THE LAND PERSPECTIVE:

Watershed health influences bay health

THE MARYLAND COASTAL BAYS 2016

This booklet provides an overview of the current science and management issues in the Maryland Coastal Bays and their watersheds in 2016. Previous assessments include the *2004 State of the Maryland Coastal Bays* and the 2009 book, *Shifting Sands: Environmental and cultural change in Maryland's Coastal Bays*. Both of these previous publications and this booklet, *Maryland Coastal Bays 2016: Land and bay perspectives* are available on IAN Press (*ian.umces.edu/press*).

Recognizing the importance of both a bay perspective and a land perspective, this booklet provides current data and insights into a) how bay health is influenced by ocean and land and b) how watershed health influences bay health. It includes two 'booklets' in one publication—one intended for those interested in the bay perspective, and the other for those interested in the land perspective. The two documents culminate in a summary centerfold which focuses on both watershed and bay issues.

Source material for this booklet is derived the 2015 Comprehensive Conservation Management Plan and the 2016 Ecosystem Health Assessment—both available at *http://mdcoastalbays.org/publications*. Data used in this publication is through 2013.

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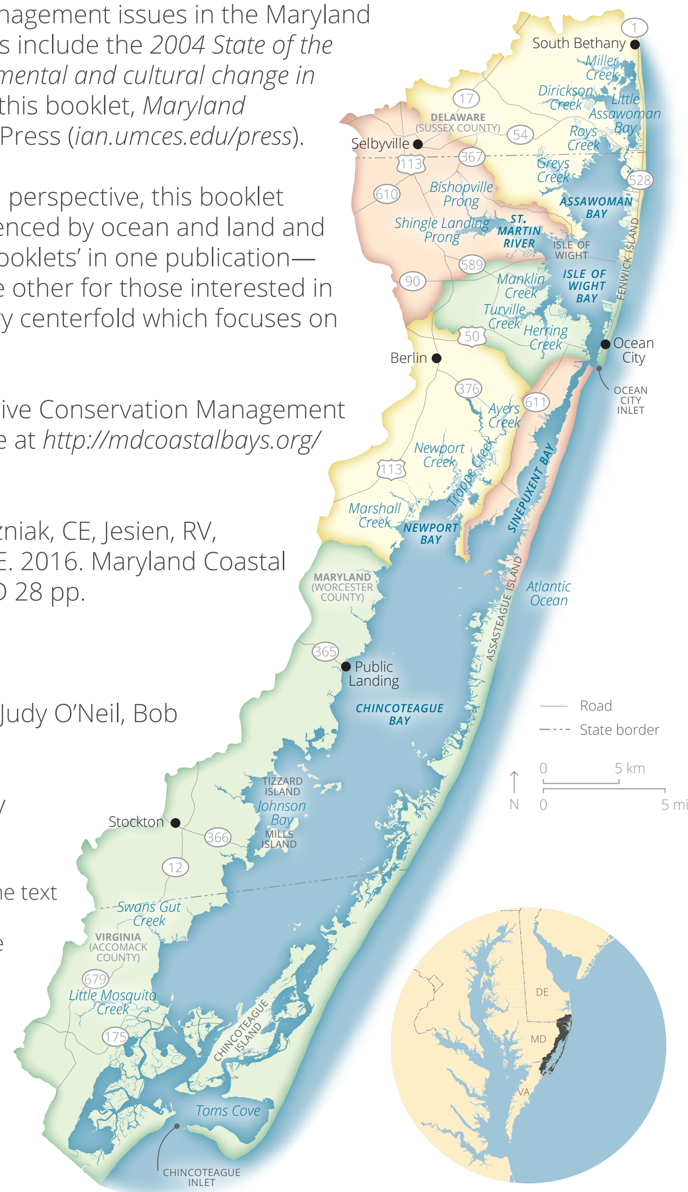

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University of Maryland
Center for Environmental Science

IAN PRESS

MARYLAND COASTAL BAYS PROGRAM

MARYLAND Department of Natural Resources

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NATIONAL PARK SERVICE

CITATIONS

Homer CG, Dewitz JA, Yang L, Jin S, Danielson P, Xian G, Coulston J, Herold ND, Wickham JD, and Megown K. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, v.81, no.5, p.345–354.
Sanford, W.E., Pope, J.P., Selnick, D.L., and Stumvoll, R.F., 2012, Simulation of groundwater flow in the shallow aquifer system of the Delmarva Peninsula, Maryland and Delaware: U.S. Geological Survey Open-File Report 2012–1140, 58 p., available only at http://pubs.usgs.gov/of/2012/1140.

