with the Delaware Department of Transportation and the surrounding communities, installed a series of attractive raingardens, ponds, wet swales, and infiltration areas were created over six years.

## LOOKING AHEAD

4,399 acres remain to be retrofitted to meet the pollution goal. The rate of stormwater retrofit implementation is not expected to increase unless public or private investment in the practices increases. This underscores the need for stormwater regulations that protect water quality and that are enforced.

Cumulative Area of Development Retrofitted with Stormwater Controls



**A series of attractive raingardens, ponds, wet swales, and infiltration areas were created as part of the Anchorage Canal Stormwater Retrofit Project along the Route 1 corridor in South Bethany.**

Anchorage Canal Stormwater Retrofit Project by Sea Colony



## WATER QUALITY

Measures of water quality are the most basic indicators of Bay health. They are key measures of the effectiveness of actions taken to reduce pollution to the Bays.

The six water quality indicators are based on the minimum requirements necessary for reestablishment of bay grasses and healthy dissolved oxygen levels. Each water quality indicator individually is useful to assess changes in the health of the Bays, and collectively they provide a clearer picture of ecological conditions.

The water quality information used in this report comes from more than 30 long-term monitoring sites located in tidal portions of the Bays. Data are collected by both the Department of Natural Resources and Environmental Control and the University of Delaware's Citizen Monitoring Program.

Overall, water quality in the Inland Bays remains fair to poor, but is improving. Compared to five years ago, nutrient and algae concentrations have improved in some areas. Many places have seen modest long-term positive trends in phosphorus and algae levels.

Water clarity and dissolved oxygen in the Bays, however, have seen no significant long-term improvements. Although seaweed abundance is down compared to the 1990s, blooms still occur. Few areas had water quality conditions that are thought to allow bay grasses to reestablish. Most tributaries and canals continue to have poor water quality.

Water quality improvements are, however, being seen near the Indian River Inlet and in Little Assawoman Bay. With its smaller ratio of land to water, and high water tables, Little Assawoman is likely to be the first Bay to respond to improved watershed management.

### Looking Ahead

Until nutrient inputs to the Bays decrease, water quality is likely to remain impaired, particularly in tributaries. Increased tidal flushing through the inlet has likely contributed to better water quality in parts of Indian River and Rehoboth Bays.

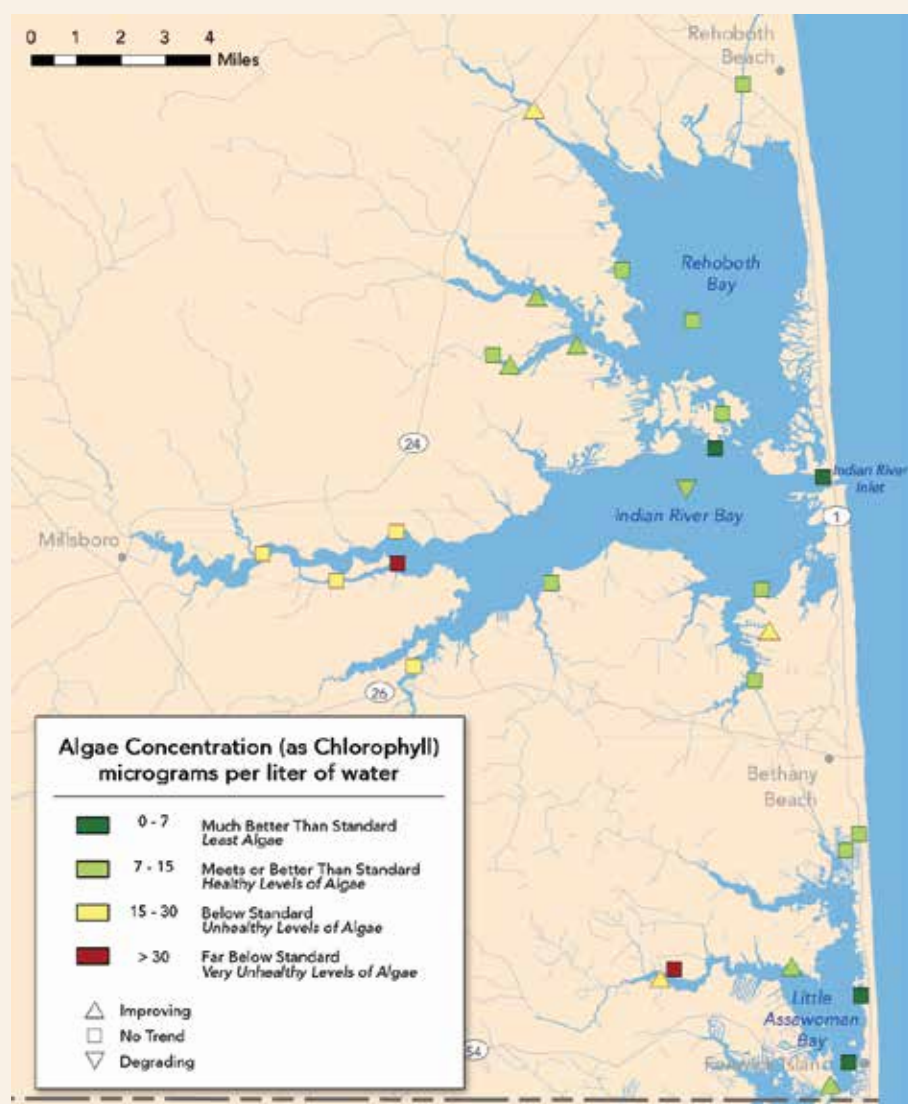


## ALGAE CONCENTRATION

In a healthy bay, floating microscopic algae provide food for fish, shellfish and other invertebrates. When too many nutrients are added to the water algae may grow out of control, and algal blooms appear. If blooms persist, they cloud the water so that bay grasses are deprived of light and cannot grow.

Chlorophyll a is a green pigment in algae. Concentration of this pigment in the Bays indicates the abundance of algae. Levels below 15 milligrams per liter of water are considered healthy.

From 2011 to 2015, the majority of locations sampled in the Bays (73%) met this standard. Indian River and Dirickson Creek had high levels of algae that often were much worse than the standard.



### LONG-TERM TREND

Over the long-term, algae levels in a number of tributaries and Little Assawoman Bay have improved. Indian River, however, has shown no improvement.

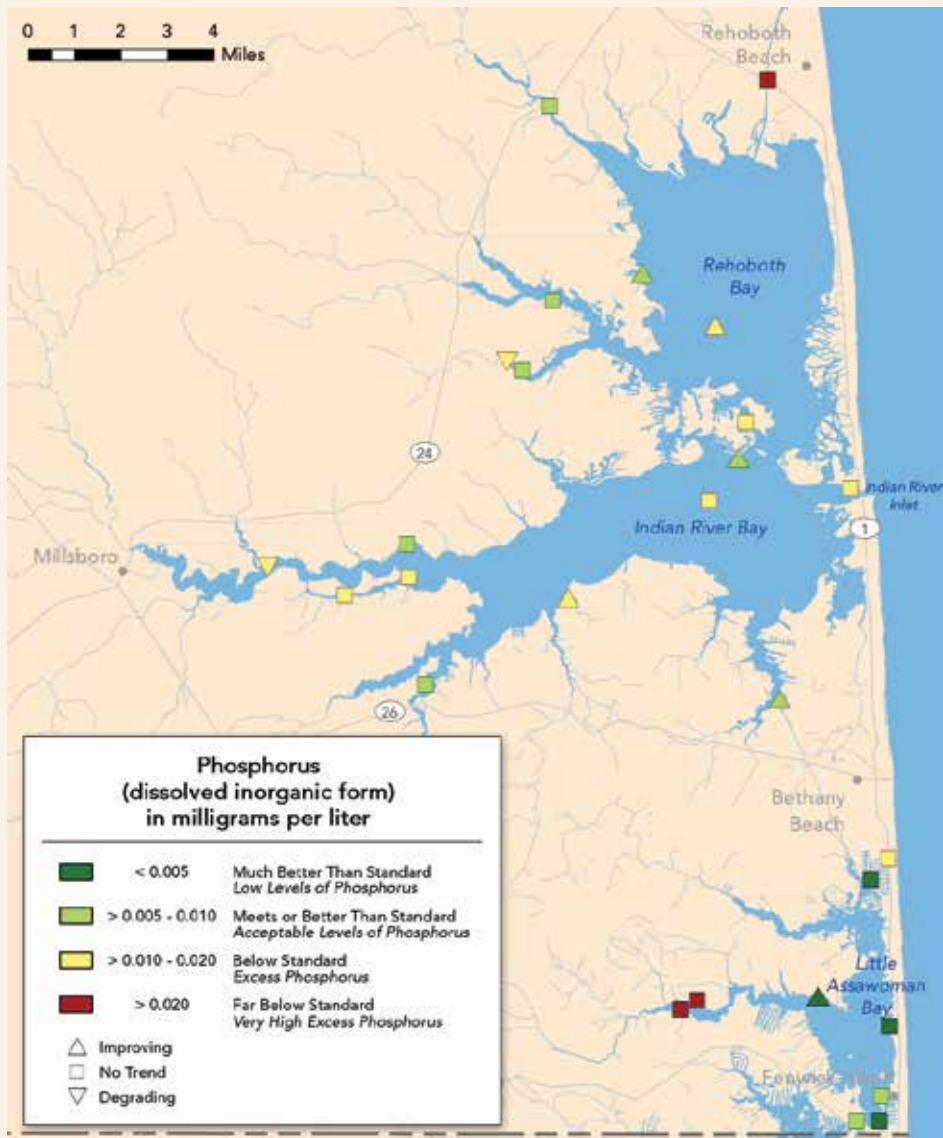
### CHANGE SINCE PREVIOUS REPORT

Algae concentrations in the Bays have decreased since the previous report was published. The number of sampling stations meeting the standard, compared to five years ago, has increased by 36%. Of all the water quality indicators, algae concentration has improved the most.

**Chlorophyll a is a green pigment in algae. Concentration of this pigment in the Bays indicates an abundance of algae.**



Testing the waters on Love Creek Photo: Judy Britz





# CONCENTRATIONS OF NUTRIENTS

Nitrogen and phosphorus are nutrients necessary for the growth of beneficial bay grasses, seaweeds and algae. But an excess of these nutrients has caused overabundances of algae and seaweeds, murky water, low oxygen levels, and disappearance of bay grasses.

Studies have determined standards for nutrient concentrations that will result in healthy oxygen levels and clear waters that allow bay grasses to reestablish.

Over the period 2011 to 2015, 52% of monitoring stations met the standard for nitrogen concentration. Most sites that met the standard are located in open bay areas near the Indian River Inlet and in Little Assawoman Bay. Tributaries generally did not meet nitrogen standards, and concentrations in Indian River and Guinea Creek are particularly high.

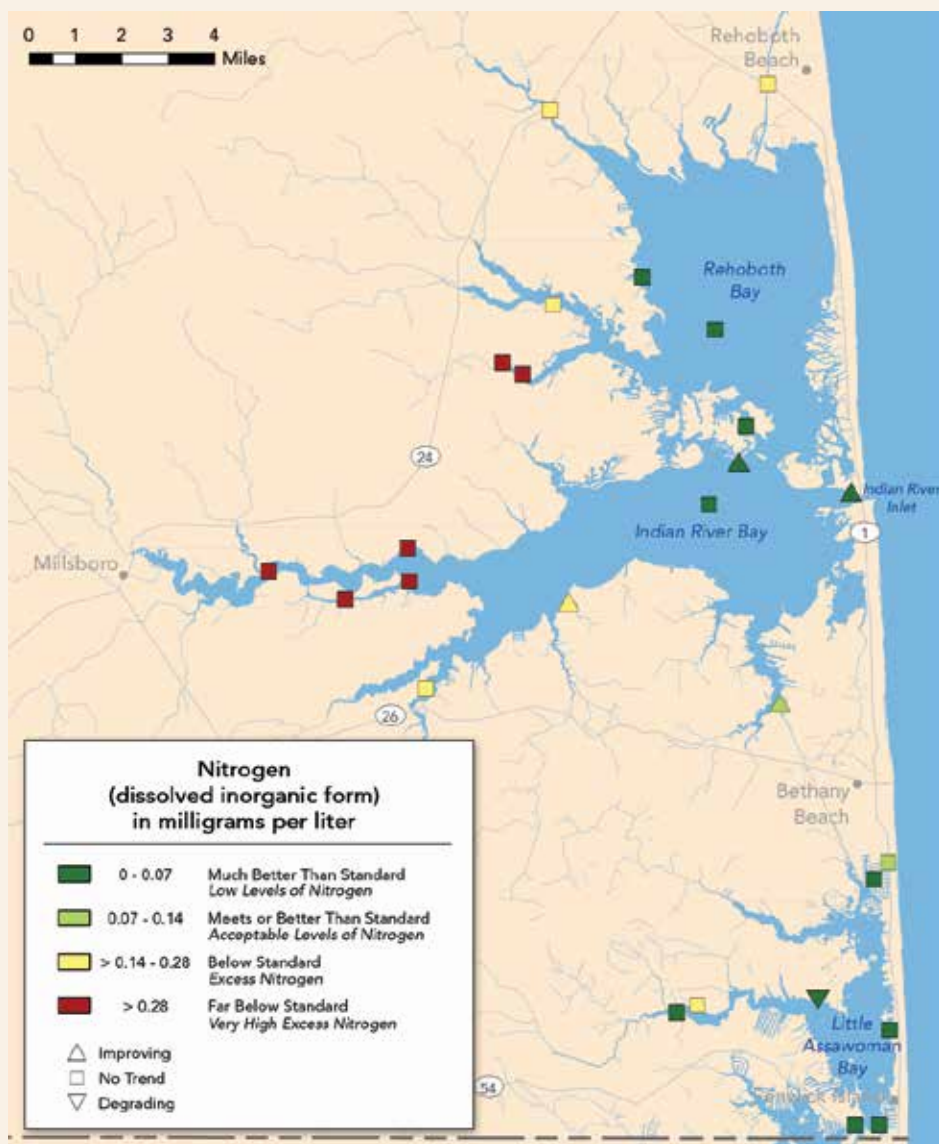
Forty-six percent of stations met the standard for phosphorus. More tributary sites meet the phosphorus standard than for nitrogen. Phosphorus concentrations are relatively low in Little Assawoman Bay, partly because its lower salinity keeps phosphorus bound to bay sediments and out of the water.

## LONG-TERM TREND

Nutrient concentrations have not changed significantly at most monitoring sites over last 10- to 15-year period. Conditions at three stations are degrading as nutrient concentrations have increased. Long-term improvements have occurred at sites closest to the Indian River Inlet, likely because the tidal flow through the inlet has increased over time.

