## The Delaware Center for the Inland Bays





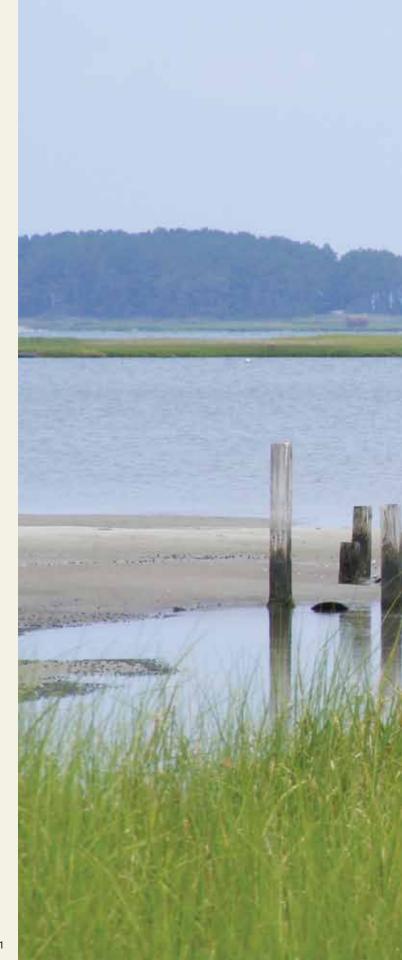
## The Inland Bays Watershed—Quick Facts

- 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.

By Christopher Bason, Deputy Director, the Delaware Center for the Inland Bays on behalf of the Scientific and Technical Advisory Committee of the Delaware Center for the Inland Bays, Dr. William Ullman, Chair

This report may be found at www.inlandbays.org

Cover photo: Young osprey on nest on Rehoboth Bay by Dennis Bartow





# The State of the Inland Bays and Their Restoration

The Inland Bays are coastal lagoons; bays that lie behind a narrow barrier island that separates them from the Atlantic Ocean. Travelling down Route 1, 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 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, 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.

### **Assessing the State of the Bays**

To assess the health of the Inland Bays, we selected a suite of environmental indicators; 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-one 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 measurements of environmental parameters and management actions
- Status and trends are assigned using best professional judgment.

To more completely document bay health, a number of new indicators were added since the last environmental indicators report published in 2004. A status bar common to state of the bay reports from other National Estuary Programs was also adopted.



Horseshoe crabs spawning on Indian River Bay.





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At 10% impervious surface coverage on a watershed, it is widely cited that a decrease in water quality begins. The Rehoboth and Little Assawoman Bay Watersheds have now crossed that 10% threshold.

The human population of the watershed continues to increase and with it, rapid changes in land use—primarily the conversion of forests, croplands, and wetlands to developments. Development increases the acreage of impervious surfaces, such as roads, roofs, parking lots; places where precipitation can't seep into the soils and be filtered.

Rain water becomes stormwater runoff as it travels across these surfaces picking up pollutants and carrying them to waterways.

At 10% impervious surface coverage on a watershed, it is widely cited that a decrease in water quality begins. The Rehoboth and Little Assawoman Bay Watersheds have crossed that 10% threshold.

Much of the new development is concentrated around waterways where it impacts bay shorelines. Forested buffers between croplands and streams also decreased in width from 1992 to 2007.

#### LOOKING AHEAD:

The increasing amount of human activity in the watershed will continue to challenge our efforts to protect and restore the Bays.

#### **WATERSHED CONDITION STATUS BAR**



**NEGATIVE** 

**POSITIVE** 

#### **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.

Buzz Henifin, former Citizen's Advisory Committee Chair, inspects storm drain in Fenwick Island.





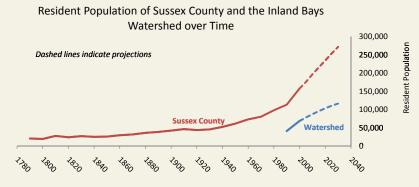
Impervious surfaces in Dewey Beach.

From 1990 to 2010, the year-round watershed population is projected to have doubled. Currently, 196,201 year round residents live in Sussex County, with 87,210 (or 44%) residing in the Inland Bays watershed.

As the number of people in our watershed increases we consume more resources and generate more waste. The success of environmental management in the Inland Bays watershed is dependent on how we plan for population growth and its impacts.

Although the watershed is a premier tourist destination and hosts hundreds of thousands of visitors each summer, its seasonal and visitor population is not directly counted. A method of estimating seasonal and visitor population by measuring flows to wastewater treatment plants found that the monthly seasonal and visitor population of the watershed ranged from 41% to 200% of the year-round resident population.

At the peak of the tourist season in July, the estimated total population of the watershed swells to 252,000 people concentrated around the Bays.



#### LOOKING AHEAD:

The year-round and seasonal populations of the watershed are projected to continue increasing. Sussex County is zoned to eventually hold a population of over 2 million residents.



# From 1992 to 2007 the Inland Bays watershed lost over a football field of forest lands every day.

# In 2007, agriculture was the largest use of land (32%) followed by developed/developing lands (22%), forested lands (17%) and then wetlands and waters (16% and 12%).

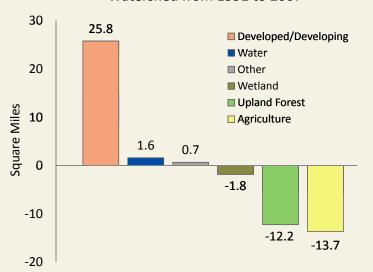
The health of the Bays depends on how the land of the watershed is used, since various land uses result in different types and amounts of pollutants entering waterways.

For example, a dense residential development constructed without stormwater management facilities can contribute four times as much nitrogen to the waters than a forest of the same size. Heavy metal contaminants and bacteria loads to waters also would be relatively higher. The success of nutrient and stormwater management is greatly dependent on land use and land management.

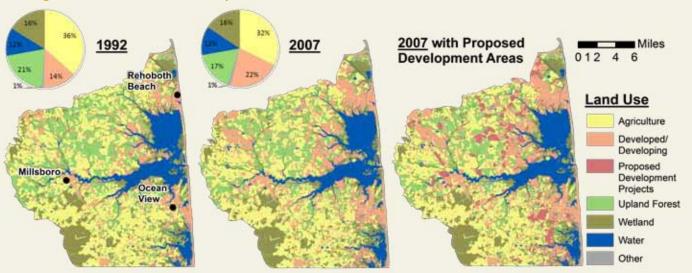
From 1992 to 2007, the land use of the watershed changed significantly. Developed lands increased by 25.8 square miles (57%), agricultural lands decreased by 13.7 square miles (12%), and upland forests decreased by 12.2 square miles (18%). A net loss of 1.8 square miles of wetlands also occurred.

(continued on page 10)

## Changes in Landuse of the Inland Bays Watershed from 1992 to 2007



#### **Changes in Land Use in the Inland Bays Watershed**



Note: Proposed Development Project Areas represent full project areas, which include some areas left undeveloped such as forests, waters, and wetlands.

Wetlands and forests play an important role in protecting water quality because of their water filtering and storage functions, so preserving wetlands and forests helps protect the Bays.

#### LOOKING AHEAD:

The conversion of croplands to development is likely to reduce nutrient loads to the Bays over time, but development may speed the delivery of pollutants to the Bays by generating more runoff due to increased acreage of impervious surfaces.

The location of development also affects water quality. Much of the development has taken pace close to waterways where it impacts the natural function of wetlands and shorelines.

# The Importance of Wetlands

Wetlands provide benefits to people and the environment by removing nitrogen from waters, trapping sediments, reducing flooding and erosion, providing habitat for plants and animals, decreasing the impact of severe storms and storing carbon.

Despite public appreciation of these benefits and federal protection of most wetlands, they are increasingly being replaced by croplands, stormwater ponds, and developments.

A recent assessment of the status of wetland condition in the watershed found that the beneficial functions of most of the existing wetland resources have been degraded and will likely continue to degrade.

Without strengthened wetland regulations and improved permit tracking and enforcement, the watershed will likely continue to suffer the loss and degradation of its wetland resources and the valuable environmental services they provide.

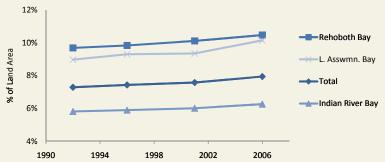
From 1992 to 2006, impervious surfaces in the Inland Bays watershed increased by 1,203 acres to a total of 14,749 acres, or about 8% of the watershed land area.

The creation of new impervious surfaces such as parking lots, roadways, and the roofs of buildings can increase the amount of runoff entering streams and with it, the loads of nutrients, pathogens, and contaminants. The increased runoff causes streams to erode and reduces their natural capacity to remove pollution from waters flowing to the Bays.

Increases in bacteria concentrations and chemical contaminants, and changes in water flow have been found when watersheds of some estuaries reach 10% impervious surface coverage.

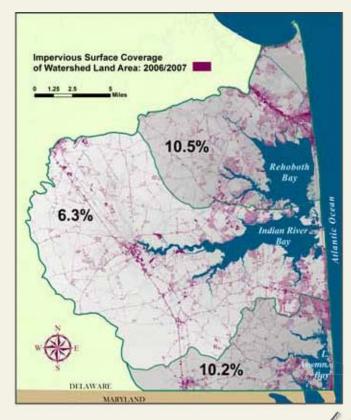
From 1992 to 2006, impervious surfaces in the Inland Bays watershed increased by 1,203 acres to a total of 14,749 acres, or about 8% of the watershed land area. The watersheds of Rehoboth Bay and Little Assawoman Bay are now over 10% impervious coverage.

Percent of Land Area Covered by Impervious Surfaces by
Watershed over Time



#### LOOKING AHEAD:

Impervious surface coverage will continue to increase. However, new stormwater regulations and ordinances are helping to limit new impervious surfaces and lessen their impact on waters. Dewey Beach, Fenwick Island, and South Bethany all have ordinances limiting the amount of impervious surface in new developments, and DNREC is expected to have improved its sediment and stormwater regulations by early 2012.





Rain gardens like this one at Millville Town Hall treat runoff from impervious surfaces before it enters waterways.

### Water Quality Buffers on Croplands

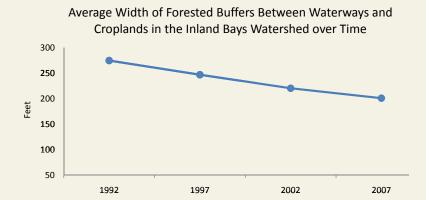
Croplands contribute the greatest amount of nutrients to the Bays of any major land use. Buffers of natural vegetation between croplands and waterways can be effective at intercepting many of these nutrients.