PHOTO CREDITS

Watershed cover: Jane Thomas and Adrian Jones.

HOW WE USE THE LAND AFFECTS COASTAL WATERS

Land use decisions affect bay habitat and the fish and animals that live there. Various land uses result in nutrient runoff. Shoreline stabilization that uses hard substrate decreases habitat for many fish and other species. Hard shorelines increase wave refraction which decreases the nearby area as potential seagrass habitat. Additionally, wetlands cannot migrate up the shoreline as sea level rises. Development in the floodplain and creation of dead-end canals has led to poor habitat and fish kills.

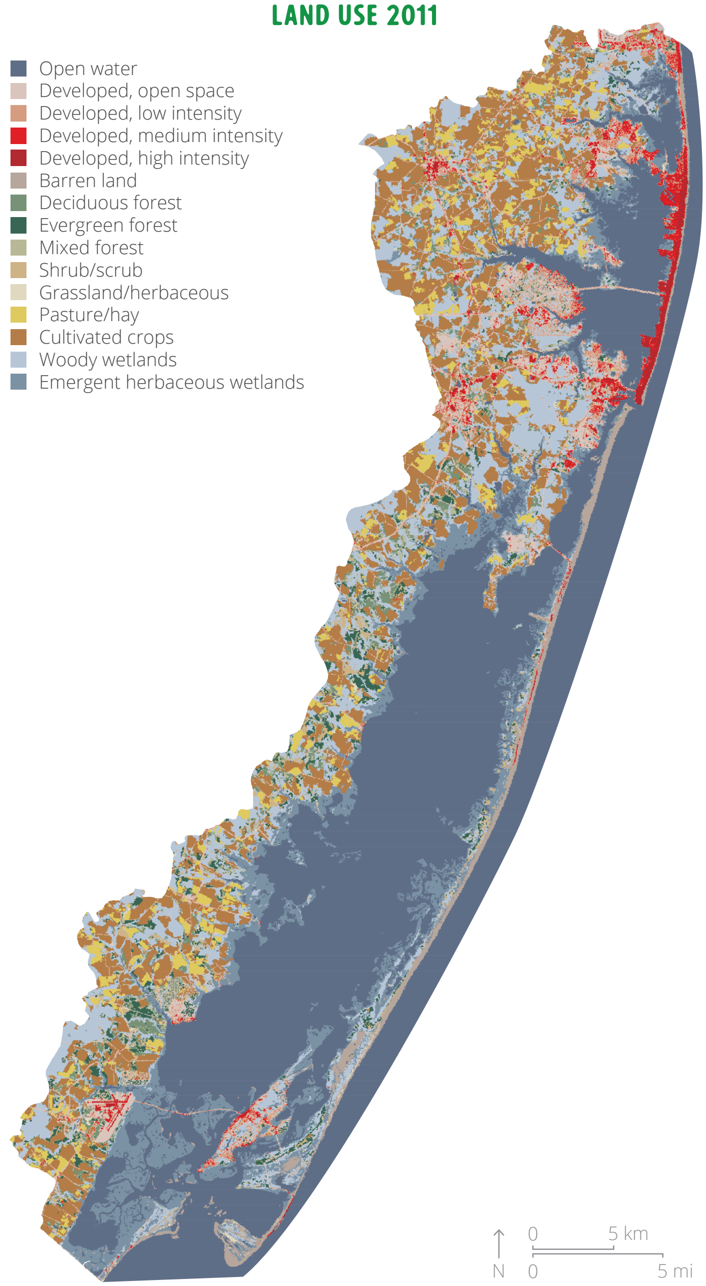
The health of the Coastal Bays remains largely influenced by activities that occur within the watershed (the area of land that drains into the bays). Nutrients and chemicals are transported into the bays via surface runoff (water running over land to creeks, rivers and streams) and groundwater (water that flows below the earth's surface), while runoff also carries sediments. Enhancing land drainage allows runoff to reach the bays quicker than in the past and may even disrupt shallow groundwater flow. Most streams suffer from poor habitat and water quality due to septics, ditching, and increased fertilizers (lawns, golf courses, and farms) that wash nutrients into the streams and bays. The nutrient components of fertilizers have also changed over the past decade and affect what type of algae grow in the bays, which in turn impacts the fish and shellfish which need healthy algae populations to live.