## CHANGE SINCE PREVIOUS REPORT

There are some signs of progress. Compared to five years ago, concentrations of both nitrogen and phosphorus have moderately improved. Roughly half of the sites now meet nutrient standards. Only a third did previously.



**52% of monitoring stations met the standard for nitrogen concentration. 46% of stations met the standard for phosphorus.**

## WATER CLARITY

Because all plants need sunlight to grow, clear water is essential for underwater bay grasses to reestablish in the Inland Bays.

Algae, sediments, and organic matter floating in the water all reduce clarity and prevent sunlight from reaching the bay bottom to support plant life.

Water clarity is measured by lowering a black and white Secchi disk into the water until its markings can no longer be seen. When all other conditions are right, bay grasses can grow in shallow waters with an average Secchi depth of at least 2.2 feet.

From 2011 to 2015, 55% of water quality monitoring sites in the Bays met or exceeded this standard. Little Assawoman Bay and areas near the Indian River inlet were clearest, while tributaries were murky and below standard.



### LONG-TERM TREND

While water clarity in Little Assawoman Bay improved over a 10- to 15-year period, five sampling sites in Indian River Bay and the Lewes-Rehoboth Canal decreased in clarity.

### CHANGE SINCE PREVIOUS REPORT

More sites in Little Assawoman Bay now meet the water clarity standard than in 2011. Waters on the western side of Indian River Bay became less clear. The status of other bay areas has not changed.



Because all plants need sunlight to grow, clear water is essential for underwater bay grasses to reestablish in the Inland Bays.

# WATER QUALITY INDEX

The Water Quality Index combines the previous four indicators (nitrogen and phosphorus concentrations, algae concentration, and water clarity) into an integrated measure of whether conditions are present to support the reestablishment of eelgrass.

The index ranges from 0 (water quality least supportive of eelgrass) to 1.0 (water quality that will support eelgrass reestablishment when other conditions allow). Index values from 0.90 to 0.99 may support some reestablishment and growth.

41% of monitoring sites in the Bays had an index value of at least 0.90, suggesting that bay grass restoration efforts could be successful in these areas where other physical conditions are met. Again, these areas are found mostly in Little Assawoman Bay, and in the open water areas of the bays near the inlet. Two sites, in Dirickson Creek and upper Indian River, had particularly low indices of water quality.

## LONG-TERM TREND

The only significant long-term trends in the index value were in Little Assawoman Bay (two stations improving, one degrading).

## CHANGE SINCE PREVIOUS REPORT

The index values for Vines Creek, and lower Indian River have improved over the past five years, but both remain below standard. Parts of Little Assawoman Bay that were below standard in 2011 now meet minimum requirements for growth of eelgrass.



**41% of monitoring sites in the Bays had an index value of at least 0.90, suggesting that bay grass restoration efforts could be successful in these areas where other physical conditions are met.**

## DISSOLVED OXYGEN CONCENTRATION

All living creatures in the Bays—from swimming fish, shrimp and crabs to the clams and worms that burrow into the mud—need oxygen to survive. Dissolved oxygen levels that are high and stable support diverse and healthy populations of bay life.

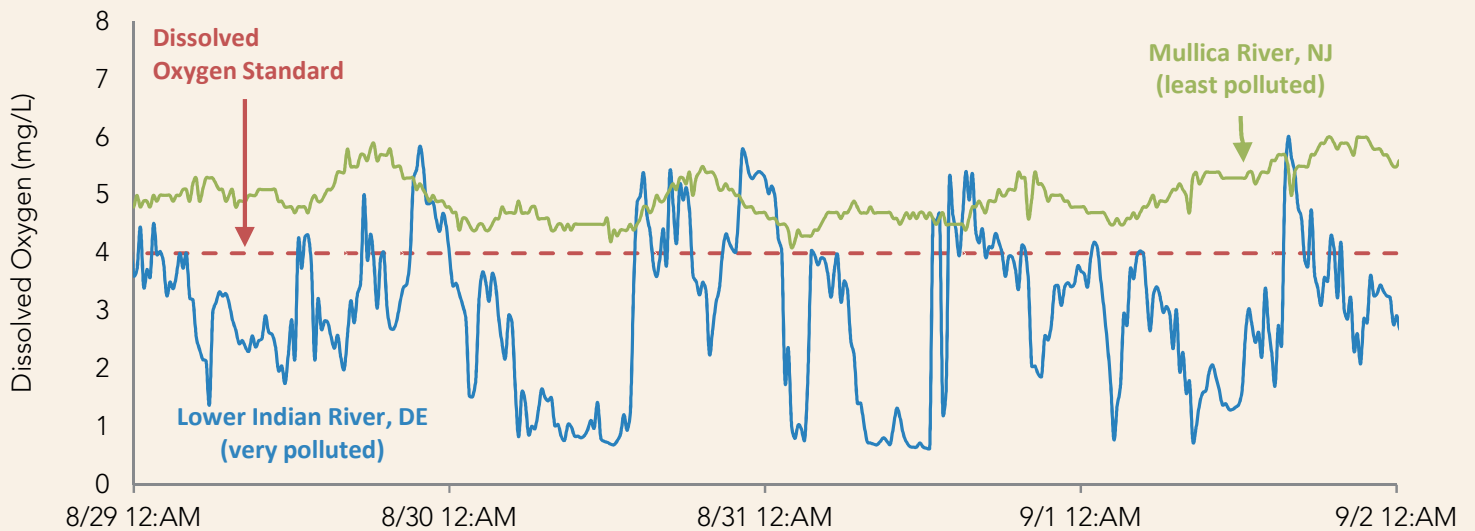
Oxygen levels in shallow bays naturally cycle over 24 hours. During the day, plants and algae release oxygen into the water through photosynthesis. At night, plants, algae, and animals continue to respire and draw oxygen out of the water. But nutrient pollution makes these cycles extreme by fueling algal blooms. When the excessive algae respire at night, they can cause oxygen to drop below healthy levels.

The dissolved oxygen indicator shows the percent of summer mornings that oxygen levels fall below the healthy standard of 4 milligrams of oxygen per liter of water. Zero to 10% of mornings is considered healthy. Higher percentages increasingly impact the feeding, growth and survival of aquatic life in the Bays.

Dissolved oxygen levels in well-flushed, open water areas of the Bays meet the standard most of the time. However, many nearshore areas and tributaries have unhealthy oxygen levels.



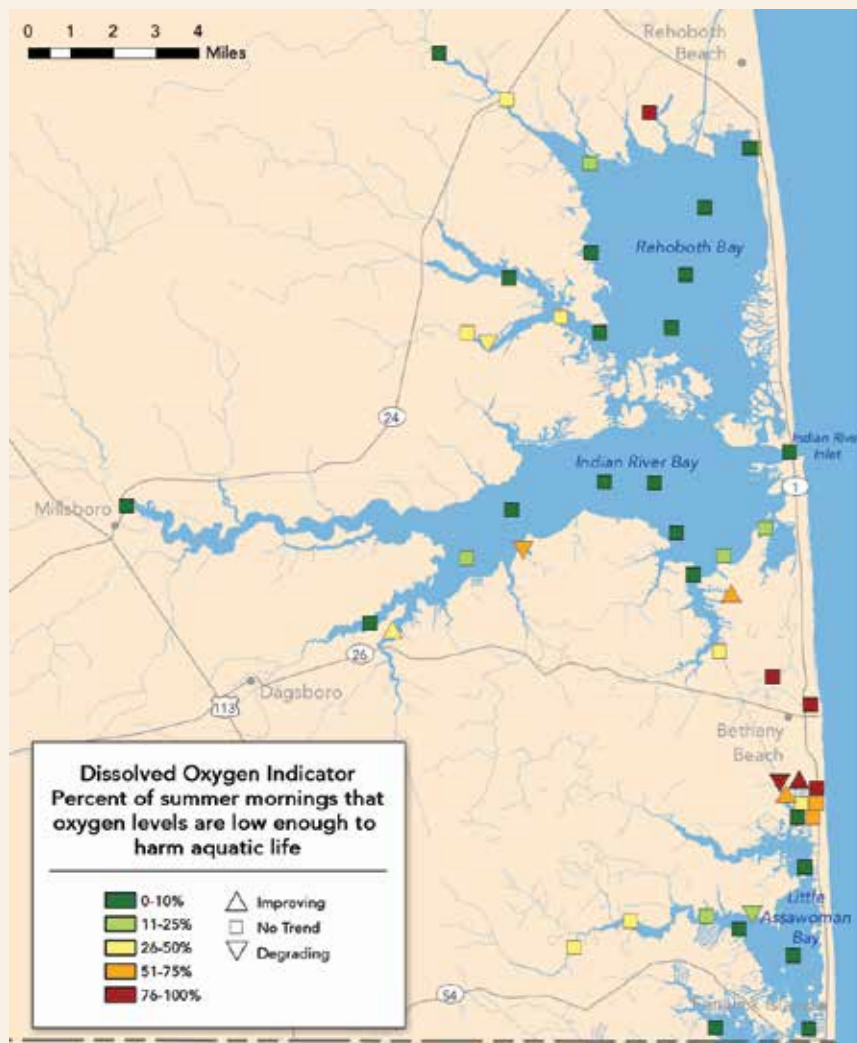
Snapshot of Continuously Monitored Dissolved Oxygen Concentrations During a Typical Period in August (2009), in Two Tidal Rivers With Contrasting Levels of Nutrient Pollution



Nutrient pollution causes oxygen levels to decrease and fluctuate wildly. This causes unsustainable oxygen levels for some fish, shellfish and invertebrates.



Diamondback terrapin Photo: Jay Fleming



### LONG-TERM TREND

Four sites have shown long-term improvement, with increasing levels of oxygen on summer mornings, while four showed decline. There are no overall trends or patterns in the location of these sites.

### CHANGE SINCE PREVIOUS REPORT

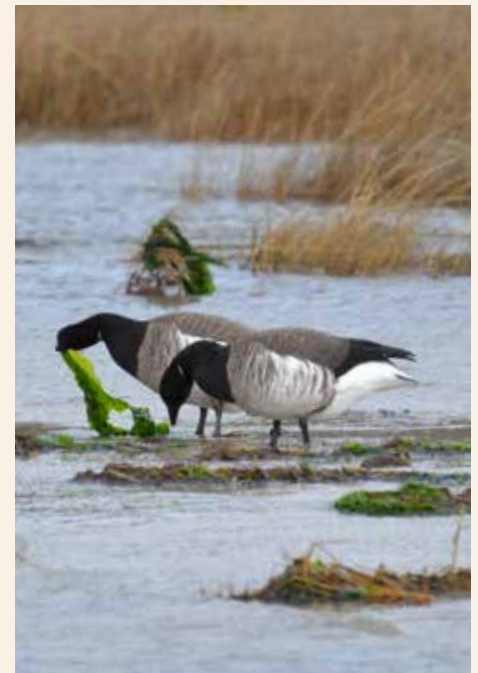
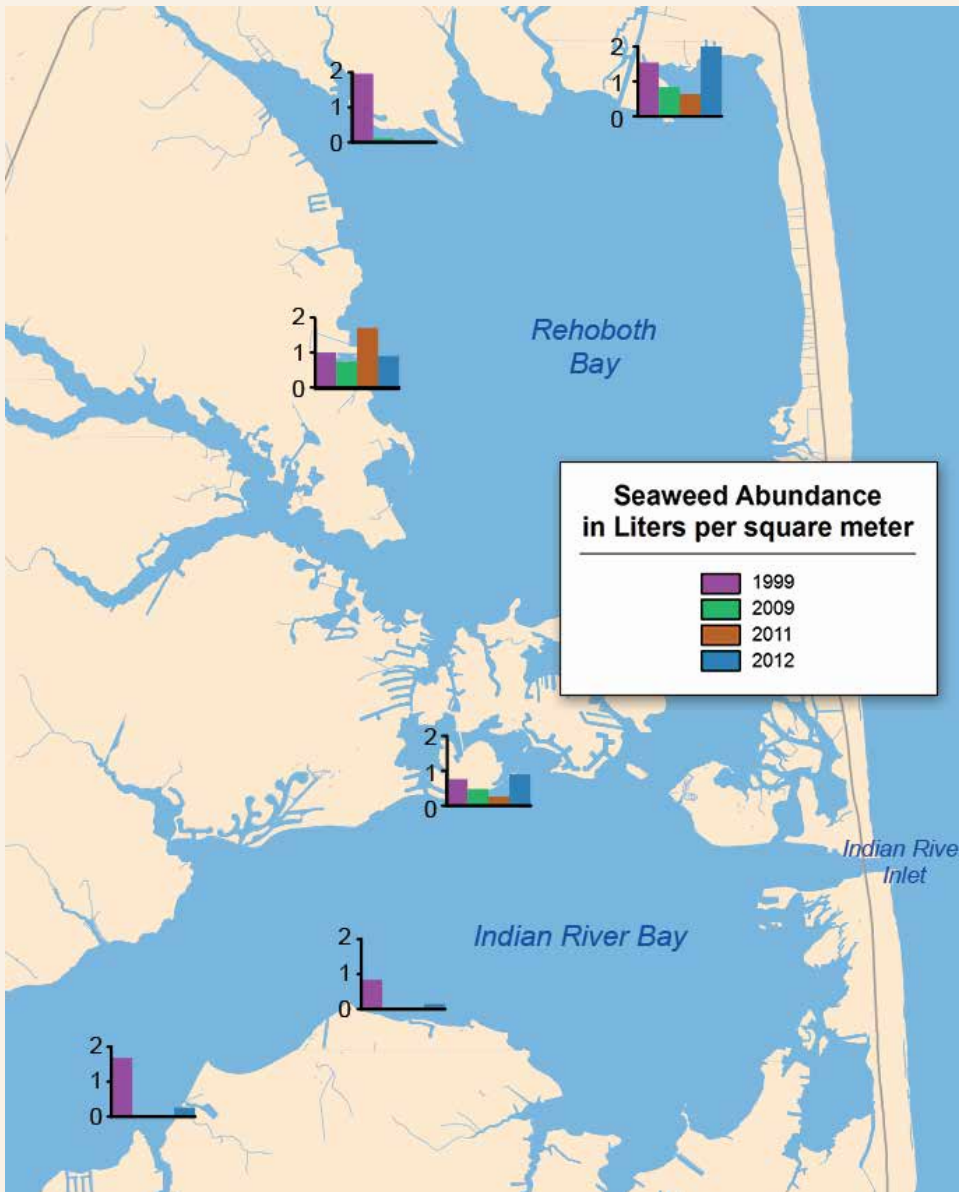
Since the previous report, dissolved oxygen has improved in the upper Indian River at Millsboro and Herring Creek. Oxygen levels in Guinea Creek are less healthy.