Croplands contribute the greatest amount of nutrients to the Bays of any major land use. Buffers of natural vegetation between croplands and waterways can be effective at intercepting many of these nutrients. Buffers vary in their effectiveness based partly on their width and type of vegetation, with wider buffers and forested buffers removing more nutrients.

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

From 1992 to 2007, the mean buffer width decreased from 274 feet to 201 feet (or 27%). In 2007 the median buffer width was less than 50 feet.

For comparison, the median buffer width of watersheds on Delmarva draining to the Chesapeake Bay was found to be 134 feet. This difference may in part be due to the many unbuffered ditches on cropland in the southern part of the Inland Bays watershed. The outlook for changes in buffer



Forested buffers help to filter nutrients from adjacent croplands before they enter Arnell Creek.



Since 2003, when tracking began, \$10 million has been spent to protect 3,000 acres and restore nearly 1,000 acres of natural habitat.

Our watershed contains a variety of natural habitats that support diverse populations of plants and animals, some of them very rare. Natural habitats also provide scenic beauty, recreational opportunities, and other ecosystem services.

**Natural Habitat Protection and Restoration** 

Acreage of natural habitats is decreasing and becoming fragmented, putting pressure on certain sensitive species that require large tracts of forests and wetlands. Protecting the watershed's remaining high-quality habitats through land purchase and conservation easements and restoring degraded habitats are high priorities of the CIB and its conservation partners.

Restoration seeks to re-establish the natural functions of ecosystems by re-introducing native species and removing ecosystem stressors.

Protection is accomplished through

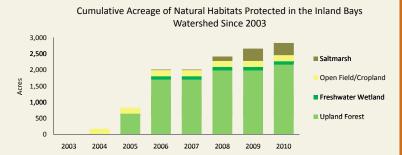
- · Purchase of land
- Conservation easements that restrict development
- · Creation of preservation agreements
- Purchase or contribution of development rights

Since 2003, when tracking began, \$10 million has been spent to protect 3,000 acres and restore nearly 1,000 acres of natural habitat. An additional 1,784 acres were managed to control invasive species. This does not include farmland preservation agreements that can also protect some natural habitats.

Protection and restoration activities have decreased due to the recent economic downturn. Unfortunately, when property values are the lowest, the least amount of public funding is available for conservation. Additional incentives are needed for land protection.

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Swamp Pink, a rare wetlands perennial.



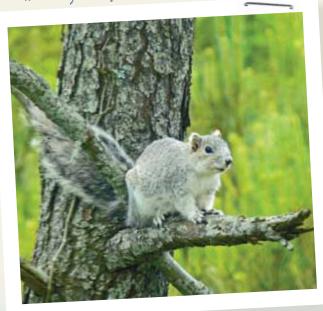
Note: Upland Forest category contains an unknown amount of Freshwater Wetland acreage.

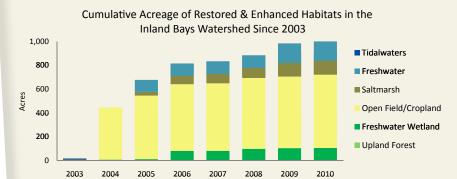


Austin Okie (left) and Roger Jones of the Delaware Nature Conservancy at the 2008 dedication ceremony for the Marian R. Okie Memorial Wildlife Preserve at Poplar Thicket, a 118-acre property on Indian River Bay. Photo by steve billups.org

### Natural Habitat Protection and Restoration cont.

Delmarva Fox Squirrel, listed as an "extremely rare species" in Delaware.





Note: Does not include acreage managed for invasive species.

Saltmarsh enhancement at Slough's Gut on Indian River Bay.

The amount of water passing through the Indian River Inlet over one tide cycle increased by 4.5 times over the period 1939 to 1991. Most of this increase occurred since 1970.

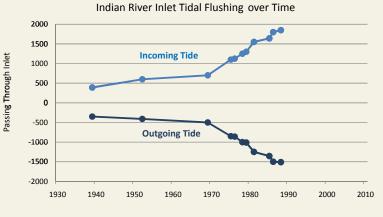
Twice a day, tides exchange water and materials through Indian River Inlet between Indian River Bay and the Atlantic Ocean. But this has not always been the case. In the past, the existence of the Indian River Inlet was subject to the whim of shifting sands and blowing storms, and its history was one of migration, closing, and reopening.

Between 1938-1940, the Indian River Inlet was stabilized by the construction of rock jetties to protect navigation and the Bays' seafood industry. Afterwards, the inlet channel began to widen and deepen, allowing more ocean water to enter and exit the Bays.

The increased tidal range and volume of seawater entering the Bays has likely reduced the amount of fresher water habitats used by spawning fish such as striped bass and shad. The increased tidal range also likely decreased the diversity of marsh habitats and may have contributed to their conversion to open water.

Significantly, the increased flushing helps remove excess nutrients from the Bays by transporting them to the ocean. This process is thought by some scientists to be vital to the current health of the Bays.

Though no estimates have been made since 1991, the flushing and its effects, both positive and negative, may have continued to increase.



Millions of Cubic Feet of Water



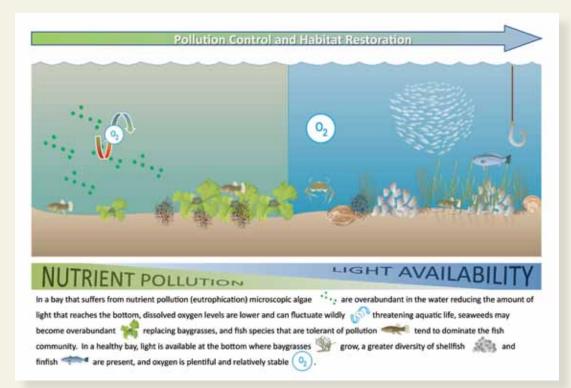
Aerial image of Indian River Inlet before stabilization in 1936. Courtesy of the Hagley Museum & Library, 70.200.09171



Indian River Inlet 1992



# Nutrient pollution is the major problem facing the Inland Bays ecosystem.



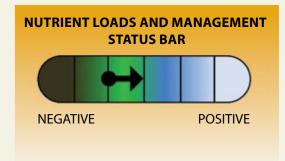
Adapted from the Maryland Coastal Bays Program using IAN Symbol Library www.ian.umces.edu.

Nutrient pollution is the major problem facing the Inland Bays ecosystem. To assist in their management, sources of nutrients are classified into three groups: point sources, nonpoint sources, and atmospheric sources.

**Point source nutrients** enter the Bays directly from a pipe such as discharge from a wastewater treatment plant.

**Non-point source nutrients** enter the Bays from surface runoff or groundwater; from activities on the land including cropland and lawn fertilization, land applied wastewater disposal, and stormwater runoff from urban areas.

Atmospheric sources are nutrients directly deposited to the surface of the Bays from the air.



The maximum amount of pollutant that a water body can receive and still support healthy environmental conditions is called its Total Maximum Daily Load (TMDL). The Inland Bays need reductions of nitrogen and phosphorus from 40 to 85% (from the baseline period 1988-1990) to meet their TMDL.

In 2008, the Delaware Department of Natural Resources and Environmental Control (DNREC) enacted a Pollution Control Strategy (PCS) for the Inland Bays that detailed the actions necessary to meet the TMDL. The PCS required elimination of all point sources, addressed septic systems and stormwater runoff, identified agricultural nutrient management practice goals, and required water quality buffers on new developments.

#### LOOKING AHEAD:

Nutrient loads from all sources have decreased. We expect all point sources to be fully addressed by 2014, goals for atmospheric sources have nearly been reached, and in most cases non-point source load reduction is apparent. Nutrient management plans have been developed for nearly all farms. However, much progress on reducing non-point sources remains to be realized.

In 1990, thirteen point sources discharged to the Inland Bays. Now only three significant discharges remain.

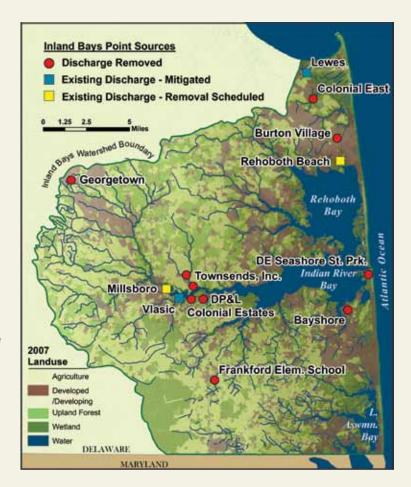
In 1990, thirteen point sources discharged to the Inland Bays. Now only three significant discharges remain. As facilities have removed their discharges or upgraded their wastewater treatment processes, point source loads to Rehoboth and Indian River Bays are estimated to have decreased by 409 lbs. per day for nitrogen (82%) and 44 lbs. per day for phosphorus (87%).

Currently only the towns of Millsboro, Rehoboth Beach, and Lewes contribute significant point source discharges.

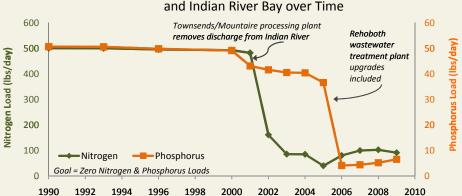
#### LOOKING AHEAD:

To meet the goal of zero nutrient loading from point sources, these municipalities are pursuing different approaches that work best for their particular situation.

- Lewes, whose wastewater flows primarily to Delaware Bay, will maintain its discharge and make up for the small amount of nutrients that reach the Inland Bays by funding nutrient management projects elsewhere in the watershed.
- Millsboro plans to remove its discharge and land-apply its treated wastewater.
- Since land application of wastewater is more expensive near the beach, Rehoboth has decided to convert its discharge to an ocean outfall by 2014.



## Loads of Nutrients from Point Sources Discharging to Rehoboth and Indian River Bay over Time



# Farms, developments, even forests contribute nutrients to waters that flow to the Bays.

Farms, developments, even forests contribute nutrients to waters that flow to the Bays. The nutrients result primarily from fertilizers, manure, and land based waste water disposal.

Loads of Nutrients from Non-point Sources

Non-point source nutrient loads are estimated by measuring the flows and concentrations of nutrients in the major streams draining to the Bays. Loads are presented as three year averages to help smooth out the effects of significant year to year differences in stream flow.