As the major source of freshwater to the bays, groundwater is also the dominant source of nutrients. Groundwater flows much slower than surface runoff (several years to decades compared to hours to days); therefore, nutrients entering the bays may be from actions that happened on land many years ago. Long-term impacts of farming and development have led to an accumulation of nutrients in groundwater that can impact the bays 10–20 years later.

The biggest concern for the health of the bays is eutrophication resulting from the high nutrient loading. Phosphorus levels in the bays are high. High soil phosphorus levels are typically found on farms that have used manure or poultry litter as a crop nutrient over an extended period. The amount of phosphorus that can be applied to fields that exceed specified thresholds will be limited under new phosphorus requirements. The new requirements utilize the best science and emphasizes that Maryland farmers are committed to restoring our Bays.

Remember that many of YOUR activities affect fish and other resources in the bays! Actions like fertilizing your lawn properly, cleaning out your septic regularly, picking up after your dog, not feeding wildlife like geese, planting natural gardens and trees to decrease runoff, decreasing driving, supporting local farmers, using soft shoreline stabilization methods, and staying off bay islands that have nesting birds have positive effects.

LAND USE 2011



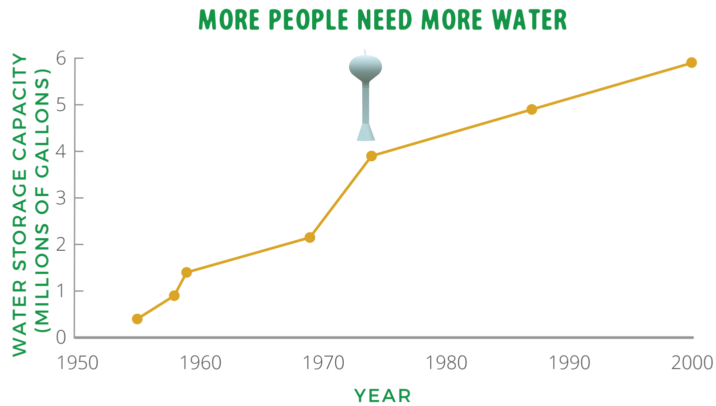
This map shows the diverse land use of the Coastal Bays watershed. Agriculture is the dominant land use, and heavy development can be seen on Fenwick Island/ Ocean City. Data: Homer et al. 2015.

THE FORGOTTEN BAYS HAVE BEEN REDISCOVERED

The Coastal Bays were known as the 'Forgotten Bays'. This reference was in relation to the better-known, nearby Chesapeake and Delaware Bays and to the main attraction of the region—the beaches of Assateague and Fenwick Islands. While the term the 'Forgotten Bays' may have indeed characterized the Coastal Bays in the past, now the Coastal Bays are an attraction in and of themselves. People have rediscovered the natural beauty of the Coastal Bays and their accessibility for boating, fishing, swimming, and bird-watching.

The increased activity in the Coastal Bays watershed is reflected in the growth of water consumption in the region. This growth in water consumption is reflected in the water storage capacity (e.g., water towers), which is needed to support more people spending time in the Coastal Bays watershed. The year-round population does not have to increase, but it can result from people spending more time (e.g., longer weekends, longer summer season) in the region. The population demographics indicate a significant increase in retirees, which could swell the population since the region is popular for retirees who desire access to the beach and a more rural lifestyle.

As a result of the increased presence of people in and around the Coastal Bays, there are more pressures currently and projected into the future. Increased recreational activities (e.g., fishing, crabbing, boating) serve as a pressure on the Coastal Bays ecosystems. In addition, rural shoreline development increase the number of septic systems, fertilized lawns and hardened shorelines can lead to more nutrient runoff, and reduced marsh vegetation means less area to intercept nutrient runoff and provide wildlife habitat.