Oxygen levels in shallow bays naturally cycle over 24 hours. During the day, plants and algae release oxygen into the water through photosynthesis. At night, plants and animals continue to respire and draw oxygen out of the water.

## SEAWEED ABUNDANCE

Seaweeds are a natural part of the Inland Bays ecosystem. They provide food and habitat for many invertebrates, fish, and water birds.

The amount of seaweed present in the Bays is a good indicator of nutrient pollution. When nutrients are in excess, seaweeds can grow rapidly and become overabundant. This was the case in the late 1990s when seaweeds bloomed so much that they smothered shellfish, depleted oxygen, killed bay grasses, and fouled beaches. Currently fewer dense blooms occur, but levels of seaweed are still high enough to prevent bay grasses from reestablishing in many locations.



Brant eating Sea Lettuce  
Photo: Dennis Bartow



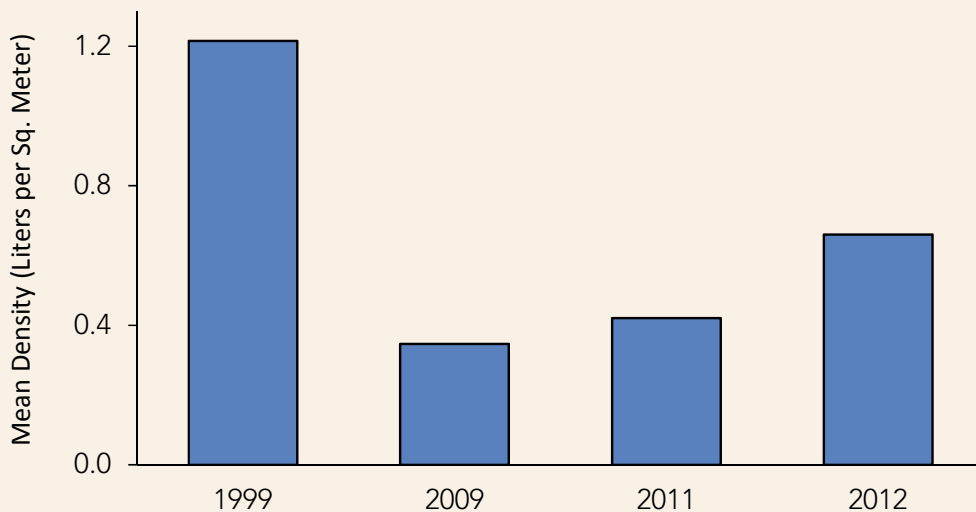
### LONG-TERM TREND

Seaweed abundance dropped significantly between 1999 and 2009, perhaps in response to decreases in phosphorus loads to the Bays.

### CHANGE SINCE PREVIOUS REPORT

On a whole, seaweed levels in the Bays remain below those seen in 1999. But densities of seaweed were relatively high at a few sites in 2012, and the overall average density may be increasing. The meaning of this is unclear, and more years of data are needed to determine if this is a trend.

Seaweed Abundance in Rehoboth and Indian River Bays



**Seaweeds provide food and habitat for many invertebrates, fish, and water birds. But when nutrients are in excess, seaweeds can grow rapidly and become overabundant.**



## LIVING RESOURCES

Abundance—or absence—of birds, fish, and shellfish in the Bays are often the most noticeable signs of environmental changes. These living resources are useful indicators of shifts in water quality, habitat, and climate; in part because they are easy for us to observe.

Since the 2011 State of the Inland Bays Report was issued, living resource indicators continue to present a mixed picture.

On the positive side, Bald Eagles and Ospreys rebounded from pesticide pollution, and the number of osprey nests continues to increase. After declines in the 1980s, the number of Black Ducks that winter here has stabilized. Hard Clam populations have been stable since 1976 and continue to support a fishery.

On the downside, numbers of wintering Brant and Canvasback in the Bays are declining. The Blue Crab population has not rebounded. Bay Anchovy populations have also declined over the years. Bay grasses remain rare in the Inland Bays, while coastal bays in Maryland and New Jersey have thousands of acres of these highly valuable habitats. Recreational fishing and its local economic benefits have decreased, likely due to the recent recession.

### Looking Ahead

Once-through cooling water withdrawal at the NRG Power Plant came to an end in 2013, along with the resulting fish and crab losses. This is expected to improve the fishery of the Indian River. Reduced nutrient inputs to the Bays should lead to future water quality improvements and, it is hoped, create conditions that allow bay grasses to re-establish.





# BAY GRASSES

Bay grass meadows create a rich underwater habitat that adds oxygen to the water, removes nutrients, and holds bay sediments in place. They provide refuge, food, and nurseries for important fish and shellfish.

The presence of bay grasses is a good indicator of water quality, since these plants need relatively clear water with low nutrients to grow and survive.

One of the most highly valued bay grasses is eelgrass. In the 1930s eelgrass declined dramatically due to disease and increasing pollution levels. By the late 1970s, eelgrass and most other bay grass species could not be found on the Bays.

Efforts to restore eelgrass beds to the Inland Bays have been unsuccessful due to nutrient pollution. In contrast, similar bays in New Jersey and Maryland continue to support thousands of acres of bay grasses.

In 2010, a meadow of Horned pondweed was discovered in the shallow waters of upper Love Creek. It prefers lower salinities and tolerates higher nutrient concentrations than eelgrass. This is the only significant area of bay grass known in the Bays.

Estimated Acreage of Known Bay Grass Beds in the Bays & Tidal Tributaries



Eelgrass off Pasture Point at James Farm

## LONG-TERM TREND

Eelgrass in the Bays has not increased.

## CHANGE SINCE PREVIOUS REPORT

Bay grasses have not been surveyed in the bays in recent years.

## LOOKING AHEAD

The hope is that improving water clarity in the Bays will eventually allow these grasses to take hold and flourish. However, destruction of forested buffers along Love Creek threaten bay grasses there.

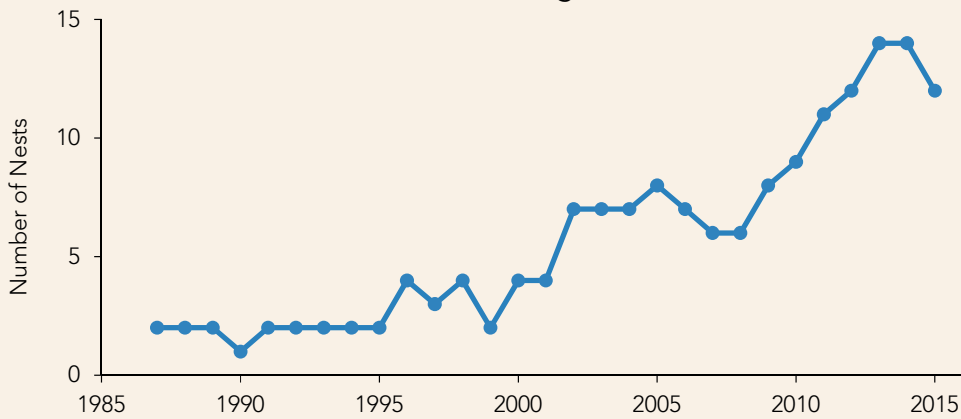
**Bay grass meadows provide refuge, food, and nurseries for important fish and shellfish.**

## EAGLE AND OSPREY NESTING

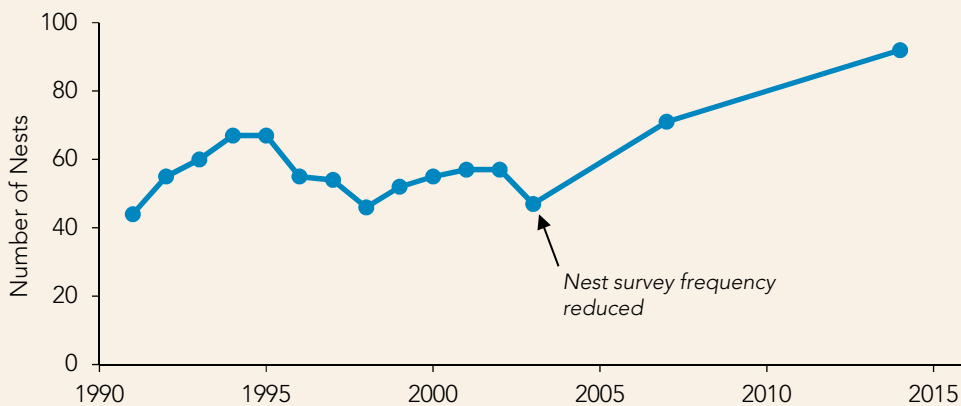
Bald Eagles and Ospreys are good indicators of environmental quality because they are at the top of the food chain. In a process called biomagnification, the birds ingest chemicals that may accumulate in the fish that they eat. The Department of Natural Resources and Environmental Control estimates Bald Eagle and Osprey populations through aerial surveys of nests.

The number of eagle nests in the Inland Bays watershed has stabilized at 12–14 each year. Ninety-two active Osprey nests were counted in 2014.

Active Bald Eagle Nests



Active Osprey Nests



Bald Eagle nesting



Osprey

### LONG-TERM TREND

Both species have rebounded significantly following the 1972 ban on use of DDT pesticides, which caused the collapse of many raptor populations due to thinning eggshells. Active nests of both Bald Eagles and Ospreys around the Inland Bays have increased over time, with a significant trend upward since the early 2000's.

### CHANGE SINCE PREVIOUS REPORT

The number of active eagle nests appears to be stable since the last report. The number of Osprey nests in the watershed increased by 30% between 2007 and 2014.

### LOOKING AHEAD

Increased development in the watershed could potentially impact eagles, as they require nesting habitat with limited disturbance. Osprey populations may continue to increase partly because they have acclimated to nesting in close proximity to human activity.

**The number of Bald Eagle nests in the Inland Bays watershed has stabilized at 12–14 each year. Ninety-two active Osprey nests were counted in 2014.**

# HARD CLAM LANDINGS

Hard Clams are harvested in the Inland Bays, both by recreational clammers and by commercial clammers. The commercial harvest is around 1 million clams per year, all from Rehoboth and Indian River Bays (landings). In 2016, there were 54 licensed commercial clammers.

Clams improve water clarity by filtering suspended particles from the water. Bay bottoms composed of shell or sandy mud support the highest densities of Hard Clams.

## LONG-TERM TREND

Commercial landings of Hard Clams in the Bays peaked at over 18 million in the mid-50s, when disease began decimating the oyster industry. The fishery has since declined due to the combined effects of over-harvesting and closure of harvest areas. Fifty-four commercial clamming licenses were issued in 2016.

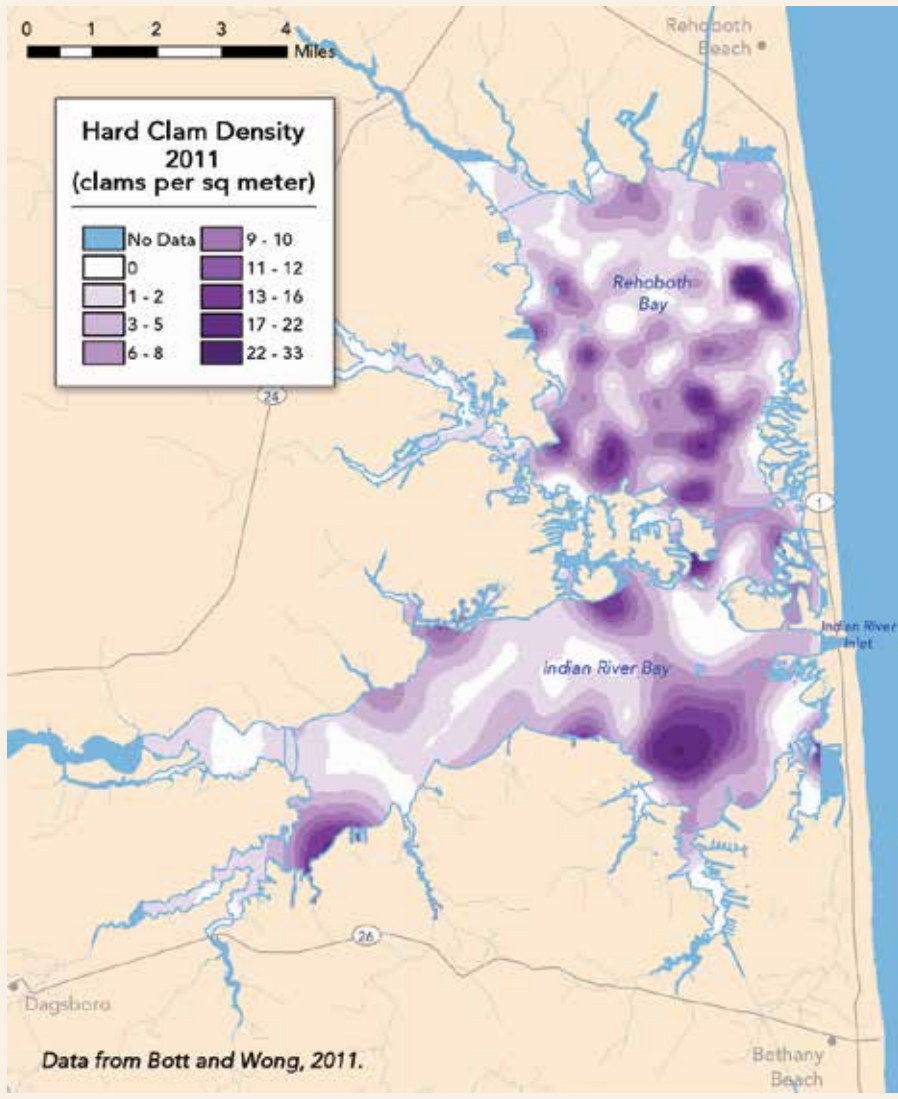
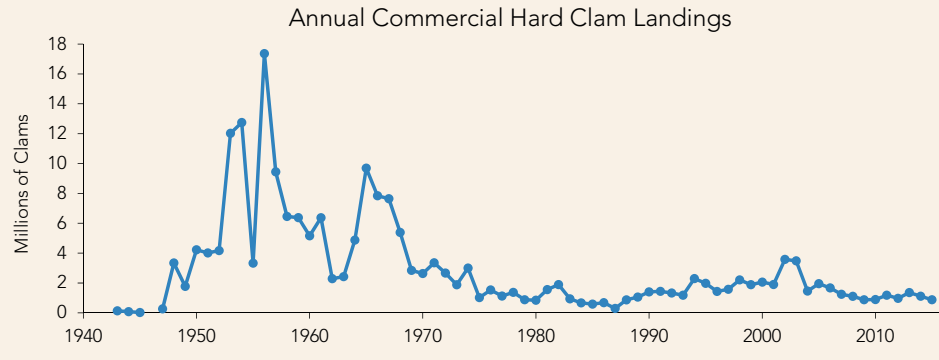
A 2011 study by the CIB and the Department of Natural Resources and Environmental Control found that clam densities have remained stable since 1976, with Rehoboth Bay showing the highest densities.