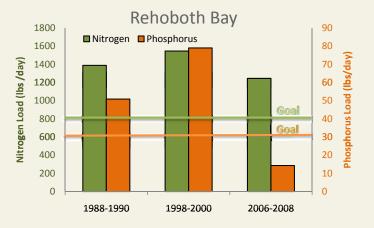
**Nitrogen loads show a mixed picture.** Loads to Rehoboth Bay increased slightly from years 1988-1990 to 1998-2000, then decreased slightly during 2006-2008. Loads to Indian River Bay doubled from 1988-1990 to 1998-2000, then were lower during 2006-2008. In Little Assawoman Bay, loads more than doubled from 1998-2000 to 2006-2008. All Bays are far from meeting their nitrogen goals.

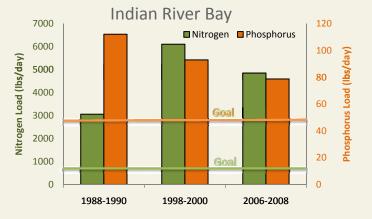
**Phosphorus loads have decreased.** In Rehoboth Bay, loads increased slightly from years 1988-1990 to 1998-2000, and then decreased greatly to surpass the Bay's load reduction goal in 2006-2008. Loads to Indian River Bay demonstrated a continued decrease but were still above the reduction goal in 2006-2008. Similar to Rehoboth Bay, loads to Little Assawoman Bay decreased from 1998-2000 to surpass the load reduction goal in 2006-2008. It is important to note that phosphorus loads are particularly difficult to estimate and the certainty of this data is low.

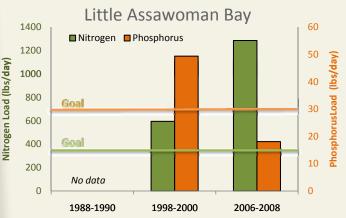
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Fertilized turf is considered a non point source of nutrients to the Inland Bays.





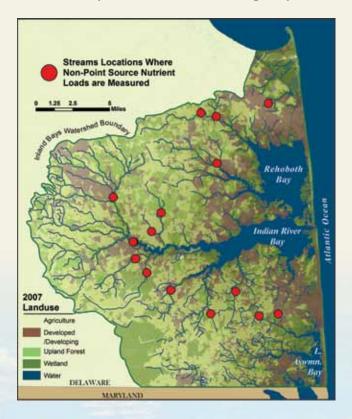


### Loads of Nutrients from Non-point Sources cont.

Reductions of phosphorus loads are thought to result from improved management of nutrients on farms, and conversion of cropland to developments. Similar reductions in nitrogen loads are expected but may take longer to observe because years can pass before nitrogen in groundwater enters streams.

#### LOOKING AHEAD:

The Bays continue to be highly polluted by excess nitrogen and remain very sensitive to additional nitrogen inputs.



### Challenges in Measuring Non-Point Nutrient Loads

Unlike controlled discharges from pipes, non-point nutrient loads come from a variety of sources across the watershed and are influenced by changes in precipitation, making their measurement difficult.

While much of the non-point source load is measured in streams discharging to the Bays, a large but unknown amount bypass these sites either in unmeasured streams or in groundwater aquifers that seep directly into the Bays and tidal creeks. Therefore the measured loads only tell part of the story.

Approximately half of the groundwater moving through the watershed's aquifers takes 10 years or less to discharge to surface waters; some groundwaters may take decades to reach surface waters. This lag time between when nutrients enter the groundwater and when they enter measured streams or the Bays can obscure progress in the management of nitrogen in particular, which tends to be transported in groundwater.

Phosphorus tends to be transported in surface waters during storms. Because load measurements are made only periodically, high flow events are often missed.

These facts create large uncertainties that must be considered when estimating nutrient loads and their changes over time. Recent improvements in measurement techniques have occurred, but at this time, data on changes in nutrient loads should be interpreted with caution.



### Loads of Nutrients from the Atmosphere

Since the early 1990s, atmospheric nitrogen loads have decreased slightly and are now near their pollution reduction goal.

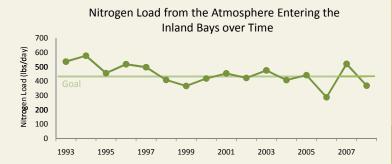
Nutrients from the atmosphere directly enter the surface of the Bays during both wet and dry weather. Research on Rehoboth Bay estimates this contributes 15% of its total nitrogen and phosphorus loads.

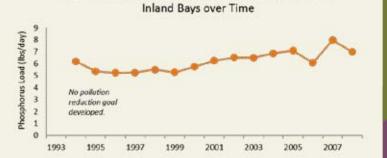
Nitrogen is deposited primarily in two forms: nitrate and ammonium. Activities that contribute nitrate to the atmosphere include combustion from coal fired power plants and vehicles.

Nitrate in the atmosphere may come from as far away as Ohio, but ammonium tends to come from local sources such as agricultural manure and fertilizers. Sources of atmospheric phosphorus are less certain but are believed to result from plants, soil particles, combustion, and herbicide and pesticide application.

Since the early 1990s, atmospheric nitrogen loads have decreased slightly and are now near their pollution reduction goal. This is due to improved federal emission standards for power plants and automobiles that have resulted in decreased nitrate concentrations. Ammonium concentrations have remained the same. These data likely underestimate actual ammonium concentrations because they are collected away from farms.

Phosphorus loads are increasing and it is not known why. No pollution reduction goal is currently set for phosphorus from the atmosphere.





Phosphorus Load from the Atmosphere Entering the

Smog over eastern U.S. Photo courtesy NASA, MODIS Rapid Response



### **Nutrient Management Practices**

The highlight of nutrient management practices is the 95% implementation of nutrient management planning on farms, an action required by the Delaware Nutrient Management Act of 1999.

To achieve the goal to reduce the amount of nutrients entering the Bays, a number of management practices for nutrients have been developed and implemented.

The practices are focused on agricultural lands, developed lands, and both wetlands and waterways. The Inland Bays Pollution Control Strategy details goals for individual management practices needed to restore the Bays. The chart on page 23 shows progress toward meeting the goals from 2005 to about 2009. Overall, progress is somewhat under-reported, but progress tracking is being improved by the Department of Natural Resources and Environmental Control.

The highlight is that 95% of farms have implemented nutrient management plans, an action required by the Delaware Nutrient Management Act of 1999.

Goals for other practices are far from being met, with some having no progress reported.

#### LOOKING AHEAD:

The outlook is good for continued nutrient management planning.

The outlook is unknown for manure relocation. The amount of excess poultry manure transported from the watershed has increased over time, but is still far from its goal.

Past performance on buffer implementation suggests the outlook for this practice is not good. Communities are showing increased interest in stormwater retrofits, but these practices are relatively expensive.

Finally, an assessment of field research on nutrient management practices shows that many are less effective than once thought, so a greater number of practices will be needed to meet the nutrient reduction goals.

### How Nutrient Management Plans Work

A Nutrient Management Plan is developed by a certified nutrient consultant to manage the amount, placement, timing, and application of nutrients in order to reduce nutrient loss or runoff and to maintain the productivity of soil when growing agricultural commodities and turfgrass.

Under Delaware law, all animal feeding operations with greater than 8 animal units, or any properties over 10 acres upon which nutrients are applied must have a nutrient management plan which specifies the level of nutrient applications that are needed to attain expected crop yields.

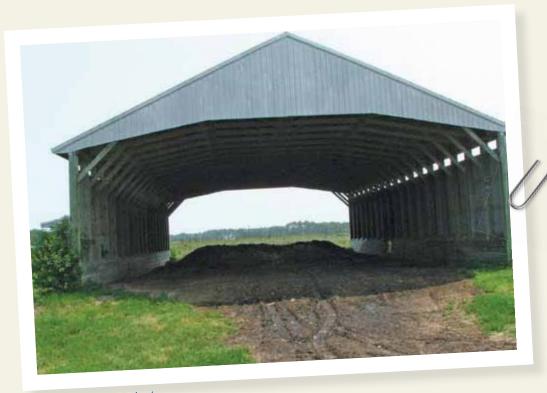
Under the plans, applications of phosphorus to high phosphorus soils cannot exceed the three year crop removal rate and nitrogen applications cannot exceed the expected yield.



Poultry house

# Progress towards the Inland Bays Pollution Control Strategy's Nutrient Management Practice Goals (since the year 2005)

Practico	Goal	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
<u>Practice</u>	Goal	<u> </u>		1	1	1	1					
Implement Nutrient Mgmt. Planning	100% of farms											
Establish Cover Crops	Avg. of 37,637 acres/year											
Establish Forested Waterway Buffers	3,037 acres											
Establish Grassed Waterway Buffers	1,718 acres											
Restore Wetlands on Former Cropland	4,147 acres											
Build Poultry Manure Sheds or Composters	50 structures											
Relocation & Alternative Use of Manure	Avg. of 20,909 tons/year											
Treat Cropland with Water Control Structures	450 acres											
Retrofit Old Development with Stormwater Controls	4,500 acres											

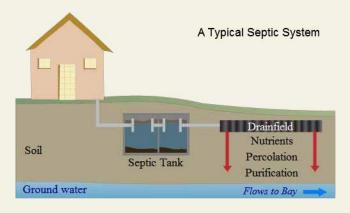


Manure storage shed

While many of the septic systems are only used seasonally, when the nutrient loads produced by them are multiplied by the 12,000 to 16,000 estimated to be in the watershed, their total nutrient contribution to the Bays is significant.

If wastewater cannot be discharged to sanitary sewers for treatment at a centralized treatment plant, it must be treated where it originates. Individual systems for onsite treatment of wastewater are commonly referred to as septic systems.

A properly located and maintained septic system that is used year round leaches 10.6 lbs. of nitrogen and 0.7 lbs. of phosphorus to groundwaters every year. While many of the septic systems in the watershed are only used seasonally, when these nutrient loads are multiplied by the 12,000 to 16,000 septic systems in the watershed, their total nutrient contribution to the Bays is significant.



Converting septic systems to central sewer provides a much higher level of sewage treatment and eliminates the potential for increased pollution that can occur when septic systems are not regularly maintained.

Since the CIB's 2004 Environmental Indicators report, Ocean View, Cedar Neck, Millville and Angola Neck have all had septic systems eliminated by central sewer expansion.