This graph shows cumulative water storage capacity for the Town of Ocean City. Water storage capacity has increased, reflecting increases in the number of residents and visitors to Ocean City. Source: Town of Ocean City.

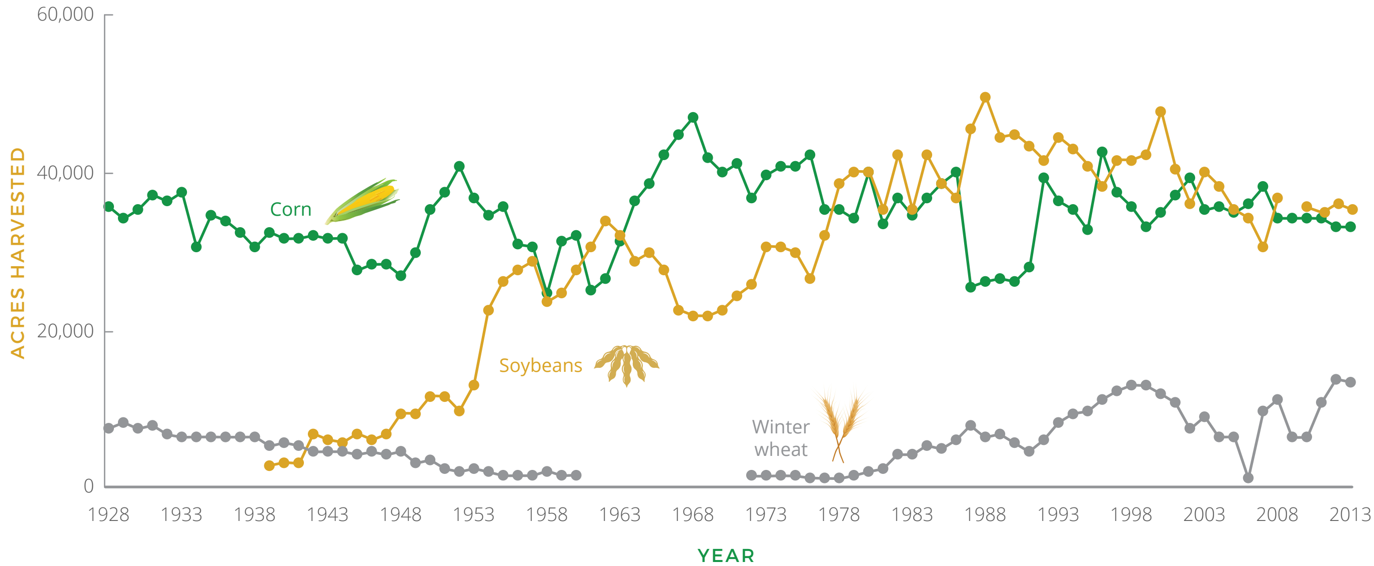
Ecotourism is just one of the ways that people use the Coastal Bays, and it has increased in recent years. Photo by Maryland Coastal Bays Program.

Fishing for blue crabs, or 'chicken-necking' (left) and jetskiing (right) are popular activities in the Coastal Bays. Photos by Sandi Smith and Adrian Jones.