## CHANGE SINCE PREVIOUS REPORT

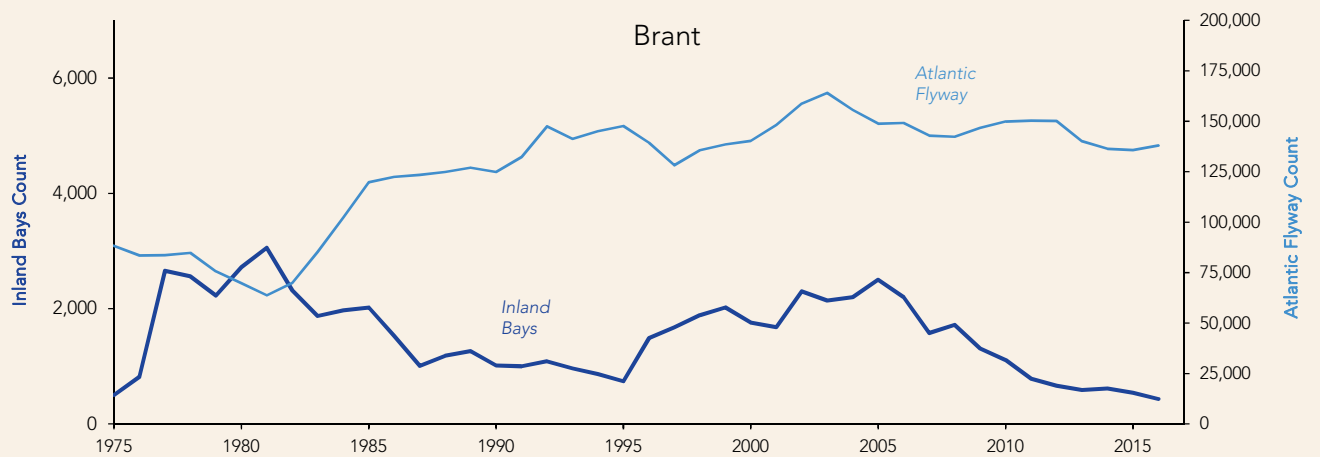
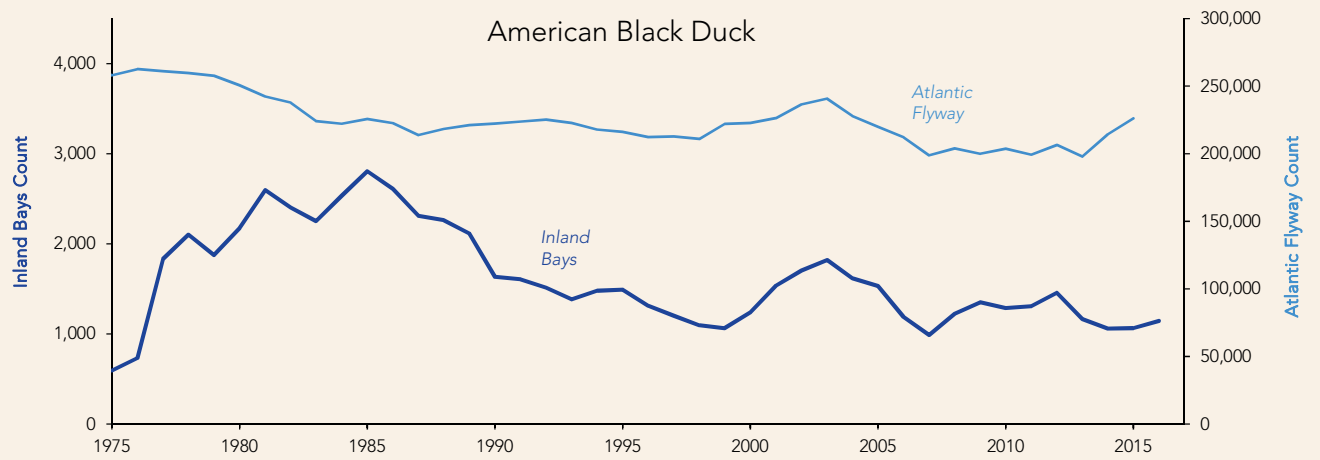
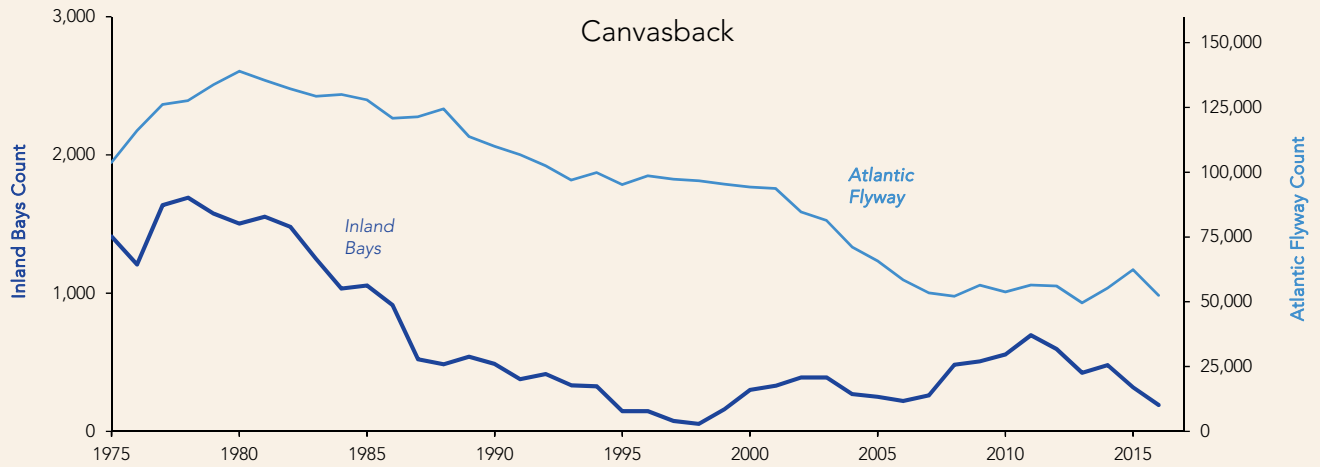
Clam landings have remained stable over the past five years.

## LOOKING AHEAD

Future water quality improvements in the Bays may allow the opening of more areas for harvest and increase pressure on the population from both commercial and recreational clammers.



**The commercial clam harvest is around 1 million clams per year.**



## WINTER WATERFOWL

Tens of thousands of wintering ducks, geese, and swans depend upon the Bays' wetlands, waters and nearby fields for survival. Observing and hunting these winter visitors are activities important to the local culture and economy.

Waterfowl populations are counted through aerial surveys conducted along the entire Atlantic Flyway in early January.

Comparing local counts of sensitive waterfowl species to counts from the Atlantic Flyway can help us understand the responses of waterfowl to changes in the Bays. Hunting pressure, weather patterns and changes in habitat at northern breeding grounds also influence the numbers of migratory waterfowl found on the Bays in winter.

Since the early 1970's, at least 29 species of waterfowl have been observed in the Bays during these surveys. Nearly 15,000 individuals of 14 species were counted in 2016.



### CANVASBACK

Historically, the Bays' marshes and bay grass meadows supported large numbers of wintering Canvasback ducks, a species prized by hunters. After increasing somewhat after 2005, Canvasback numbers on the Bays are again very low.



### AMERICAN BLACK DUCK

The Inland Bays watershed hosts both year-round and migratory winter populations of Black Ducks. Atlantic Flyway numbers decreased sharply beginning in the mid-twentieth century. Reasons for the decline are thought to include loss of marsh habitat, as well as

hunting pressure and interbreeding with mallards. Data suggest that since 2007, both local and regional wintering populations have stabilized.



### BRANT

Brant winter in coastal environments where eelgrass is a staple of their diet. In the 1930s, a sudden die-off of eelgrass along the Atlantic coast led to a collapse of the Brant population. Since then, Brant adapted their diets to include other foods—such as

sea lettuce, salt marsh cordgrass, and lawn grass—and Atlantic Flyway populations have stabilized. However, Inland Bays populations remain low and continue to decline.

### LOOKING AHEAD

Waterfowl hunting season dates and harvest limits in Delaware follow recommendations of the U.S. Fish and Wildlife Service, and are revised annually based on Atlantic Flyway, not state, counts. The most important actions for retaining species such as Canvasbacks and Brant in the Bays are wetlands protection and improving water quality to allow regeneration of underwater bay grasses.

Climate change will increasingly impact northern waterfowl breeding habitats and/or migration patterns.

**Tens of thousands of wintering ducks, geese, and swans depend upon the Bays' wetlands, waters and nearby fields for survival.**

## OYSTER ENHANCEMENT

A healthy oyster population provides tremendous ecological benefits in an estuary. One adult oyster can filter up to 50 gallons of water per day to greatly improve water clarity. Oysters build reef ecosystems that are hotspots of nitrogen removal and desirable habitat for dozens of other bay species.

Oyster reefs used to be common around the Bays, and a healthy commercial fishery existed until disease devastated the population in the 1950s. Today, wild oysters are rare, but studies show that they are reproducing in some areas of the Bays.

For more than a decade, volunteer oyster gardeners have grown oysters in floating cages to be used in restoration projects. This program has demonstrated that oysters grow successfully throughout the Bays. Interest in the economic and environmental potential of aquaculture led to passage of a bill in 2013 that once again allows oyster and clam farming on the Inland Bays.

In 2016, two thousand bushels of oyster shell were collected from local restaurants by the CIB's "Don't Chuck Your Shucks" program. The recycled shell will be used to build living shorelines and offshore reefs. The CIB is also researching the effectiveness of floating oyster cages to improve residential canals.

Bagged oyster shell headed for the Loop Canal Living Shoreline Demonstration Project on Salt Pond

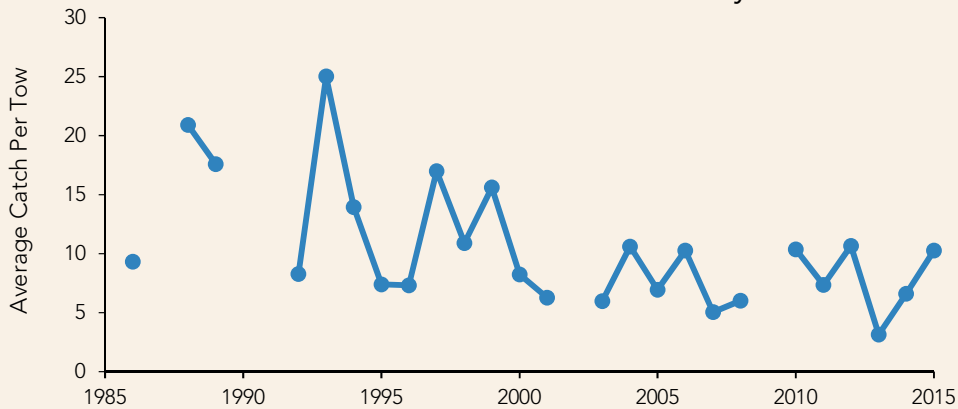


# BLUE CRAB ABUNDANCE

Blue Crabs are a summer delicacy in Delaware, and crabbing is popular with local residents and vacationers. Blue Crabs play a key role in the ecology of the Inland Bays, where they are an important link in the food chain. Crabs are scavengers and predators, eating live or dead fish, clams, snails, and aquatic vegetation. In turn, they provide food for birds, fish, and terrapins.

Populations of crabs in the Bays vary from year to year, partly in response to the severity of winter temperatures. But other factors such as bay grass density, oxygen levels, predators, and harvest pressure also influence populations.

Blue Crabs in Rehoboth & Indian River Bays



Herring gull with Blue crab Photo: John A. Fritchey

## LONG-TERM TREND

Annual trawl surveys conducted in Rehoboth and Indian River Bays have shown a long-term decrease in the average catch of crabs per tow from 1986 to the mid-2000's. Reasons for this decline are uncertain.

## CHANGE SINCE PREVIOUS REPORT

Blue Crab populations in the Bays have remained low the past five years, with no trend.

## LOOKING AHEAD

The elimination of once-through cooling water at the NRG power plant in 2013 was expected to boost crab numbers in the Indian River, but data do not yet support this.

**Crabs are scavengers and predators, eating live or dead fish, clams, snails, and aquatic vegetation.**

## FISH ABUNDANCE

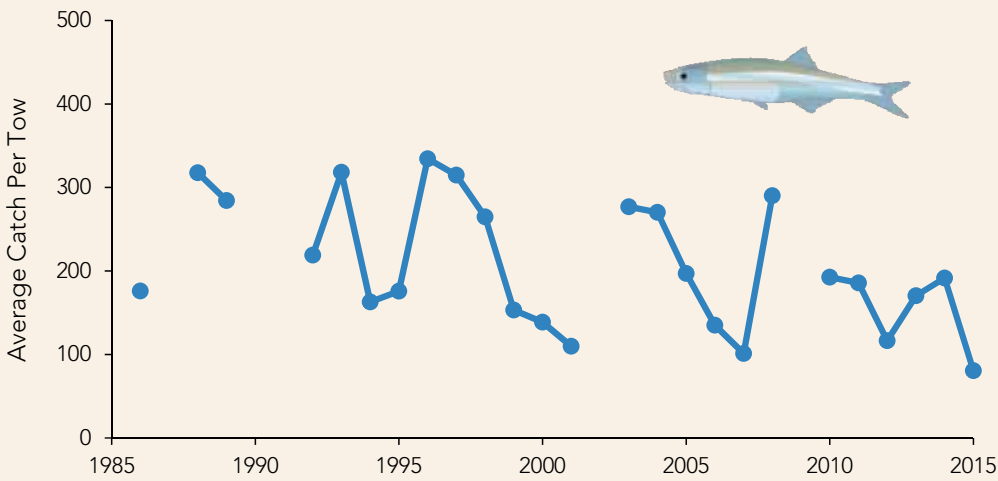
Over a hundred species of fish live, feed and grow in the Inland Bays. The Bays' shallow waters and wetlands offer protection, and serve as nurseries for species valued by recreational anglers and commercial fisheries.