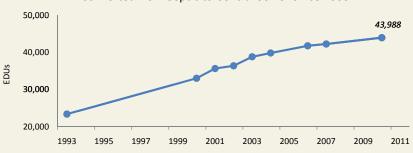
#### LOOKING AHEAD:

Sussex County continues to facilitate the conversion of septic systems to central sewer primarily through grants from the county, state, and the U.S. Department of Agriculture.

Central sewer expansion on Angola Neck.



Cumulative Number of Equivalent Dwelling Units (EDUs)
Converted from Septic to Central Sewer Since 2003





Nutrient Loads & Management



# Observing improvements in water quality is a core measure of success for protecting and restoring the Bays.

Measures of water quality are the most basic indicators of Bay health. The water quality indicators for the Inland Bays are based on the minimum requirements necessary for reestablishment of bay grasses and healthy dissolved oxygen levels.

Observing improvements in water quality is a core measure of success for protecting and restoring the Bays. The water quality indicators are presented in an order that shows how they respond to one another:

Nitrogen and phosphorus levels affect the amount of algae that can grow in the water



which affects the amount of light that reaches the bottom



where it can be used for growth by seaweeds and/or bay grasses

Generally, as nitrogen and phosphorus levels increase, bay grasses become displaced by seaweeds, which in turn can be outcompeted by floating algae. Dissolved oxygen is placed at the end because it responds to all these parameters together, and is an integrative indicator of Bay health.



Each water quality indicator individually is useful to assess changes in the health of the Bays, and together they paint a clearer picture of ecological conditions in the Bays.

Bay water quality remains fair to poor depending on location. No areas had water quality conditions that are known with confidence to allow bay grasses to reestablish. However, these conditions were satisfactory in the waters nearer the Indian River Inlet, where dissolved oxygen levels were also healthy. Most tributaries continued to have poor water quality.

Seaweed abundance decreased in Rehoboth Bay possibly in response to improved treatment at the Rehoboth Wastewater Treatment Plant. Algae levels in Little Assawoman Bay have also decreased, most likely in response to agricultural nutrient management and a decrease in croplands where nutrients were applied. However, decreases in nutrient concentrations were not observed as expected given the observed reduction in nutrient loads.

The values of the water quality index in the Indian River have declined without good explanation.



Frank McNeice, George Junkin, Ron Wuslich and Jay Headman collect water quality data in Little Assawoman Bay.

Over the period 1998 to 2007–2008, 68% of bay waters met the standard for nitrogen but only 15% met the standard for phosphorus.

Nitrogen and phosphorus are nutrients that plants need to grow. In the Bays, algae, seaweeds, and bay grasses use the dissolved inorganic form of these nutrients.

When excess amounts of nitrogen and phosphorus enter the Bays it;

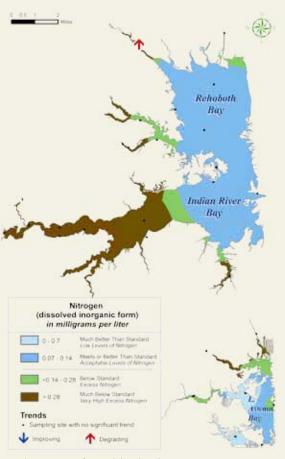
- · Promotes seaweed and algal growth
- Negatively affects oxygen levels
- Reduces water clarity
- Displaces bay grasses

Studies have determined standards for concentrations of nitrogen and phosphorus that will result in healthy dissolved oxygen levels and that should allow bay grasses to reestablish.

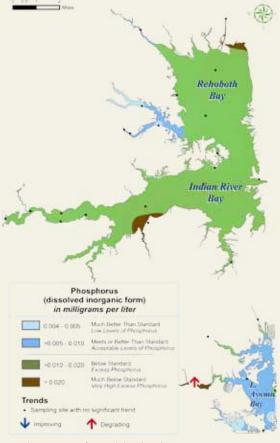
Over the period 1998 to 2007/2008, 68% of bay waters met the standard for nitrogen but only 15% met the standard for phosphorus. The better flushed waters of the open Bays met the nitrogen standard, while upper Indian River Bay and bay tributaries did not.

Few areas of Rehoboth and Indian River Bay met the standard for phosphorus. Much of Little Assawoman Bay met the standard partly because its relatively lower salinity keeps phosphorus bound to bay sediments and out of the water column.

Only 2 stations had significant trends in nitrogen or phosphorus concentrations, but no overall pattern of increase or decrease was apparent. This is somewhat surprising given the estimated reduction in nutrient loads entering the Bays.







Based on measurements from March through October taken during 1998 to 2008.

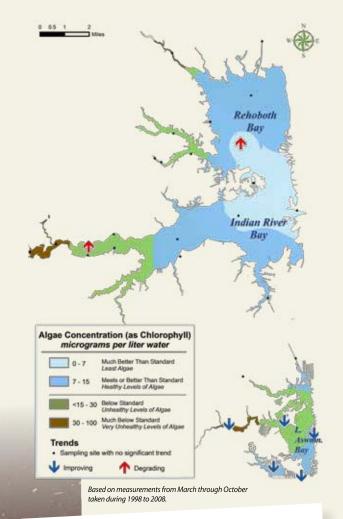
# Floating microscopic algae, or phytoplankton, help form the base of the bay food chain.

Floating microscopic algae, or phytoplankton, help form the base of the bay food chain. Algae can respond quickly to additions of nutrients, dividing their cells until algal blooms (referred to as green, red, and brown tides) appear. If blooms persist, they reduce water clarity so that bay grasses are deprived of light and cannot grow. High concentrations of algae also cause wide swings in dissolved oxygen levels.

Algae are measured in water samples as Chlorophyll *a*, a plant pigment. For bay grasses to re-establish, an average concentration of 15 micrograms of Chlorophyll *a* per liter of water or less is needed.

From 1998 to 2008, 79% of bay waters met this standard. Areas of Rehoboth and Indian River Bay near the Indian River Inlet had algae concentrations that were much better than the standard. Indian River and many tributaries had very high levels of algae that were much worse than the standard.

In Little Assawoman Bay, algae concentrations decreased at most sampling locations but it is uncertain why. Since phosphorus loads to Little Assawoman Bay decreased, it may be that the algae decreased in response to changes in phosphorus concentrations that were not detected.





Filtering water samples to measure algae concentrations Photo by Hillary Stevens

For bay grasses to reestablish, light needs to reach the bottom of the bay. The clarity of the water determines if this is possible.

For bay grasses to reestablish, light needs to reach the bottom of the bay. The clarity of the water determines if this is possible.

Algae, suspended sediments, and dissolved organic matter reduce water clarity. Bay waters should be clearest where algae are scarce and sediments are held on the bottom by rooted seaweeds, bay grasses, or oysters.

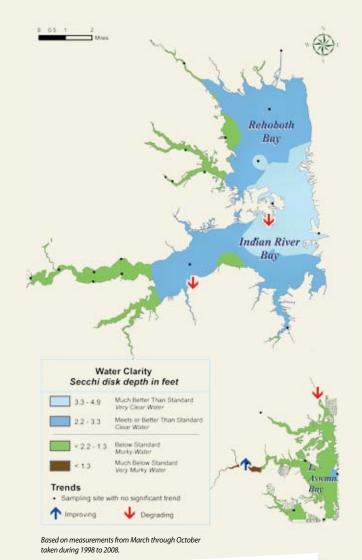


Photo by Adrain Jones via IAN

To measure water clarity, a Secchi disk is lowered into the water to a depth where its markings can no longer be seen. Bay grasses grow in shallow waters that have an average Secchi depth of at least 2.2 feet.

From 1998 to 2008, 73% of the bay waters were estimated to meet or exceed this standard. Areas of Indian River and Rehoboth Bay near the inlet were clearest and well exceeded this standard. Most bay tributaries and Little Assawoman Bay do not have clear water.

No overall change in water clarity was detected. Two sampling sites in Indian River Bay and one site on the Assawoman Canal had decreasing water clarity, while Dirickson Creek had increasing water clarity.





54% of bay waters had an index value ranging from 0.90 to 0.99, suggesting that bay grass restoration efforts might be successful in these areas where other conditions such as water depth allow.

The water quality index combines four previous indicators that affect eelgrass reestablishment and growth: water clarity, algae concentration, and nitrogen and phosphorus concentrations.

It is an integrated measure of bay waters used to determine if conditions are present to support the reestablishment of eelgrass.

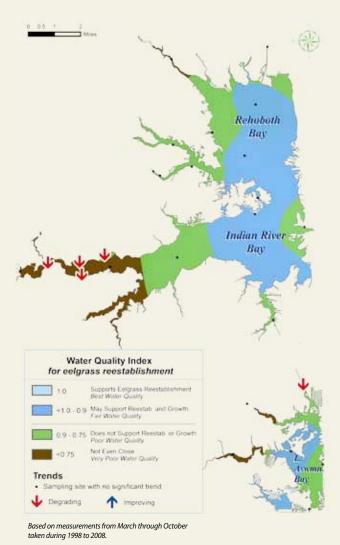
The index ranges from 0 (conditions least supportive of eelgrass) to 1.0 (conditions found to allow eelgrass reestablishment). Index values from 0.90 to 0.99 may support some reestablishment and growth.

No areas of the Bays had an index value of 1.0. However, fifty-four percent (54%) of bay waters had an index value ranging from 0.90 to 0.99, suggesting that bay grass restoration efforts might be successful in these areas where other conditions such as water depth allow.

Significant decreases in the index value were found at four sampling locations in the Indian River.



Eelgrass (a type of bay grass) is an important species that provides fish and shellfish habitat and stabilizes bay sediments. By the late 1970s, eelgrass was gone from the Inland Bays, a victim of disease and nutrient pollution.



The water quality index and its sub-indices do not yet consider other factors that allow eelgrass reestablishment and growth, such as water depth and bay sediment type. These factors are being assessed and will be used to refine this indicator and develop goals for eelgrass restoration activities.

Seaweed abundance was much lower in 2009 compared to 1999. However, in 2009 levels of seaweed were still high enough to prevent bay grasses from reestablishing in many locations.

Seaweeds are algae that are a natural part of the Bays' ecosystem and are an important food source and habitat for many invertebrates, fish, and waterfowl.

When concentrations of the nutrients nitrogen and phosphorus go up in bay waters, seaweeds can increase their growth rapidly. So the amount of seaweed present is a good indicator of nutrient over-enrichment. With excess nutrients, seaweed growth increases and bay grasses decline.

Seaweeds can become so abundant that they smother shellfish, remove oxygen from the water, and foul shorelines when they are washed ashore. In the late 1990s these conditions existed in the Bays.