AGRICULTURAL PRACTICES HAVE INTENSIFIED

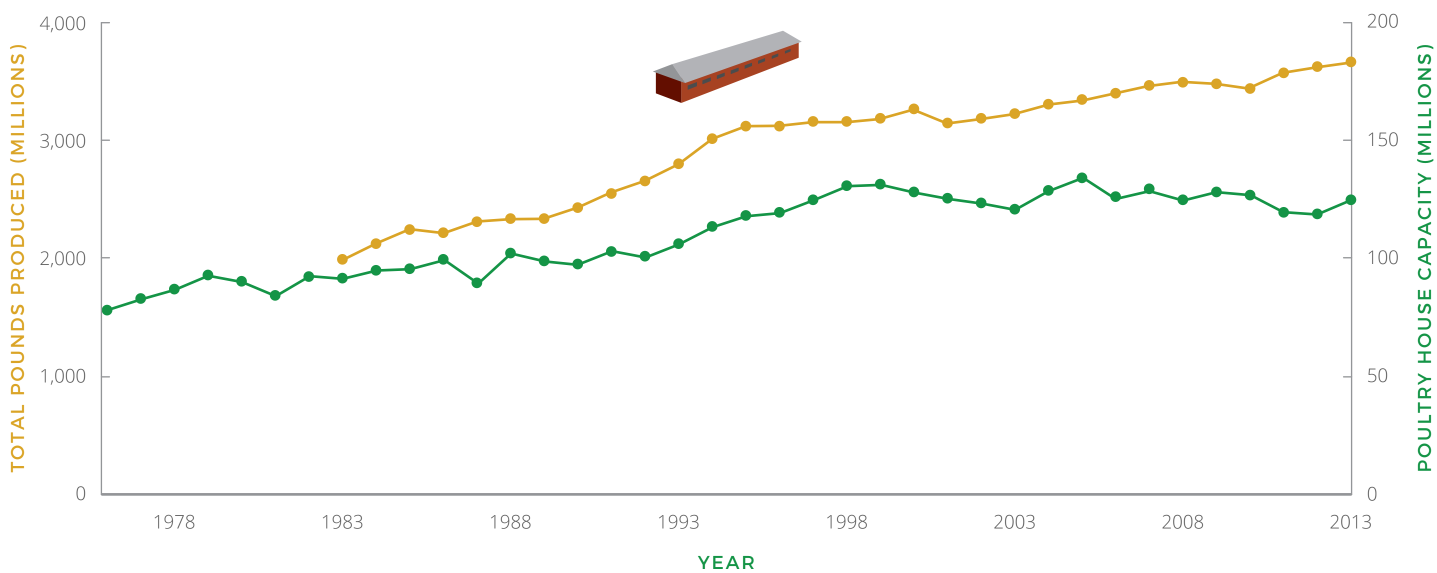
Agriculture has been a mainstay of the Worcester County economy for many years. Corn, soybeans, winter wheat, and poultry have been the major components of this industry. The amount of acres in corn has ranged between 30,000 and 40,000 acres since the late 1920s. Soybean acres increased shortly after World War II and has generally tracked the amount of corn since then. Winter wheat acreage fluctuated the most. The poultry industry expanded rapidly during World War II because of the shortage of beef and pork, which require a much longer time to develop—only seven weeks are required to produce a broiler and five months to produce a laying hen. The industry started on a commercial scale on the Delmarva Peninsula and then spread farther south and southwest. Total pounds of poultry in Delmarva increased steadily from 1983, reflecting the increase in production capacity of each poultry house. The recent increase of winter wheat is related to its use as a winter cover crop to help protect soils and prevent erosion.

AGRICULTURAL YIELDS IN WORCESTER COUNTY



Crop agriculture—in particular, corn, soybeans, and winter wheat—have long been a mainstay of the Coastal Bays economy. Source: USDA.

POULTRY PRODUCTION ON DELMARVA



Poultry production across the whole of Delmarva has been increasing over time, due to the increasing capacity of poultry houses. Note: this data is for the whole Delmarva peninsula, not just the Coastal Bays watershed. Source: Delmarva Poultry Industry, Inc.