The Department of Natural Resources and Environmental Control conducts annual trawl surveys at twelve open water locations on the Inland Bays to assess fish populations. Trends in the number of fish caught may indicate changes in the environment of both the Bays and nearby coastal waters of the Atlantic Ocean.

In 2015 surveys, 43 species of finfish were recorded. Bay Anchovy, Atlantic Silverside, Silver Perch, and Weakfish comprised over 80% of the catch.

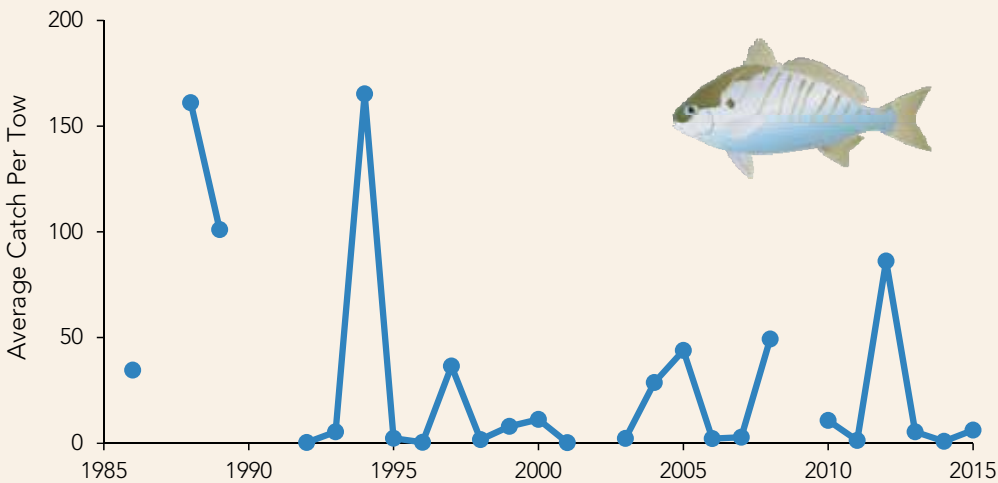
Top right: Pufferfish  
 Bottom right: Shorezone  
 Fish Survey volunteers  
 sorting their catch  
 Photos: Dennis Bartow

### Bay Anchovy



Bay Anchovy are the most plentiful fish caught in the trawl survey. Using the bays to grow and feed from spring through fall, this silvery forage fish is a critical link in the food chain between plankton and bigger fish. Numbers of Bay Anchovy are declining in the Bays.

### Spot



Used for both bait and food, Spot are an important species in the Inland Bays. Because the Bays are at the northern range of this species' distribution, the population here is subject to large fluctuations influenced by the currents and weather of a particular year.





### LONG-TERM TREND

Large year-to-year differences in the abundances of many species are common. Bay Anchovy has declined significantly over the past 30 years. The population of summer flounder has remained relatively stable in the Bays.

### CHANGE SINCE PREVIOUS REPORT

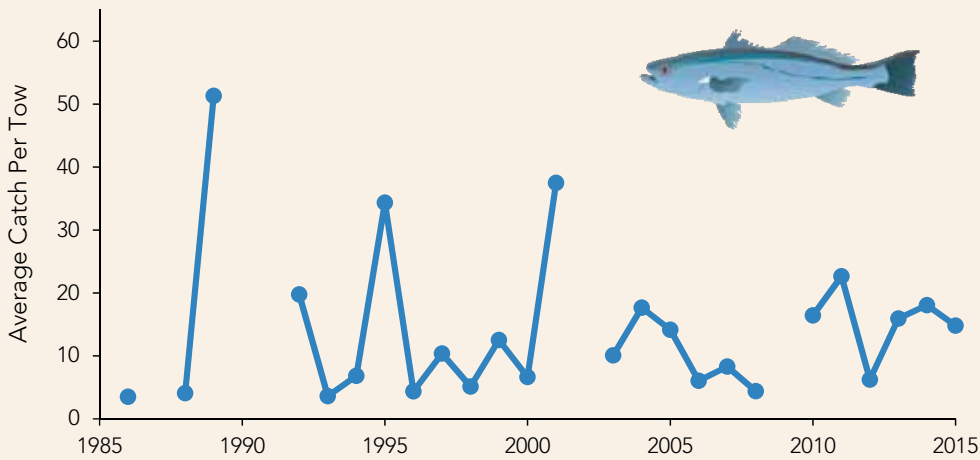
Abundance of Bay Anchovy continued to decrease slowly. Other species showed little change.

### LOOKING AHEAD

Protection of wetlands and shore-zone habitat in the Bays will be critical to maintain populations of species that use these areas. Long-term reductions in algae blooms in the Bays should lead to improved oxygen levels that will benefit young fish, particularly in tributaries. Spot appear to be moving northward along the Atlantic coast in response to climate change, and this may stabilize numbers of this fish in the Bays.

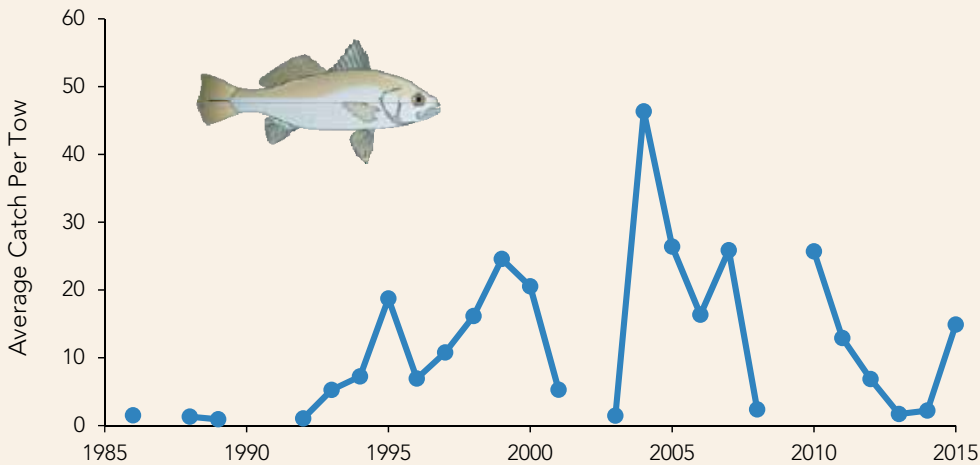
**Over a hundred species of fish live, feed and grow in the Inland Bays.**

### Weakfish



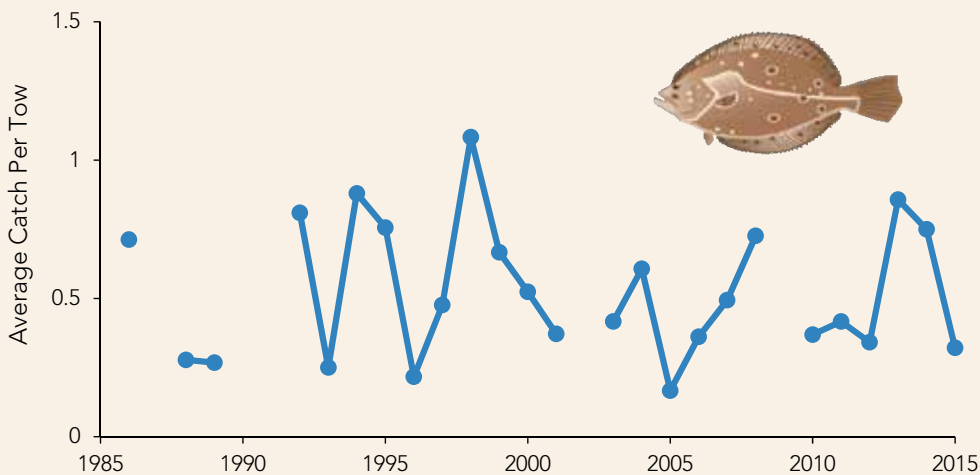
Weakfish spawn in and near the Bays. Juveniles concentrate in tidal creeks where they feed and then migrate offshore in the fall. Formerly plentiful, Weakfish populations dramatically decreased in the late 1980's and early 1990's. Recovery has been slow, and the low survival of adults seen in the mid-Atlantic region is not fully understood.

### Silver Perch



Silver Perch are a lesser known fish that have increased in abundance since the 1990s. In spring and summer, they spawn in the Bays where the young grow from two to six inches before migrating offshore in late fall.

### Summer Flounder



Summer Flounder support a significant recreational fishery in the Inland Bays, annually ranking among the top five in recreational landings. Young fish feed in the shore zone and move into the deeper waters of the estuary as they grow. Numbers have not changed over time.

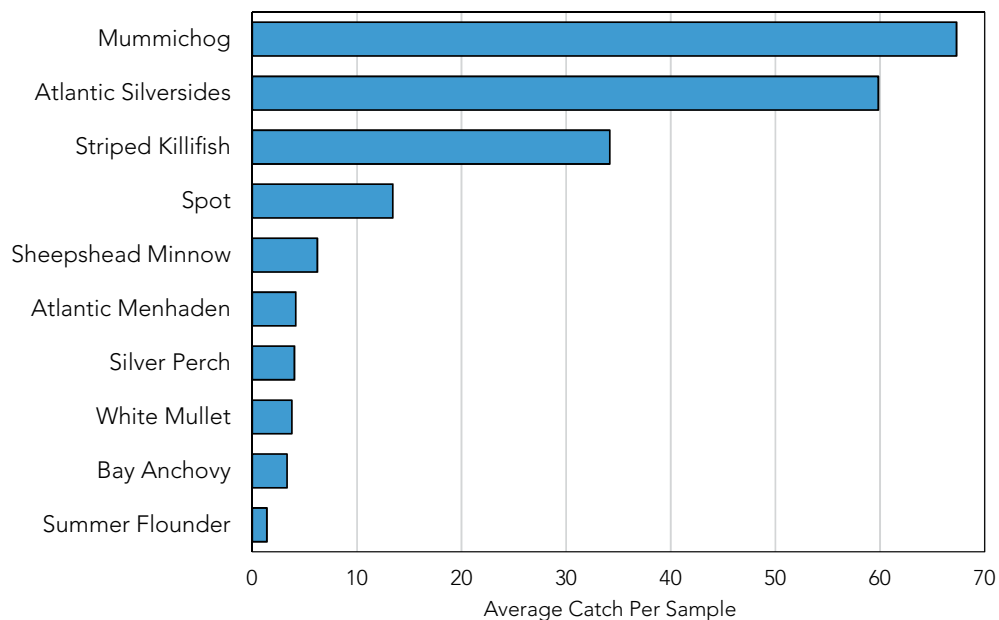
## SHORE-ZONE FISH

The CIB conducts a volunteer survey of fish and Blue Crab populations in the shallow waters near shorelines. These productive areas support high densities of small fishes.

The composition of fish communities in the shore-zone can be an indicator of water quality and habitat quality. Menhaden, Bay Anchovy, and Spot, for example, are sensitive to low oxygen resulting from nutrient pollution. Striped Killifish, Mummichog, and Sheepshead minnow have a higher tolerance for low oxygen levels.

Shore zone fish communities in the Bays were once dominated by oxygen-sensitive species. In the late 20<sup>th</sup> century, however, poor water quality caused Mummichog and Sheepshead Minnow to dominate. Current levels of Spot, Menhaden, and Bay Anchovy in nearshore areas may be a sign of improving conditions in the Bays.

Most Abundant Shore-Zone Fish  
2011-2015



Shorezone Fish Survey volunteers seining  
Photo: George Rosenberg

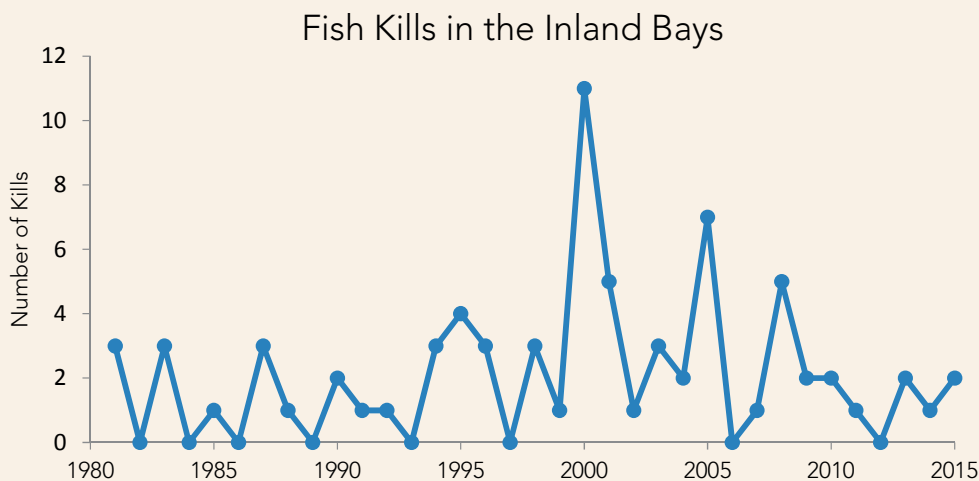


## NUMBER OF FISH KILLS

Fish kills are an indicator of stress in the bay environment, usually caused by a combination of nutrient pollution and weather conditions. Nutrient pollution stimulates algae blooms that can cause oxygen levels to drop low enough to kill fish.

Most fish kills happen in summer when there are abundant algae, high temperatures, low oxygen, and high numbers of fish. The majority of kills in the Bays involve Atlantic Menhaden, which feed in large schools where algae is plentiful.

Roughly 60% of fish kills occurred in tidal creeks and rivers and 40% occurred in residential canals and lagoons.



### LONG-TERM TREND

The number of fish kills investigated by the Department of Natural Resources and Environmental Control varies greatly from year to year. More were reported in the 2000s, but there has been no significant trend over time.

### CHANGE SINCE PREVIOUS REPORT

One to two fish kills continue to be reported annually in the Bays. Those reported in the past five years have included juvenile menhaden, but in smaller numbers per incident than in the past.

### LOOKING AHEAD

Water quality improvements that have reduced algae concentrations should lead to fewer incidents of fish kills caused by low dissolved oxygen.



Menhaden fish kill on canal.