Seaweed abundance was much lower in 2009 compared to 1999. However, in 2009 levels of seaweed were still high enough to prevent bay grasses from reestablishing in many locations.

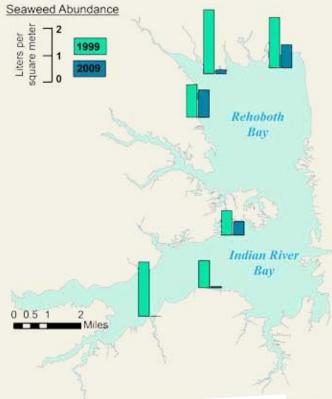
Seaweed in the bays may be decreasing in response to decreases in nutrient loads. However, measurements of the concentrations of nutrients in the Bay waters have not shown significant decreases.

#### LOOKING AHEAD:

The outlook is for even less seaweed in Rehoboth Bay when the Rehoboth Beach wastewater discharge is removed by the year 2014.



Heavy to moderate accumulations of seaweed in Indian River Bay 2009. Dark areas indicate seaweed lighter areas indicate bare bottom. Photo by Melanie Thymes





DNREC Scientist, Robin Tyler, conducts rapid surveys of macroalgae volume using a grappling hook method that he developed, Rehoboth Bay, 2009.

# By the late 1970s, eelgrass and most other bay grass species could not be found in the Inland Bays.

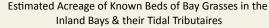
Bay grasses are a 'canary in the coal mine' for assessing the health of the Bays. All of the species of bay grass that grow in our region require relatively clear water with low nutrient concentrations, so they are an excellent indicator of water quality.

If healthy bay grasses are abundant, then nutrient levels are generally considered acceptable. One of the most widely valued of the bay grasses is eelgrass. Over the 1900s eelgrass began to decline as a result of disease and increasing nutrients in the Bays. By the late 1970s, eelgrass and most other bay grass species could not be found in the Inland Bays.

When it seemed that water quality might be improving in the late 1980s, conditions for eelgrass reestablishment seemed possible; however, since no source of seeds existed in the Bays, a natural recovery was very unlikely. Scientists obtained seeds and plants from out of state to start founder colonies in the Bays.

Unfortunately, nutrient levels were still too high for eelgrass survival in much of the Bays, and overabundant seaweeds smothered many restoration attempts.

Efforts through the 1990s were able to restore 1 acre of eelgrass in Indian River Bay off Pasture Point. In 2008, the existence of a previously undocumented meadow of Horned Pond Weed, a bay grass preferring lower salinities, was discovered in upper Love Creek.





For comparison, the Maryland Coastal Bays had over 10,000 acres of bay grass in 2006.

#### LOOKING AHEAD:

Since the 1990s, conditions for bay grass appear to have improved in parts of Rehoboth and Indian River Bays because seaweed levels have decreased. Bay grass restoration is again underway and the CIB will develop a habitat suitability map to help select planting sites most likely to be successful.

Young fish and shellfish rely on healthy dissolved oxygen levels in their bay nursery grounds.

Levels of dissolved oxygen that are normal and relatively stable are important to support healthy and balanced populations of aquatic life. Young fish and shellfish rely on healthy dissolved oxygen levels in their bay nursery grounds.

Excess nutrients fuel algal growth and eventual decomposition, causing oxygen to drop below healthy levels during the growing season.

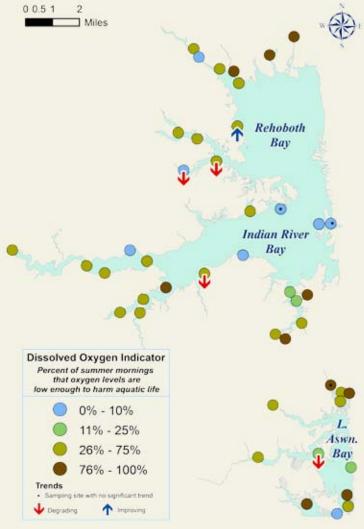
The dissolved oxygen indicator shows the percent of summer mornings that oxygen levels fall below the State of Delaware's standard of 4 milligrams of oxygen per liter of water. Zero to 10% is considered healthy with higher percentages known to increasingly impact the feeding, growth and reproduction of aquatic life.

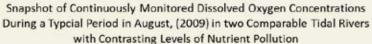
Only a few stations sampled over 1998 to 2008 had dissolved oxygen levels that met the standard almost all of the time.

While much of the open water areas of the Bays are known to have healthy dissolved oxygen, many areas close to the shoreline and most tributaries have unhealthy oxygen levels which are sometimes severe.

Of the sites with significant trends, only one showed improvement with increasing levels of oxygen on summer mornings, while four showed decline with decreasing oxygen levels during summer mornings.

Low dissolved oxygen remains a severe problem for the tributaries of the Inland Bays and overall is not improving.







Nutrient pollution causes oxygen levels to decrease and fluctuate wildly. This causes habitat loss and degradation for many types of fish, shellfish, and invertebrates.



Mariners Cove fish kill

# Understanding Dissolved Oxygen

Aquatic animals need healthy levels of oxygen to grow and reproduce.

- There is a daily cycle of oxygen in bay waters controlled by aquatic life. During the day aquatic plants photosynthesize to produce oxygen. During both day and night plants and animals respire to consume oxygen. The result is that oxygen levels fluctuate from their highest point during the day to their lowest point during the early morning.
- When nutrient levels in the water are normal, oxygen levels fluctuate slightly creating a stable and healthy environment for aquatic life.
- When nutrient levels go up, algal blooms occur. They cause oxygen to be much higher than normal during the day, and much lower than normal at night and in the early morning.
- Animals that cannot avoid low oxygen conditions (clams, worms, and very young fish) suffer reduced growth and may die. Animals that can avoid these conditions must flee their preferred habitat, which can reduce their growth.

 Reducing nutrient pollution can restore healthy, stable oxygen levels and important habitat for aquatic life.



Certain animals have a way of capturing our imagination. Some inspire us with their physical beauty and strength, others speak to our hearts, and still others to our appetite.

Living resources respond to changes in the Inland Bays, in the nearby coastal waters, and in the climate. In turn, the Bay ecosystem and the people that use it are affected by changes in individual species.

Certain animals have a way of capturing our imagination. Some inspire us with their physical beauty and strength, others speak to our hearts, and still others to our appetite. These living resources are useful indicators for the quality of bay ecosystems, in part because they are easy for us to observe.

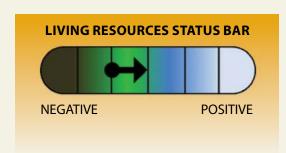
### The living resource indicators of the Inland Bays present a mixed picture.

Eagles and ospreys have rebounded from toxic pollution, but waterfowl populations generally have not recovered from habitat degradation and overhunting. The Inland Bays continue to be a premier east coast fishing destination, but icons like the weakfish are in decline and the blue crab population of Indian River and Rehoboth Bays appears to be decreasing. While the Inland Bays Oyster Gardening Program demonstrates that oysters can grow successfully in all three bays, wild oysters are still very rare.

On the positive side, the ongoing fish and crab kill from oncethrough cooling water withdrawal at the Indian River Power Plant is in the process of coming to an end. This single action is anticipated to be a major improvement to the fishery of the Indian River.

### LOOKING AHEAD:

Living resources present a mixed picture with some selected indicator species increasing, some decreasing, some sustained at apparently normal levels, and some at greatly reduced numbers. The reduction in once-through cooling water withdrawal (and its eventual end) at the Indian River Power Plant, and the success of the Oyster Gardening Program warranted the increasing trend.







Eagles and ospreys are good indicators of environmental quality because they are at the top of the estuarine food chain and are therefore exposed to high concentrations of contaminants by biomagnification through their diet.

Bald eagles and Ospreys are large birds of prey that can be seen flying over the bays with fish in their talons. They are favorites of wildlife watchers who statewide contribute over \$200 million to Delaware's economy each year.

Eagles and ospreys have undergone a tremendous national resurgence after their populations plummeted from the 1950s through the 1970s in response to the toxic effects of DDT pesticides on their reproduction.

They are good indicators of environmental quality because they are at the top of the estuarine food chain and are therefore exposed to high concentrations of contaminants by biomagnification through their diet.

Department of Natural Resources and Environmental Control's Natural Heritage and Endangered Species Program nest surveys show that the osprey population fluctuates annually, but has remained stable since surveys began in 1991. The bald eagle population has increased, with eagles seeming to choose nest sites near tidal creeks and sources of fresh water. For both species, the number of chicks per nest fluctuated annually but was stable over the long term.

### LOOKING AHEAD:

Populations appear to have recovered from pesticide contamination. The outlook is one of stability with some concern about the influence of increased development on the growth of the bald eagle population, as they require nesting habitat with limited disturbance.



Number of Active Bald Eagle Nests in the Inland Bays
Watershed over Time

1999

2007

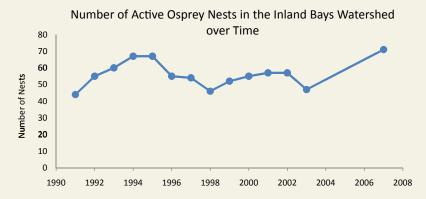


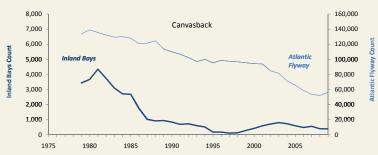


Photo by Dennis Bartow

The Bays are an important stop over and wintering ground for at least 25 species of ducks and geese. Observing and hunting these winter visitors are activities important to the local culture and economy.

Winter waterfowl surveys are not the best measures of total populations, but they are useful to measure changes in waterfowl management and the environment.

Comparing local counts of certain sensitive waterfowl species to counts from the entire Atlantic flyway can help to reveal responses of waterfowl to changes in the local environment.



Note: Winter Waterfowl Counts for the Inland Bays and the Atlantic Flyway over Time

### Canvasback

A species prized by waterfowlers, canvasbacks are wary of humans and require foods provided by marshlands and bay grasses. Their numbers declined from 1975 to 1990, but now appear stable at much reduced levels.