LOCALIZED CONDITIONS IMPACT STREAM HEALTH

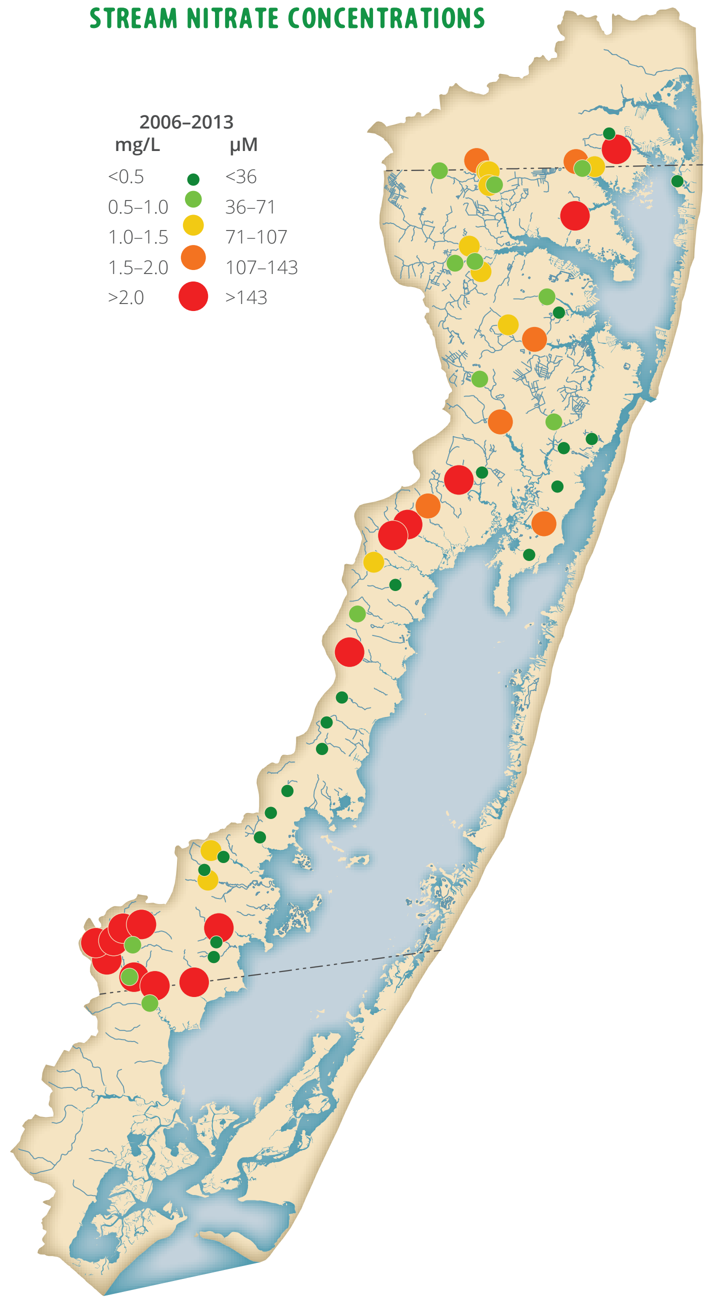
Unlike the neighboring estuaries such as Chesapeake and Delaware Bays, the Coastal Bays have few large freshwater rivers that transport nutrients and sediments. In contrast, the Coastal Bays have small streams that drain small watersheds. As a result, surface waters (and shallow groundwater) are affected almost solely by the adjacent land use. The assessment of stream health is a reflection of conditions very close to each stream.

In Chesapeake Bay, large-scale sewage treatment upgrades have led to major improvements in water quality. This will not likely be the case for the Coastal Bays since there are few large treatment facilities. The largest, in Ocean City, discharges offshore but some fraction may make its way back into the Coastal Bays. Other small sewage treatment facilities discharge to the Coastal Bays, and one has land application outside the watershed. The majority of the watershed has diffuse non-point sources of nutrient input from residential areas and agriculture, so there are no easy fixes to curbing nutrient enrichment in the Coastal Bays. Elevated stream nitrate concentrations are attributable to groundwater input as well as surface runoff. Because of the gently sloping topography and sandy soils of the watershed, most rainwater infiltrates rather quickly into the shallow groundwater picking up nutrients and the rest moves downstream as it picks up sediment. Natural background concentrations of nitrate in streams is 0.6 mg/L with concentrations greater than 1.0 mg/L indicative of human—termed anthropogenic—input (USGS).

Concentrations that are above thresholds for healthy streams may impact stream biota as well as contribute to total nitrogen loads in the bays. Continual monitoring is necessary to determine changes in stream health based on land uses. Enrichment of specific streams in the small watersheds is being used to focus management practices to reduce the nutrient impacts to the downstream bay waters.

Urban streams, which can get choked with trash after storm events, can contribute sediments, toxicants, and nutrients to downstream areas. Photo by Roman Jesien.

STREAM NITRATE CONCENTRATIONS



Average stream nitrate concentrations in Coastal Bays streams between 2006 and 2013.