**Most fish kills happen in summer when there are abundant algae, high temperatures, low oxygen, and high numbers of fish.**

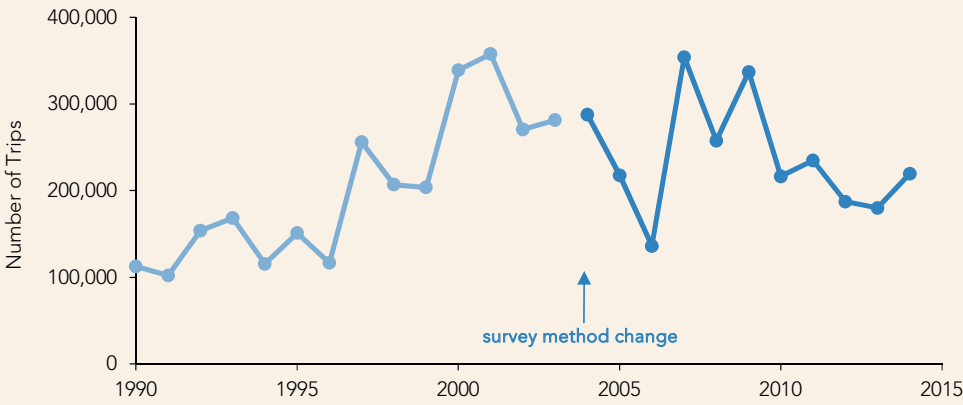
# RECREATIONAL FISHING

The Bays offer a multitude of opportunities to reel in fish. Recreational fishing also boosts the local economy—spending in Delaware was over \$165 million in 2014.

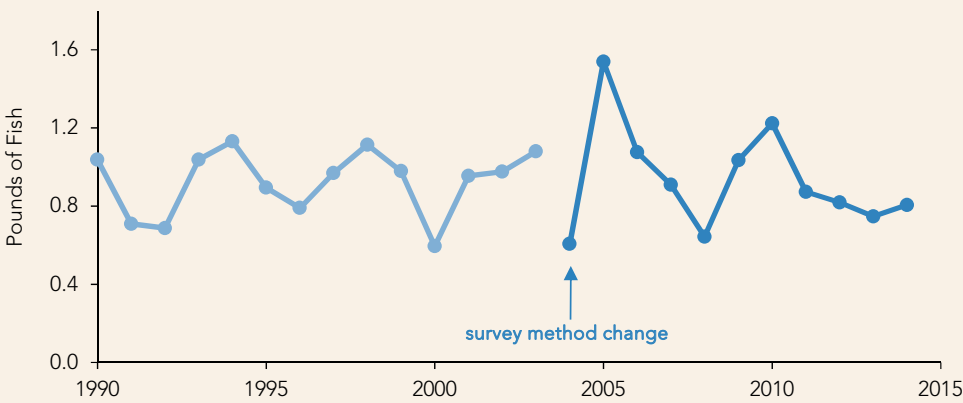
The number of recreational fishing trips and total catch from the Inland Bays are estimated through angler surveys. They indicate trends in fishing, prevalence of adult fish, and maybe skill of the anglers.

Currently over 200 thousand fishing trips are made each year in the Bays, reeling in an estimated 176 thousand pounds of fish.

Number of Fishing Trips Per Year



Pounds of Fish Caught Per Trip



Note: In 2004, the method used to estimate recreational catch was revised by the National Oceanic and Atmospheric Administration.

## LONG-TERM TREND

Fishing trips in the Bays increased over the 1990s into the 2000s, and then declined back to mid-1990s levels over the last eight years. Catches of recreationally important fish generally reflect this decline. Pounds of fish caught per trip has changed little over the last 25 years.

## CHANGE SINCE PREVIOUS REPORT

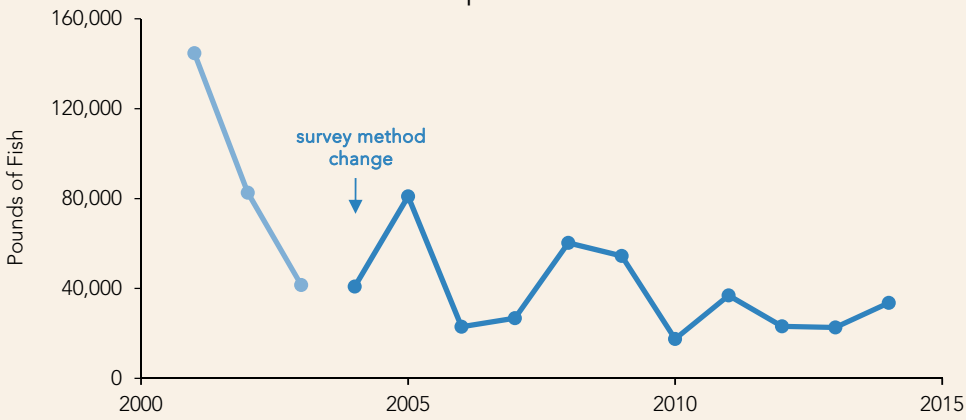
The decline in fishing since the last report mirrors regional and national decreases. The effects of the economic recession on personal income and leisure time are likely responsible. Fish population changes, such as the crash of adult weakfish, and potential shifts in species distributions to cooler waters further north and offshore also have an influence on catches.

**Recreational fishing spending in Delaware was over \$165 million in 2014.**

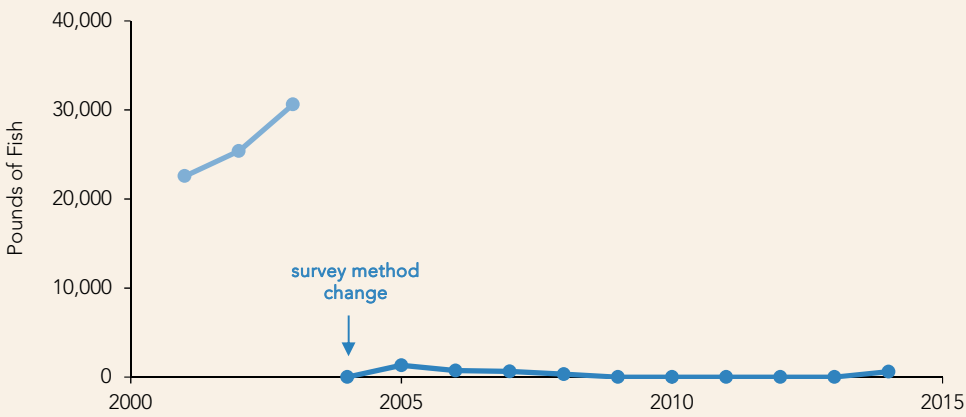
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# RECREATIONAL FISHING

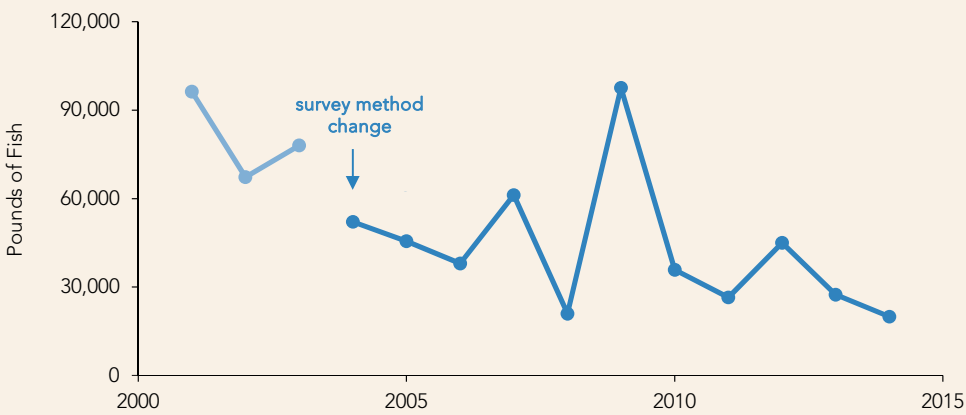
### Striped Bass Catch



### Weakfish Catch



### Summer Flounder Catch



## HUMAN HEALTH RISKS

Water recreation and eating fresh seafood are some of the great joys of living on the coast; however, there is reason for caution when using many areas of the Inland Bays.

Pathogens—illness causing bacteria, viruses, and parasites—can enter water from many sources, including waste from wildlife, humans, and domestic animals. Some bacteria that occur naturally in the Bays also can be pathogenic. Exposure to these pathogens through water contact may cause acute gastrointestinal illness or infect open wounds. People may also be exposed to pathogens by eating contaminated shellfish.

The open waters of the Inland Bays are generally safe for recreational contact such as swimming. However more poorly flushed tributaries and canals regularly fail to meet safe swimming standards.

Currently 61% of the Inland Bays are approved for shellfishing year-round—down 1% since the previous report. An additional 3.6% of Bay waters were moved from seasonally-approved to prohibited status.

Chemical contaminants from a variety of industrial, urban, and agricultural sources can also enter surface waters, where they accumulate in fish. Mercury and polychlorinated biphenyls (PCB's) have been identified as 'contaminants of concern' present in migratory Bluefish and Striped Bass caught in the Inland Bays, though the chemicals likely are picked up elsewhere. Both species are currently under consumption advisories.

### Looking Ahead

Concentrations of PCBs and mercury in fish are expected to decrease slowly but it may be decades before consumption advisories are lifted.

Removal of the Rehoboth Beach Wastewater Treatment Plant discharge scheduled for 2018 may allow reopening of some waters closed to shellfishing near the Lewes-Rehoboth Canal.



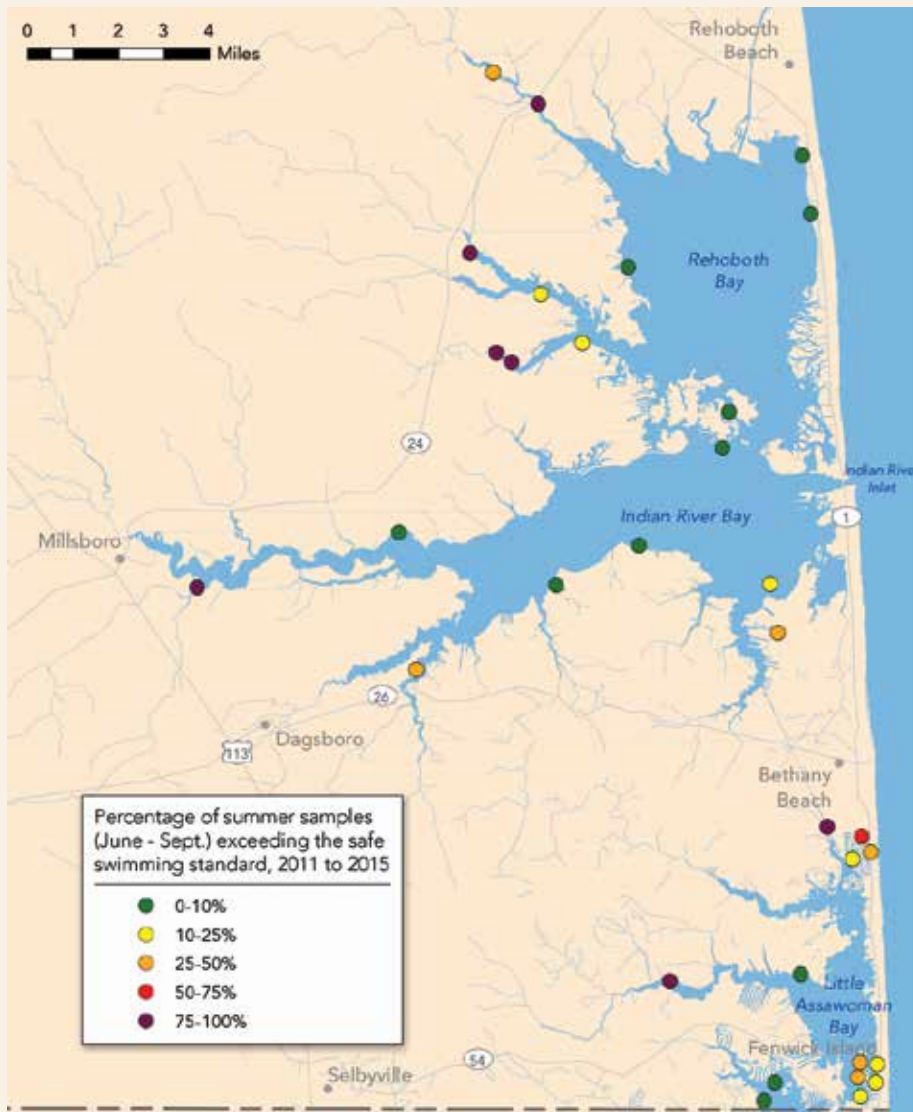
## BACTERIA POLLUTION

Most bacteria in the Bays are harmless to humans. But harmful bacteria, viruses, and parasites (pathogens) may be introduced by pollution, especially from human or animal feces. Some bacteria that live naturally in the Bays may also cause infection, particularly in people with compromised immune systems.

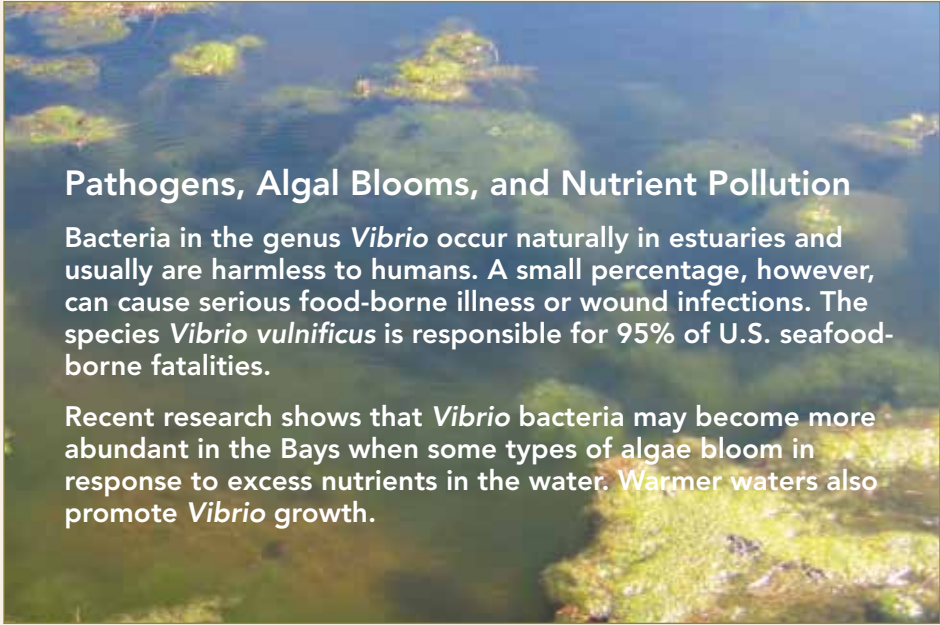
Bacteria of the genus *Enterococcus* are used as indicators of fecal contamination because they are found in the intestinal tracts of warm-blooded animals. High numbers of *Enterococcus* bacteria in water indicate that pathogens might also be present and pose a health risk to recreational users.