(continued on page 40)



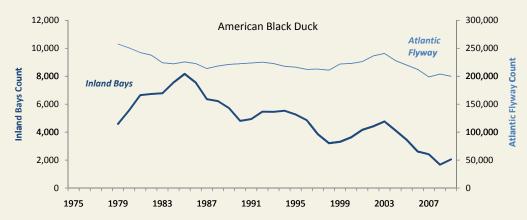
Living Resources

### **American Black Duck**

The Inland Bays watershed has a year-round resident population of Black ducks, as well as a migrating population that arrives to our coves and saltmarshes in the fall and winter. Both local and Atlantic Flyway populations decreased from 1975 to 2009, with a much greater rate of decrease around the Bays. Overhunting, inbreeding with mallards, and loss of marsh habitat are thought to be reasons for the population decrease. As their marsh habitats continue to degrade, the current outlook for Black ducks is not good.



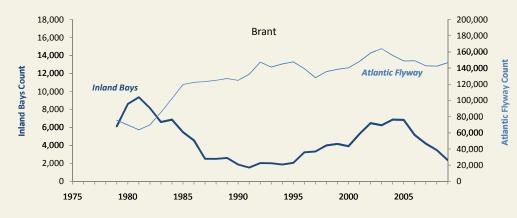
Photo by Henry T. McLin



### **Brant**

Brant are geese that live exclusively in coastal environments where they prefer to feed on eelgrass. The Brant population collapsed following the collapse of the eelgrass population in the 1930s. Since then, Brant have expanded their diet to include more seaweed and lawn grasses and have increased their numbers. But the Inland Bays population remains low, possibly due to the continuing lack of eelgrass.





Note: Winter Waterfowl Counts for the Inland Bays and the Atlantic Flyway over Time

Data are 5-year moving averages.

Landings of hard clams peaked in 1956 when nearly 18 million clams were harvested commercially. Today, the commercial harvest is around 1 million clams per year.

The hard clam, also called littlenecks, cherrystones or chowder clams depending on their size, is the most important commercial and recreational shellfish species in the Inland Bays. Clams are filter feeders and they help to improve water clarity by filtering suspended particles from the water.

Hard Clam Landings

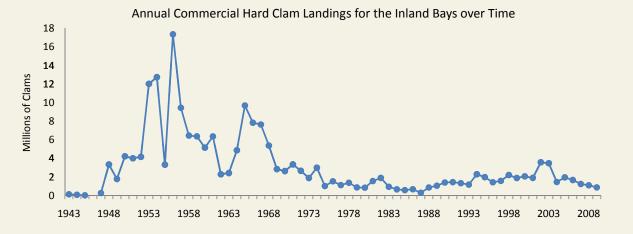
Landings of hard clams peaked in 1956 when nearly 18 million clams were harvested commercially. During that period, many oystermen turned to clamming after the oyster population collapsed due to disease. Clam landings have since declined due to the combined effects of over harvest, closure of harvest areas due to poor bacteriological water quality, and slow recruitment of new clams to the population.

Today, the commercial harvest is around 1 million clams per year. Clam landings per trip have recently decreased, coinciding with a decrease in the number of trips beginning in 2003. Clamming remains a viable means of income for a few, and a treasured pastime for many.

### LOOKING AHEAD:

A joint CIB-DNREC study is underway to determine the change in the actual clam population, which will provide a better indicator of the condition of the resource than landings alone can provide.





Great oyster reefs used to be scattered around the Bays and a healthy fishery existed until oyster disease devastated the population in the 1950s.

Oysters can filter up to 50 gallons of water per day, pumping water through their gills to filter out plankton and other tiny particles that they feed on. Acting like a filter in a fish tank, this process improves water clarity. Oysters also build reef ecosystems that are hotspots of nitrogen removal as well as desirable habitat for many estuarine species.

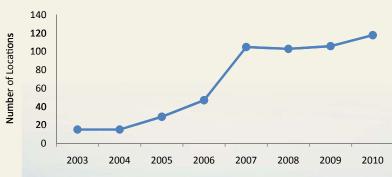
Great oyster reefs used to be scattered around the Bays and a healthy fishery existed until oyster disease devastated the population in the 1950s.

Volunteer oyster gardeners now grow oysters in dockside floating cages. When oysters are full-sized, they are transplanted around the Bays in an attempt to reestablish self-sustaining populations. Since the program began in 2003, the number of gardening sites has grown to 118, and there is evidence that wild oyster populations are beginning to reestablish.

### LOOKING AHEAD:

In the future, plans are for this indicator to be expanded to include the number of successfully established restoration sites.

### Number of Oyster Gardening Locations on the Inland Bays over Time





 $\hbox{E.J.}$  Chalabala, CIB and John Ewart, University of Delaware seed rip-rap with oyster spat.

In the early 1920s, crab shipments from the Inland Bays averaged about 60,000 crabs per day at a market value of \$65,000 in today's dollars. Now, only recreational crabbers are permitted to harvest crabs from the Bays.

Blue crabs are a Delmarva icon. Crabs provide food for people, fish, and even oysters which filter crab larvae from the water. Crabs are also voracious consumers themselves, true omnivores, eating anything from young fish, to marsh snails, to detritus.

In the early 1920s, crab shipments from the Inland Bays averaged about 60,000 crabs per day at a market value of \$65,000 in today's dollars. Now, only recreational crabbers are permitted to harvest crabs from the Bays.

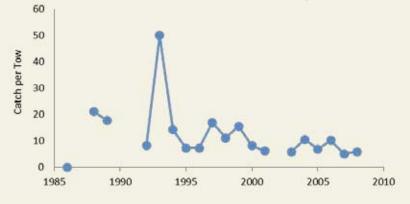
Department of Natural Resources and Environmental Control fish trawl surveys of Rehoboth and Indian River Bay include crab abundance data, which show a continuing decrease in the catch of crabs per trawl from 1986 to 2008.

It is uncertain why the population appears to be decreasing. Reasons could include a possible increase in recreational crabbing as the human population around the Bays has grown, or other unknown factors.

### LOOKING AHEAD:

More recent data not included in this report suggests crab numbers may be rebounding. The crab population of Indian River is expected to get a boost after once-through cooling water withdrawal from the Indian River Power Plant is ended in 2013.

### Average Catch per Trawl Tow of Blue Crabs in Rehoboth and Indian River Bays



### The End of Once-Through Cooling

Once-through cooling water withdrawal uses circulating pumps to move water through a power plant where it is used for cooling and then returned heated back into the waterbody from which it was withdrawn. The Indian River Generating Station operated three electricity generation units that required a maximum of 411 million gallons per day of water from Indian River.

This process annually killed the equivalent of millions of important adult fish and hundreds of thousands of adult blue crabs, and degraded 150 acres of estuarine habitat in Island Creek where the heated water was discharged. The practice affected the bay food chain by reducing the amount of forage fish available for adult fish and decreasing the amount of important fish species that reached adulthood.

To address this longstanding impact, DNREC and NRG agreed in 2010 that NRG would retire the three aging generation units that required once-through-cooling (the oldest of which was built in 1957) by 2013. The power plant's major production unit will continue to run using a closed cycle cooling tower.



Many species of fish use estuaries as nurseries where their young grow rapidly on the abundant food resources of these sheltered environments.

The shallow waters of the Inland Bays provide habitat for at least 112 species of fish.

Many species of fish use estuaries as nurseries where their young grow rapidly on the abundant food resources of these sheltered environments. These fish are very numerous and are an important link in the food chain between plankton, at the bottom of the food chain, and the commercially and recreationally important fish species. Changes in their numbers indicate changes in the environment of the Bays and the nearby coastal ocean.

Trends in the four most plentiful fish of the estuary are presented using data from Department of Natural Resources and Environmental Control trawl surveys conducted at 12 locations in Rehoboth and Indian River Bay. The trawls catch mostly juveniles of some species such as weakfish. Large year-to-year differences in the abundances of many species are common.

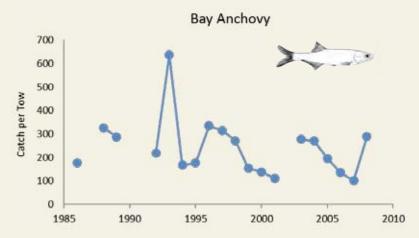
Although years with high numbers of anchovy, spot, and weakfish have not occurred lately, no significant trends in abundance were found. Silver perch have increased significantly in abundance but it is unknown why.



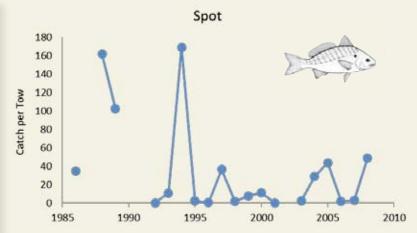
Bluefish

Photo by Richard Ling

### Average Catch Per Trawl Tow of the Four Most Numerous Fish

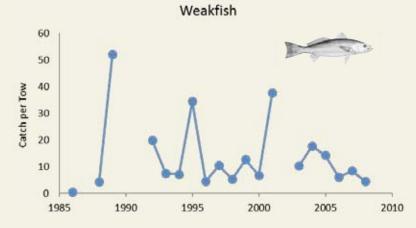


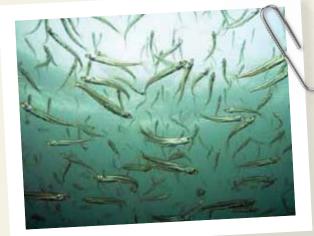
By far, the most plentiful fish caught during surveys, Bay anchovy, spawn and grow in the Bays from April to November, leaving the Bays to overwinter off the coast.



A popular bait fish, Spot, spawn off the coast during fall and winter. In spring, their larvae enter the Bays to feed until they migrate back to the coastal Atlantic in the fall after having grown to 2 to 8 inches in length.

### Species in Rehoboth and Indian River Bays Over Time





Atlantic silversides Photo by www.seagrassli.org

In spring and summer, Weakfish spawn in and near the Bays. The young weakfish often concentrate in tidal creeks where they feed. In the fall, they migrate offshore. Weakfish usually return to the estuaries where they were born. It is unknown why these young fish are now rarely reaching adulthood in the Bays.



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

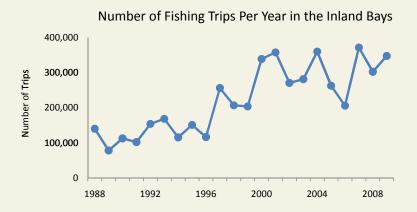
# The success of the fisher is linked to the health of the fishery.

The Inland Bays are a premier fishing destination. On any given summer weekend, hundreds of people hook-and-line for their favorite catch. Bait and tackle shops surround the Bays, some of the many businesses that benefit from the \$97 million spent annually on fishing in Delaware.