Bay waters are tested regularly for levels of *Enterococcus*. The concentrations measured are compared to both a single-sample safe swimming standard of 104 colonies/100 milliliters of water, and a long-term mean standard of 35 colonies/100 milliliters.

Summer samples collected from 2011 to 2015 show that the majority of open bay waters meet the single-sample safe swimming standard over 90% of the time, indicating these areas are usually safe for recreation. Most tributary sites exceed the safe swimming standard more than 75% of the time, demonstrating that these areas are frequently unsafe for recreation.







## Pathogens, Algal Blooms, and Nutrient Pollution

Bacteria in the genus *Vibrio* occur naturally in estuaries and usually are harmless to humans. A small percentage, however, can cause serious food-borne illness or wound infections. The species *Vibrio vulnificus* is responsible for 95% of U.S. seafood-borne fatalities.

Recent research shows that *Vibrio* bacteria may become more abundant in the Bays when some types of algae bloom in response to excess nutrients in the water. Warmer waters also promote *Vibrio* growth.



### LONG-TERM TREND

Of the twelve stations that have long-term data, two (Pasture Point and the mouth of Love Creek) have had significantly increasing bacteria levels. Other areas show no trend.

### CHANGE SINCE PREVIOUS REPORT

Concentrations of fecal indicator bacteria remain similar to those reported previously. Canals and tributaries continue to exceed the long-term maximum safe swimming standard, while open bay waters have consistently safe levels of *Enterococcus*.

### LOOKING AHEAD

In healthy bays, many fecal indicator bacteria come from wildlife, rather than human sources. More research is needed to determine sources of fecal bacteria in order to develop management practices that reduce public health risks.

**Disease-causing microorganisms can come from many sources—malfunctioning septic systems, manure, pet waste, wildlife, sewage from boats, and stormwater runoff.**

WATERSHED CONDITION

NUTRIENT POLLUTION

WATER QUALITY

LIVING RESOURCES

HUMAN HEALTH RISKS

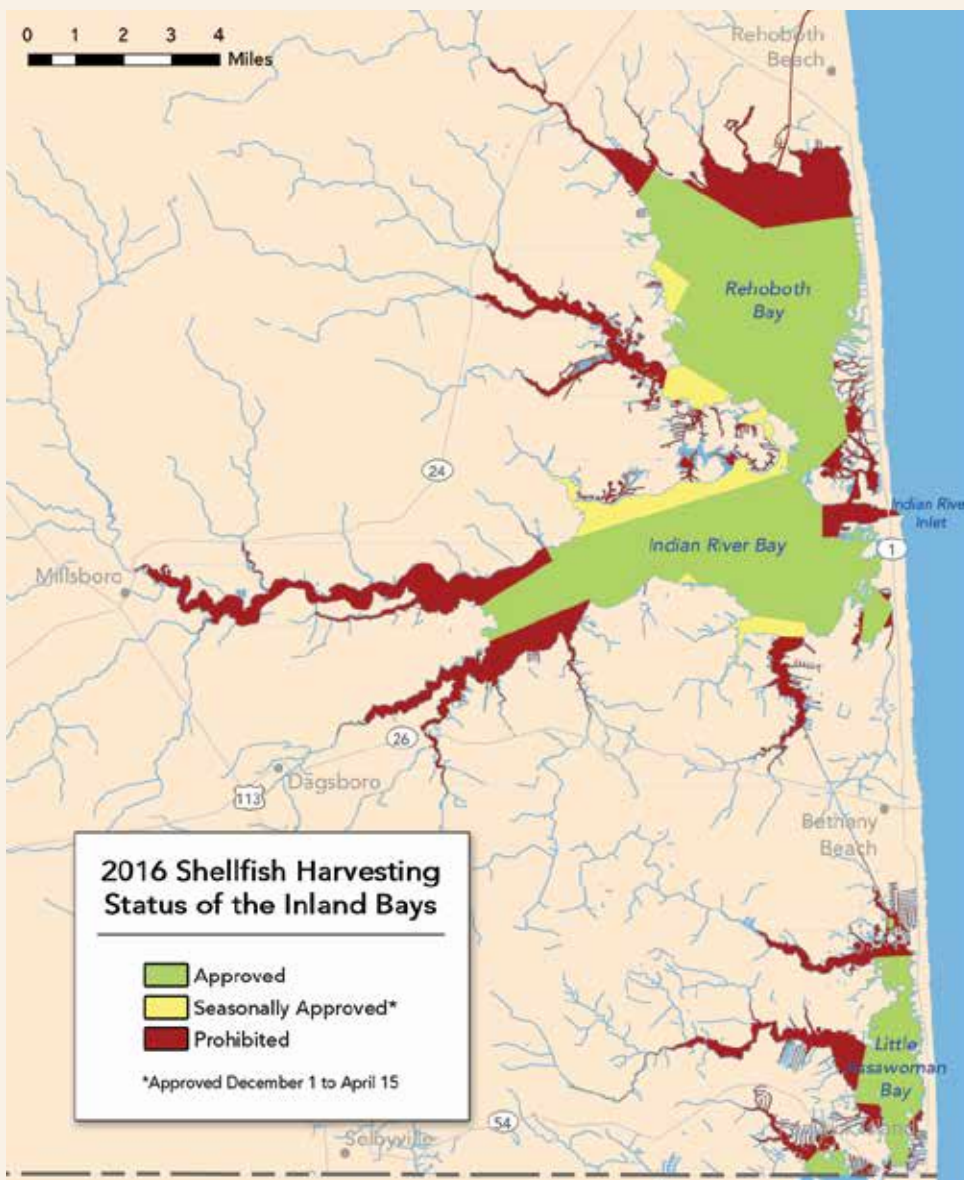
CLIMATE

## APPROVED SHELLFISH GROWING WATERS

Clams, oysters and mussels are filter feeders and can accumulate bacteria, viruses and other pollutants as they feed. The risk of illness from consuming contaminated shellfish is much greater than from other seafood because shellfish are frequently eaten raw.

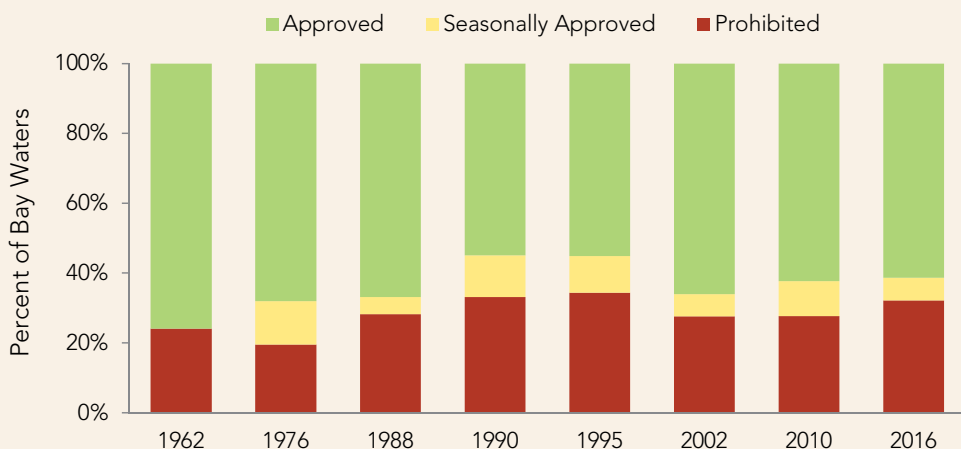
The Department of Natural Resources and Environmental Control determines approved shellfishing areas based primarily on proximity to potential pollution sources such as wastewater discharges and marinas.

In 2016, the harvest of shellfish was prohibited in 32% of the Inland Bays. An additional 7% were approved for harvest only seasonally (December to April).



"Oysters" by Jeffrey Vary/CC BY 2.0

### Shellfishing Area Designation Changes



### LONG-TERM TREND

Construction of marinas and elevated bacteria concentrations led to an increase in prohibited and seasonally-approved areas between 1960 and 1990. Some previously prohibited areas were reopened in the early 2000's; however, this trend has reversed.

### CHANGE SINCE PREVIOUS REPORT

Since 2011, 1,042 acres of approved or seasonally-approved waters were reclassified as prohibited. This included a portion of Love Creek; the northeastern corner of Rehoboth Bay also was closed because of increased flow rates at the Rehoboth Wastewater Treatment Plant.

### LOOKING AHEAD

Portions of Rehoboth Bay may be reopened for shellfishing when the Rehoboth Wastewater Treatment Plant's discharge is removed in 2018.



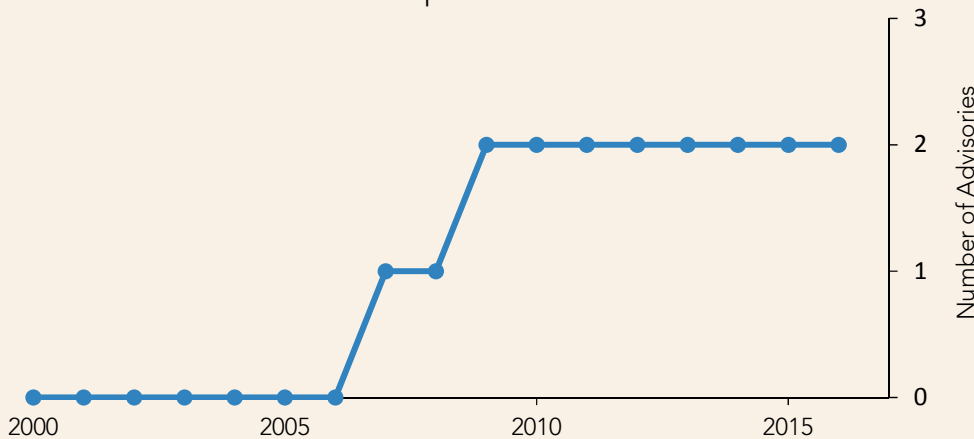
**The risk of illness from consuming contaminated shellfish is much greater than from other seafood because shellfish are frequently eaten raw.**

## FISH CONSUMPTION ADVISORIES

Consumption advisories are in effect for Bluefish and Striped bass caught in the Inland Bays, due to elevated concentrations of polychlorinated biphenyls (PCBs) and mercury. An advisory is a recommendation to limit consumption to specified quantities, species, and sizes of fish to minimize the risk from contaminants. These migratory fish may pick up the contaminants outside of the Bays.

PCBs are organic chemicals now banned from manufacture, but they still persist in the environment. Mercury continues to enter the environment from many sources, including the burning of fossil fuels. Their accumulation in fish depends on the species, size, age, and feeding area of the fish. Both contaminants have negative effects on the health of people including neurological and developmental disorders.

Number of Inland Bays Fish Species with Consumption Advisories



### LONG-TERM TREND

Consumption advisories were first issued for Bluefish beginning in 2007 and for Striped bass in 2009.

### CHANGE SINCE PREVIOUS REPORT

Both species remain under advisory in the Inland Bays.

### LOOKING AHEAD

It is projected that there will be slow, continued improvement in PCB levels in these fish. Reduced emissions from coal-fired power plants should bring about declines in mercury levels. However, it may be decades before consumption advisories change.



**Consumption advisories currently are issued for Bluefish and Striped bass caught in the Inland Bays, due to elevated concentrations of polychlorinated biphenyls (PCBs) and mercury.**

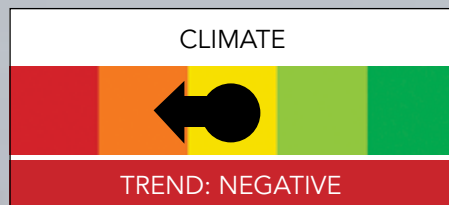
## CLIMATE

Global emissions of greenhouse gases are bringing about higher temperatures, longer growing seasons, and rising sea levels. These changes influence everything from the chemistry of bay water to the location and distribution of ecosystems like saltmarshes and bay grass meadows. The timing and degree to which migratory fish and birds use the estuary may change; species of plants and animals may shift in favor of those that prefer or tolerate warmer weather.

Increasing heat is a significant concern. The growing season will continue to lengthen, and heat waves are expected to become more extreme. As a result, the Bays will likely be warmer for a longer period each year. While no changes in average annual precipitation have been observed, increasing frequency of droughts and floods may be occurring and are projected. This could increase the transport of nutrients to the Bays, which can lead to conditions that create oxygen-depleting algal blooms.

### Looking ahead

The State of Delaware has taken action to address climate change through the signing of Executive Order 41 in 2013. This order directs state agencies to address both the causes and consequences of climate change by developing actionable recommendations to reduce greenhouse gas emissions that contribute to climate change, increase resilience to climate impacts, and avoid and minimize flood risks due to sea level rise. While full implementation of this directive will result in reduced greenhouse gases, emissions must be reduced worldwide to make an impact.



# CARBON DIOXIDE CONCENTRATION AND AIR TEMPERATURE

Greenhouse gases act like a blanket around the earth, trapping heat in the atmosphere. Carbon dioxide, an abundant and powerful greenhouse gas, is produced from burning fossil fuels. Its presence is a good indicator of global climate change.

Global atmospheric carbon dioxide is measured at Hawaii’s Mauna Loa Observatory, located in a remote area far from industry and urban traffic. Levels increased from 315 parts per million (ppm) in the late 1950s to 402 ppm in 2015.

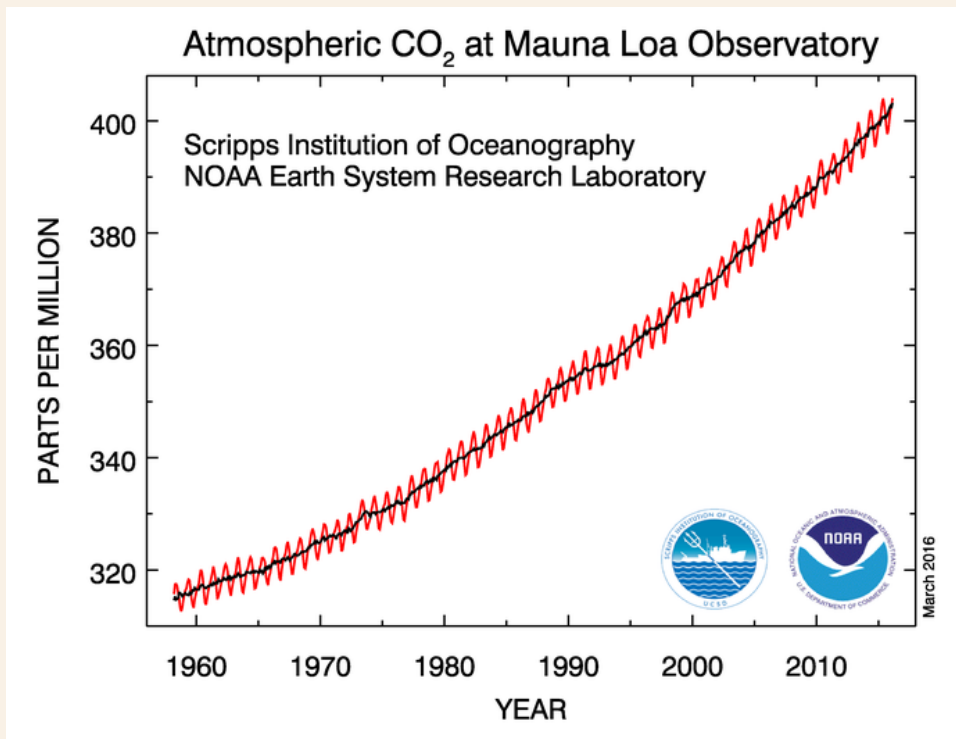
Over the same time period, average annual air temperatures in Delaware have also risen by about two degrees Fahrenheit. Warmer air means warmer water, especially in shallow waters such as the Inland Bays.

## CHANGE SINCE PREVIOUS REPORT

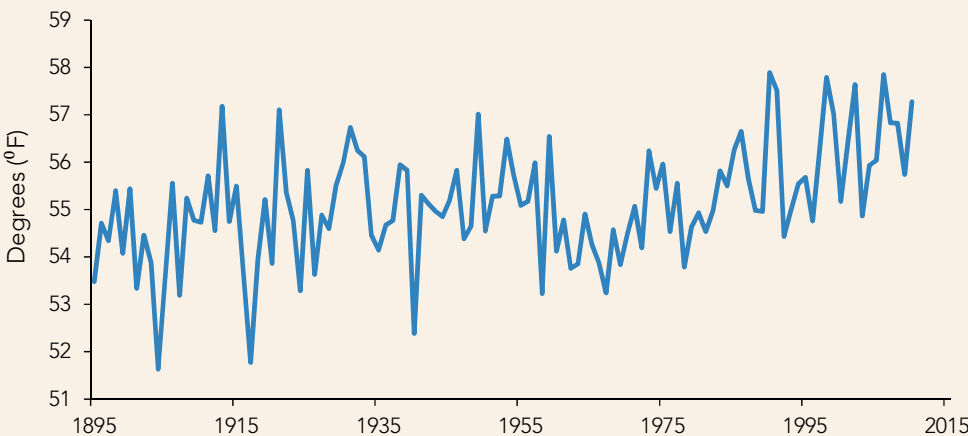
Global atmospheric carbon dioxide levels continue to increase, rising 4% from 390 ppm in 2010 to 402 ppm in 2015.

## LOOKING AHEAD

Global greenhouse gas emissions are projected to increase in the future unless actions are taken to reverse the trend. Climate models suggest that average summer air temperature in southern Delaware could increase eight degrees Fahrenheit by the end of the century. Delaware has taken statewide action to address this global problem by decreasing its total greenhouse gas emissions by 30% between 2000 and 2010—the most of any state in the US.



Average Annual Air Temperature in Lewes, DE



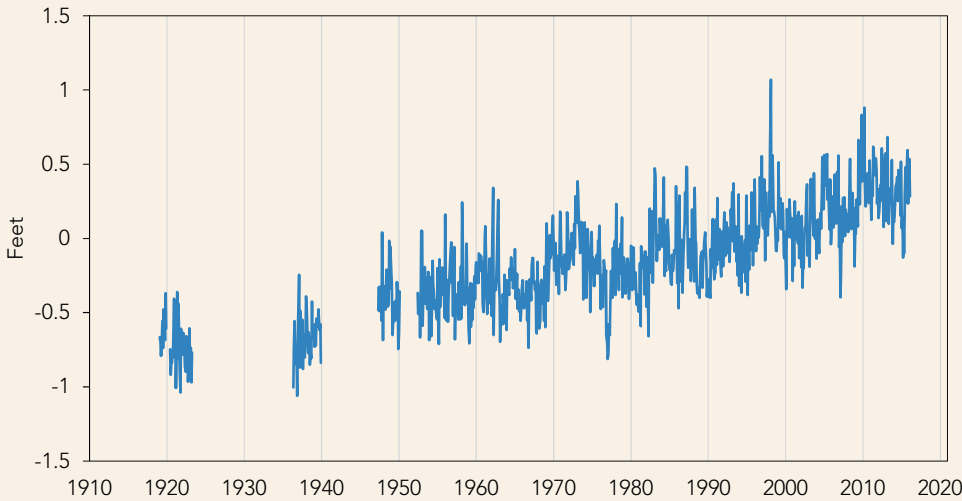
**Carbon dioxide levels increased from 315 parts per million (ppm) in the late 1950s to 402 ppm in 2015.**

# SEA LEVEL RISE

Warmer water temperatures raise the sea level by expanding ocean water and causing land-locked ice to melt into the oceans. On the Delaware coast, sea level is rising at a rate of 1.1 feet per century.

The Inland Bays are already experiencing effects from sea level rise, including increased flooding, shoreline erosion, and drowning of tidal wetlands. A combination of rising water, sinking lands, and very low elevation makes our watershed particularly vulnerable to the effects of sea level rise.

Monthly Average Sea Level Rise at Lewes, DE



## LONG-TERM TREND

Sea level on Delaware's coast has risen over the past 1,000 years at an estimated rate of 0.3 feet per century. The rate has accelerated in the last 100 years, with a total rise of more than one foot since 1900.

## LOOKING AHEAD

Sea level rise projections for Delaware depend largely on global emissions of greenhouse gasses into the atmosphere. The highest projection adds almost five feet by the end of the century. At that level, existing bayside communities and coastal habitats would be inundated. Independent of future greenhouse gas emissions, we are locked in to significant future sea level rise due to a lag time in the thermal expansion of the oceans.

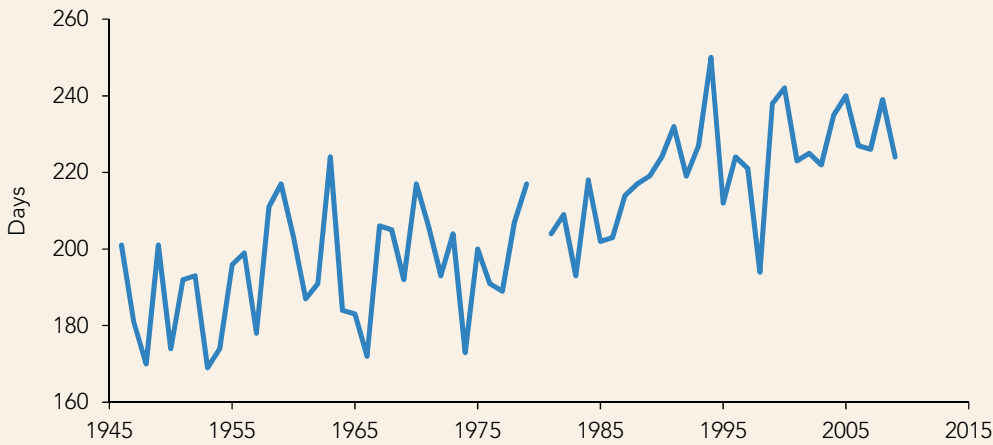
**On the Delaware coast, sea level is rising at a rate of 1.1 feet per century.**

## GROWING SEASON LENGTH

The growing season is defined as the number of days between the last frost in spring and the first frost in fall. Changes in growing season length can affect the Bays by causing shifts in the ranges of species and stimulating growth of excessive algae and invasive species.

Currently, the statewide growing season in Delaware averages 210 days per year. Local data for estimating length of the growing season is available from Lewes, Delaware where the average is currently 230 days per year. The growing season around the Bays is relatively longer due to its proximity to the ocean.

Growing Season Length in Lewes, DE



### LONG-TERM TREND

Local growing season length, as measured in Lewes, has increased by at least 45 days (25%) since 1945.

### CHANGE SINCE PREVIOUS REPORT

Growing season data are not available from Lewes after 2009 when the monitoring station was temporarily relocated.

### LOOKING AHEAD

By mid-century, the growing season in Delaware is expected to lengthen by another 20 days.



**The growing season is defined as the number of days between the last frost in spring and the first frost in fall.**

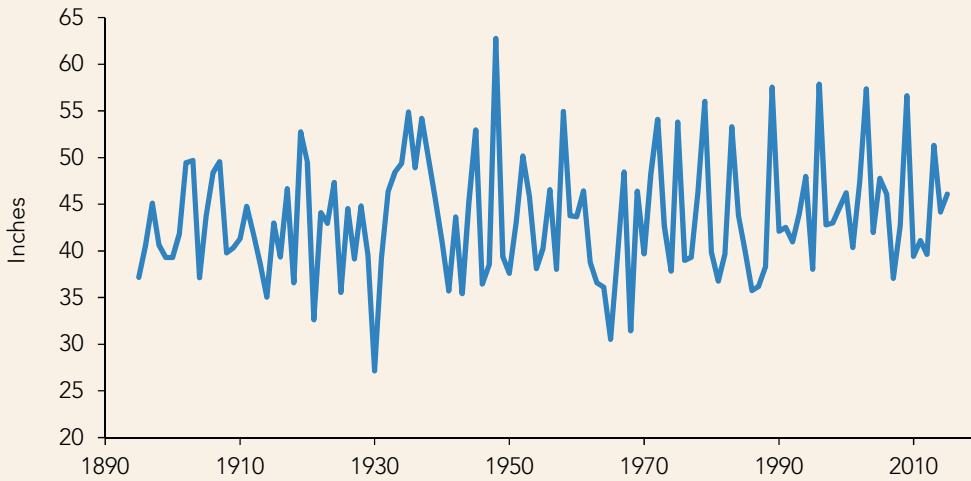


# PRECIPITATION

Rising temperatures at the Earth's surface causes more evaporation to occur from land and waterbodies. More moisture in the air can alter the amount and timing of precipitation which will affect the flow of freshwater to the Bays. Changes in precipitation can alter pollution inputs, salinity, and circulation patterns in the estuary affecting the types of plants and animals that can survive.

On average, the state of Delaware receives 45 inches of precipitation annually.

Annual Precipitation in Lewes, DE



## LONG-TERM TREND

Precipitation varies greatly from year to year, so trends must be assessed through long-term measurements. Currently, there is no trend in total annual precipitation in coastal Delaware.

## LOOKING AHEAD

As the climate warms, precipitation in Delaware is projected to increase annually, particularly during the fall.

**On average, the state of Delaware receives 45 inches of precipitation annually.**

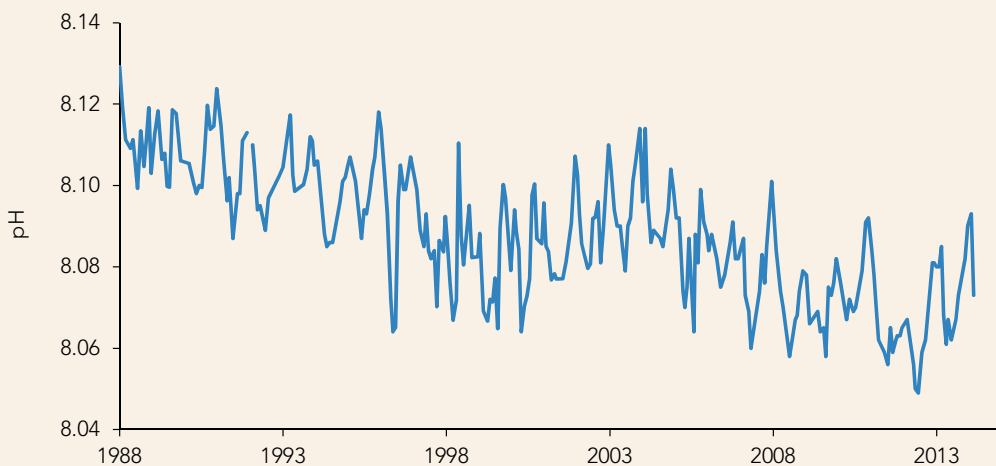
## OCEAN ACIDIFICATION

Warming oceans allow more carbon dioxide from the atmosphere to dissolve in the waters. Once in the ocean, carbon dioxide turns into carbonic acid, which increases the acidity of the water.

Sea life that produce calcium carbonate shells—such as corals, clams, and mussels—are vulnerable to increasing acidity. Rising acidity can damage shells and slow the growth of new shells, threatening the survival of these organisms.

Because bays are smaller systems, they are more vulnerable to change. Acidification in estuaries is more complex than in the open ocean and is less understood.

Ocean pH near Mauna Loa, Hawaii



Adapted from Dore et al., 2009.

### Measuring Acidity

Acidity of water is measured on a pH scale, which ranges from 0 to 14. A pH of 7 is neutral, a pH less than 7 is acidic, and a pH greater than 7 is basic.

The pH scale is logarithmic and as a result, each one-unit change in the pH scale corresponds to a ten-fold change in acidity. For example, pH 6 is ten times more acidic than pH 7, and 100 times more acidic than pH 8.

### LONG-TERM TREND

Measurements at the Mauna Loa Observatory in Hawaii provide a good indicator of ocean acidification. There the average ocean pH has dropped 0.04 pH units since 1988. Because the pH scale is logarithmic, this means that the ocean has become 9% more acidic in 27 years.

### LOOKING AHEAD

Oceans are expected to become more acidic as climate change continues. What this means for estuaries such as the Inland Bays is uncertain. Local monitoring data is needed on pH in the Inland Bays.

**Sea life that produce calcium carbonate shells—such as corals, clams, and mussels—are vulnerable to increasing acidity.**



WATERSHED CONDITION

NUTRIENT POLLUTION

WATER QUALITY

LIVING RESOURCES

HUMAN HEALTH RISKS

CLIMATE

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DELAWARE CENTER FOR THE  
**INLAND BAYS**  
Research. Educate. Restore.

Delaware Center for the Inland Bays  
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**[inlandbays.org](http://inlandbays.org)**

The Delaware Center for the Inland Bays is a nonprofit organization and a National Estuary Program. It was created to promote the wise use and enhancement of the Inland Bays watershed by conducting public outreach and education, developing and implementing restoration projects, encouraging scientific inquiry and sponsoring needed research, and establishing a long-term process for the protection and preservation of the Inland Bays watershed.