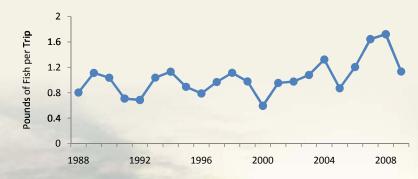
The success of the fisher is linked to the health of the fishery. Many factors, both in and beyond the Bays, contribute to the number of fish that are available and legal to catch.

Since Marine Recreational Fisheries Statistics Surveys were initiated for the Inland Bays in 1988, fishing has increased almost threefold to around 300,000 trips per year. Since the mid-2000s, anglers may have started catching more fish per trip.

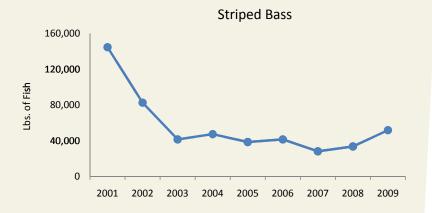
Catches of striped bass have decreased over time. Catches of summer flounder have fluctuated from year to year without a noticeable trend. However, in 2009, more pounds of fish were caught since record keeping began. Catches of weakfish peaked in 2003 at 30,606 lbs and have since declined to zero lbs from 2006 to 2009. Overfishing and an unknown source of mortality are to blame for the near disappearance of adult weakfish. Changes in catch sizes and limits do not appear to be affecting the decreases in catches of striped bass and weakfish.



Pounds of Fish Caught Per Trip in the Inland Bays over Time

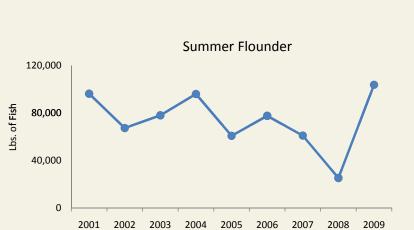


### Pounds of Popular Sport and Food Fish Caught Per Year by Recreational Fishers in the Inland Bays.











Butch Evans of Old Inlet Bait and Tackle. Butch grew up on the Assawoman Canal and has been in the business for 48 years. He can remember the thriving oyster industry of the Inland Bays of the 1950s and how plentiful bay grasses and clear water allowed you to see flounder on the bottom from the surface.

Most fish kills happen during the summer when there are abundant algal blooms, high temperatures, low oxygen, and high numbers of fish.

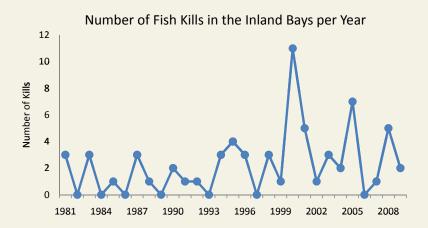
Fish kills are indicative of stress in the bay environment, usually caused by a combination of excess nutrients and weather patterns. Nutrient pollution creates wide swings in dissolved oxygen levels that can lead to fish kills.

Most fish kills happen during the summer when there are abundant algal blooms, high temperatures, low oxygen, and high numbers of fish.

There is significant year-to-year variability in the number of fish kills. Although it appears there were more fish kills in the 2000s, there is not a significant trend over time.

Over three quarters of the fish kills involved just one species, the Atlantic Menhaden. Menhaden are small oily fish that feed in large schools where phytoplankton is most plentiful. Sometimes millions of fish died during one event. When Menhaden numbers in the Bays are high, there is more potential for a fish kill.

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





Menhaden fish kill Photo by Aria Fotografia



Pathogens and contaminants enter the bays from a variety of industrial, urban, and agricultural practices and can have a range of negative effects on the health of aquatic life and people.

Though different in nature and origin, both pathogens and contaminants pose health concerns for people using the Inland Bays. Pathogens may cause acute human illness while contaminants can chronically affect human and environmental health.

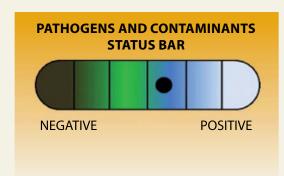
Pathogens are illness-causing bacteria, viruses, and parasites that can be found in the fecal material of warm blooded animals. When water is fouled by waste, there is increased risk that swimmers will be exposed to disease-causing organisms. People can also be exposed to pathogens by eating contaminated shellfish.

Malfunctioning septic systems, waste from pets and waterbirds, manure, runoff from impervious surfaces, and even bay sediments can all be sources of pathogens to the water.

Chemical contaminants include heavy metals, pesticides, and other potentially harmful organic chemicals such as PCBs (polychlorinated biphenyls). Mercury and PCBs have been identified as 'contaminants of concern' present in migratory fish that use the Inland Bays, and arsenic has been identified as a potential 'contaminant of concern' near the Indian River Power Plant.

Contaminants enter the bays from a variety of industrial, urban, and agricultural practices and can have a range of negative effects on the health of aquatic life and people depending on the amount and frequency of consumption.

Pathogens and contaminants are a concern in the Inland Bays, but are much less so than in other waters of Delaware. The number of fish species with consumption advisories has increased due to elevated safety standards. However, the PCB loads of fish are decreasing.



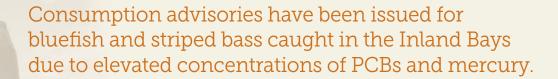
Concentrations of indicator bacteria in bay waters regularly fail to meet safe swimming standards (sometimes by large amounts), but the well flushed areas where most people swim do so infrequently. Approved shellfishing areas have increased slightly since peak closures in the 1990s.

### LOOKING AHEAD:

The outlook for pathogens and contaminants is improving but changes in the indicators may take time to become apparent. The risk associated with heavy metal contamination from the Indian River Generating Station's coal ash landfill is being assessed. Loads of PCBs and mercury in fish are expected to decrease. Recreational water quality is also expected to increase given the conversion of septic systems to central sewer and nutrient management actions. The removal of the Rehoboth Beach Wastewater Treatment plant discharge by 2014 may allow reopening of some waters closed to shellfishing.



Wilis Warren, crabbing on Little Assawoman Bay.
Photo by Cristina Pinkerton



The number of fish species under a 'consumption advisory' is tracked to indicate changes in the risks to people who eat fish caught in the Bays. A consumption advisory is a recommendation to limit consumption to specified quantities, species, and sizes of fish to minimize the risk from contaminants.

Consumption advisories were issued for bluefish beginning in 2007 and striped bass in 2009 due to elevated concentrations of PCBs and mercury.

PCBs are organic chemicals that are now banned from manufacture but can still be found in the environment. Mercury continues to enter the environment from many sources, including the burning of fossil fuels. PCBs and mercury have many negative effects on the health of people and animals including neurological and developmental problems.

Bluefish and striped bass are thought to obtain most of their contaminants from time spent in polluted waters outside the Inland Bays.

Based on data from the entire east coast of the United States, levels of PCBs in these fish are in decline (improving); levels of mercury are not declining.

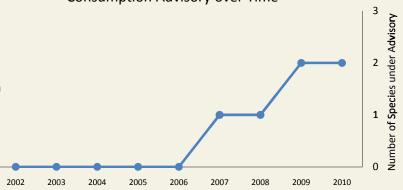
### LOOKING AHEAD:

The outlook is for slow continued declines in PCBs, and eventual declines for mercury as newly required pollution controls are installed on coal fired power plants and other sources.

## Fish Consumption Advisory

In 2009, the State of Delaware advised that individuals eating fish from coastal waters including the Inland Bays 1) eat no more than one meal per month of bluefish less than 14 inches, 2) eat no more than one meal per year of bluefish greater than 14 inches, and 3) eat no more than two meals per year of striped bass. No consumption of bluefish greater than 14 inches and striped bass were recommended for women of child-bearing age and children. A meal is considered an 8 ounce serving for an adult and a 3 ounce serving for a child.

Number of Inland Bays Fish Species Under Consumption Advisory over Time





Ellen Dickey of DNREC and son Jacob Dickey hold a striped bass prior to testing its safety for consumption.

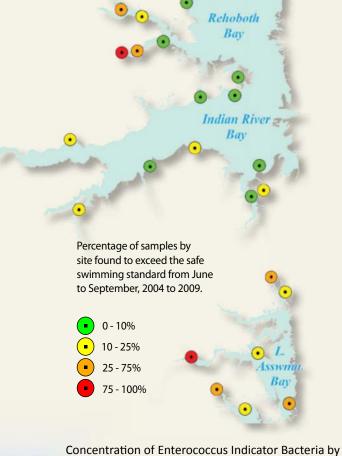
The Inland Bays are perfect for swimming and watersports.

The University of Delaware Citizen Monitoring Program and the Delaware Department of Natural Resources & Environmental Control test waters for levels of *Enterococcus*, a type of bacteria that can indicate the presence of other harmful bacteria and pathogens. A safe swimming standard of 104 colonies of *Enterococci* per 100 milliliters of marine water is used to advise water users.

Data collected from 2004 to 2009 show the percentage of samples that exceed the safe swimming standard for waters of the open bays, residential canals and marinas, and tributaries, and for over 30 individual sites.

No significant trends were found in *Enterococcus* levels from 2004 to 2009. However, 2009 had relatively high levels, exceeding the long-term swimming standard of 35 colonies per 100 milliliters of water in canals & marinas and tributaries. More years of data are needed to better pick out trends. That said, many septic systems have recently been converted to central sewers and manure management has improved; actions that scientists hope will decrease bacterial levels.

Waterborne bacteria and pathogens can come from multiple sources. Malfunctioning septic systems, waste from pets and waterbirds, manure, and even bottom sediments all can contribute bacteria and pathogens to the water. Impervious surfaces such as roofs and roads prevent water from filtering into the soil and thus speed the delivery of wastes to waters as runoff.



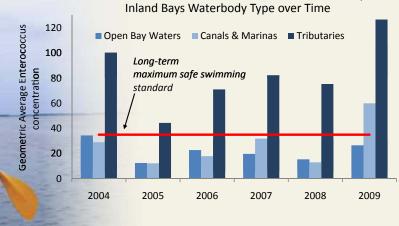


Photo by Karen Knight

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Currently, 28% of waters are closed to shellfish harvesting, 10% of waters are seasonally-approved, and 62% of waters are approved year-round.

Approved shellfish growing waters in the Inland Bays are posted by Department of Natural Resources and Environmental Control to protect public health. The approved waters are based on measured levels of indicator bacteria and an assessment of potential pollution sources.

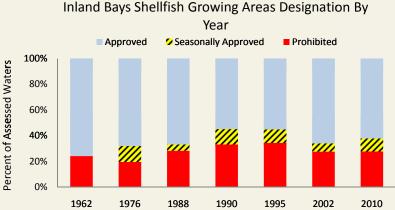
Shellfish may be harvested from approved waters yearround because long-term water sampling and the absence of significant sources of bacterial pollution, indicates consistently acceptable water quality.

Seasonally-approved waters are open to harvesting during months when pollution from marinas and other seasonal inputs are minimal (December 1 through April 15). Prohibited waters are closed to harvesting year-round.

The percentage of waters designated as approved or prohibited has changed over time. The construction of marinas, and degraded bacteriological water quality, caused an increase in prohibited and seasonally approved areas from the 1960s to 1990s. Improvements in water quality in the early 2000s reopened some prohibited areas to shellfishing. Currently, 28% of waters are closed to shellfish harvesting, 10% of waters are seasonally-approved, and 62% of waters are approved year-round.

### LOOKING AHEAD:

The outlook is for the reopening of closed growing areas as wastewater discharges are removed from the Bays and septic systems are converted to central sewer.







Climate is always changing, but is now warming rapidly in response to increased greenhouse gasses in the atmosphere. These changes pose new challenges for the restoration of the Inland Bays.

Changes in temperature, rainfall, and weather patterns influence everything from the chemistry of bay water to the location and distribution of ecosystems like saltmarshes and bay grass meadows. Climate is increasingly recognized for its influence on water resources.

Climate is always changing, but is now warming rapidly in response to increased greenhouse gasses in the atmosphere. These changes pose new challenges for the restoration of the Inland Bays.

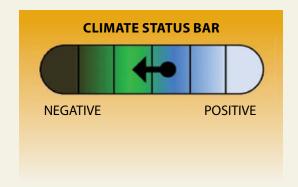
With a warming climate we can expect that the growing season will lengthen. As waters warm they hold less oxygen, and oxygen is depleted more rapidly, increasing stress on living resources in the Bays. Native species may have to compete with species that favor warmer waters. Warmer waters might limit eelgrass reestablishment because the Inland Bays currently have temperatures near the upper tolerable limits for this species. When, and how much, migratory fish and birds use the estuary may change. Increases in droughts and floods could also increase nutrient transport to the Bays.

### LOOKING AHEAD:

To develop strategies for adaptation, research must differentiate between water quality changes due to climate, and changes due to pollution. In turn, restoration goals will also need to change to reflect what is possible under new climate conditions. These changes are likely to make Bay restoration more difficult and could obscure actual progress in managing nutrients and fisheries.

Climate change and sea level rise complicate Bay restoration. Many public and private initiatives are underway to evaluate the potential impact of climate change, but present land use policy continues to encourage development in areas that will be most affected by sea level rise.





### Carbon Dioxide Concentration and Air Temperature

Carbon dioxide emissions caused by human activity in Delaware have decreased by approximately 5% from the early-1990s to the late-2000s.

Carbon dioxide is one of many greenhouse gases that are increasing in the atmosphere due largely to human activities. Because it is a powerful greenhouse gas and is being measured worldwide, carbon dioxide concentration is a good indicator of climate change.

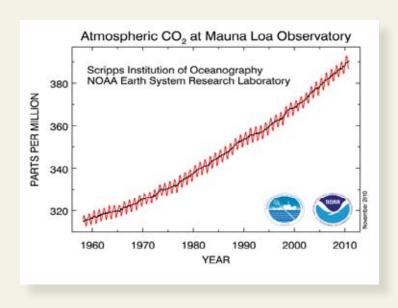
Carbon dioxide in the atmosphere (as measured at Hawaii's Mauna Loa Observatory) has increased from approximately 315 parts per million (ppm) in the late 1950s to 390 ppm in 2010. Studies of deep Antarctic ice indicate these levels are well above the range of variation over the last 800,000 years.

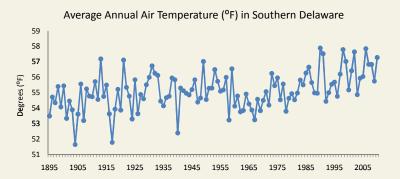
Air temperatures, globally and in Delaware, are also on the rise. The average annual temperature in southern Delaware has increased by approximately 2 degrees Fahrenheit since the 1960s. Climate models suggest that average summertime air temperatures have the potential to increase by an additional 8 degrees by the end of the century. Warmer air will result in warmer water, especially in shallow waters such as the Inland Bays.

Although greenhouse gas emissions may continue to cause warming for decades or more, steps are now being taken to reduce emissions. Human-caused carbon dioxide emissions in Delaware have decreased by approximately 5% from the early-1990s to the late-2000s.

### LOOKING AHEAD:

The State of Delaware intends to reduce its emissions further by mandating that 20% of energy sales to Delaware users be from renewable sources by 2019. A significant reduction in emissions is now being realized in our watershed, where the NRG Indian River power plant is retiring 3 of their 4 coal-fired generating units. These steps demonstrate that Delaware is acting to address this global problem in our state.





Using radiocarbon dating of saltmarsh cores, sea-level-rise over the past 1,000 years was estimated to be about three and half inches per century off Delaware's coast. During the last 100 years, sea-level-rise accelerated to 1 foot per century, according to tide gauge data from Lewes.

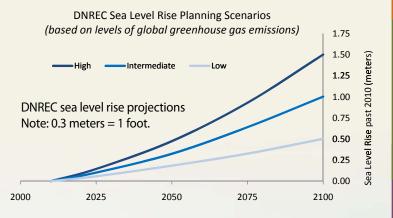
Warmer water temperatures raise the level of the sea by expanding ocean water and causing land-locked ice to melt into the ocean. Land subsidence also raises the level of the sea. relative to the land.

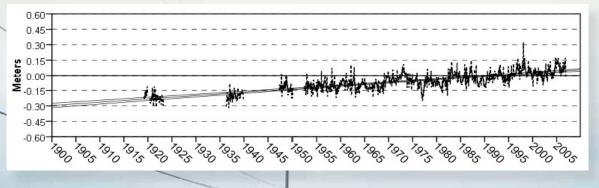
Sea level rise projections adopted by Department of Natural Resources and Environmental Control (DNREC), depend largely on how much more greenhouse gas is added to the atmosphere globally. The highest sea-level rise projection adds almost 5 feet (1.5 meters) of sea level rise by the end of the century.

Because the Inland Bays watershed is both low-lying and populated, it is very susceptible to the impacts of sea level rise. Even a 3.28 foot (1 meter) rise in sea level, DNREC's intermediate projection, would dramatically affect existing waterside communities and ecosystems.

### LOOKING AHEAD:

Accelerated sea level rise increases the difficulty of balancing environmental quality with coastal development. Proactive land use planning and land preservation to prepare for sea level rise can help to minimize the societal costs of sea level rise while maximizing future environmental quality.





Monthly average sea level from tide gauge measurements at Lewes, DE (with seasonal variations removed) showing trend with 95% confidence intervals. Data are relative to the mean sea level from 1983 to 2001 (0.3 meters = 1 foot). Sea level rise is 1.05 feet per century.



# Overall, the wide array of pollution control efforts being implemented are bearing fruit as nutrient loads to the Bays decrease.

The water quality in the Inland Bays remains fair to poor, with the best conditions occurring in waters nearer the Indian River Inlet and the worst conditions occurring in Bay tributaries. Low dissolved oxygen conditions remain widespread. Very few bay grass meadows exist and no areas support water quality found to allow reestablishment of bay grasses with good confidence. Seaweed levels are still limiting to bay grass restoration in many areas, but have decreased significantly. Algae levels in Little Assawoman Bay have also decreased. The water quality index for Indian River Bay shows a decline in water quality.

### Recreational water quality ranges from good to poor, but is fair to good in the open bays where most people swim.

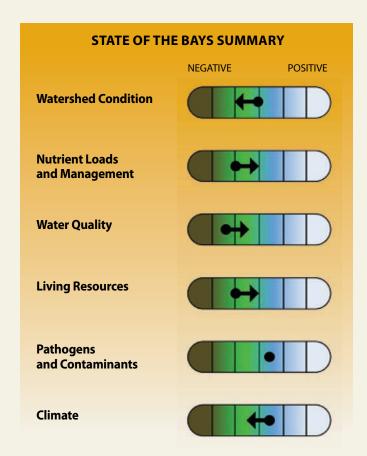
Two species of fish have consumption advisories due to pollutant loads likely obtained outside the estuary. Approved shellfish growing areas are at 62% of assessed water.

### Recreational fishing is increasing while commercial clamming appears to be declining somewhat.

Management of important fish stocks shows mixed success with summer flounder improving and the weakfish population collapsed. Blue crabs appear to be decreasing in number. Eagles and ospreys continue their recovery while populations of waterfowl indicator species remain well below historic levels.

Big improvements in nutrient management have occurred and are showing positive results in decreasing nutrient loads from all sources in most bays. By the next State of the Bays report, it is expected that all point sources will be addressed and that pollution reduction goals for atmospheric deposition will be met. Non-point source nutrient loads appear to be decreasing in response to 1) reduction in manure and fertilizer application resulting from improved agricultural nutrient management and 2) cropland conversion to developments.

However, the significant changes in nutrient loads to the estuary have not resulted in significant changes to the nutrient concentrations in the estuary, and it is not clear why.



The growth in human population in the watershed and associated environmental impacts such as deforestation and wetland loss have increased with consequences to the Bays that are not fully understood. The local climate appears to be warming and scientific models predict increases in the rate of sea level rise that will have important consequences for living resources.

### Overall, the wide array of pollution control efforts being implemented are bearing fruit as nutrient loads decrease.

It is thought that the small improvements in some water quality indicators that are now being observed will continue if these efforts can continue as planned. These improvements should allow for success in the bay grass and shellfish restoration efforts that are now underway.

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**Ed Whereat** 

Ed Lewandowski, Executive Director Sally Boswell Eric Buehl E.J. Chalabala Jennifer Jones **Rov Miller** Loretta Smith Glenn Christmann, Volunteer

Tom Greco, Volunteer **University of Maine** 

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"The quiet, modest estuary is, in reality, a powerful biological engine driven by currents, the sun, land drainage and the tide-nudging moon."

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CENTER FOR THE INLAND BAYS

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Delaware Center for the Inland Bays 39375 Inlet Road Rehoboth, DE 19971

302-226-8105 www.inlandbays.org

The Delaware Center for the Inland Bays is a non profit 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.