HOW WE USED THE LAND IN THE PAST AFFECTS CURRENT CONDITIONS

The history of the land is written in the bays. The remnants of historic inlets caused by oceanic storms to old river deltas from the last ice age are still recognized in the bay sediments. Long-term removal of forests and wetlands has led to increased nutrient and sediment runoff to the bays. Nearly all the headwaters of streams feeding the Coastal Bays have been ditched and are poor habitat for fish and other important animals. Phosphorus bans in the mid-1980s decreased blue-green algae blooms and allowed seagrass to flourish in the bays providing habitat for clams, crabs, and fish.

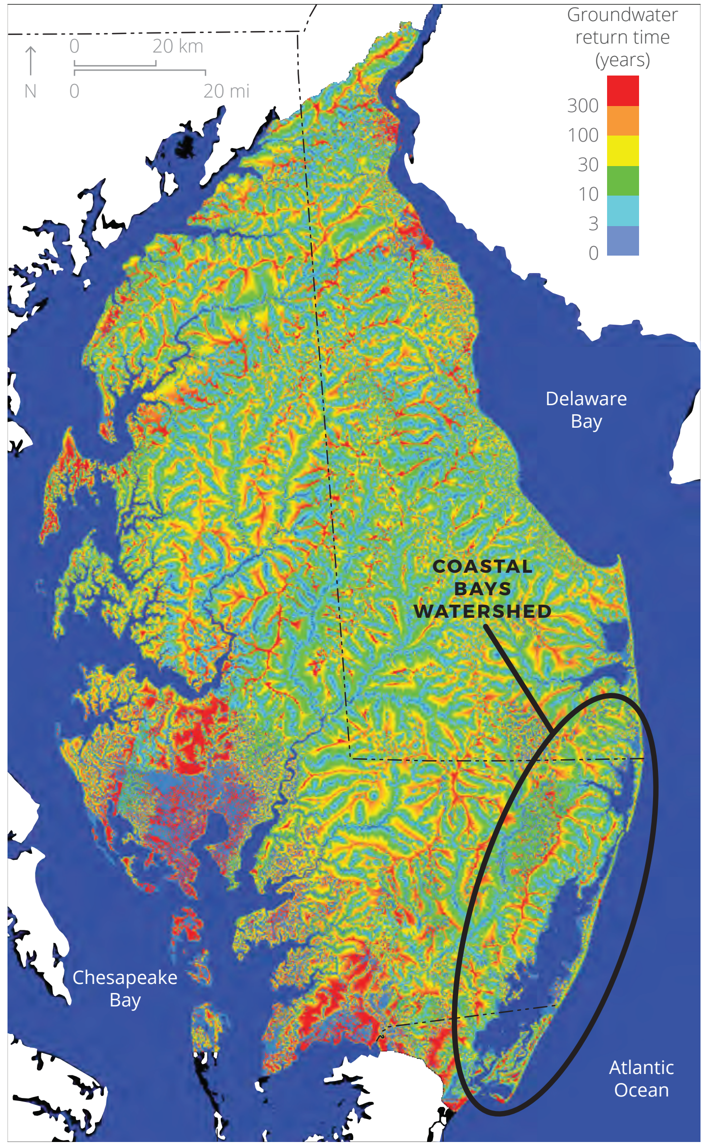
The watershed of the Maryland Coastal Bays has very little relief and very sluggish groundwater movement. As a result of this topography, there are substantial time lags between when nutrients (e.g., fertilizer, chicken manure) are applied to the watershed and when the groundwater containing these nutrients reaches the Coastal Bays. This means that management practices instituted previously will not be manifested in the Coastal Bays until years to decades later.

Furthermore, one of the major agricultural best management practices that has been increasingly implemented is winter cover crops to soak up excess fertilizer at the end of the growing season. Research has shown that it takes up to five successive years of cover crop application before reductions in groundwater nitrate levels are fully realized. This adds more lag times to the realization of impacts of this best management practice.

The exception to the long groundwater lag times is on the sandy barrier islands including Fenwick, Assateague, and Chincoteague Islands. Rapid groundwater percolation through the sandy soils reduces groundwater lag times.

The installation of wells to allow monitoring of groundwater gives information about the concentration of nutrients in the groundwater. Photo by Roman Jesien.

GROUNDWATER FLOW IN THE DELMARVA PENINSULA



Base modified from U.S. Geological Survey 1:100,000-scale digital data

Simulated return time of groundwater travelling from the water table to its discharge location. Groundwater from the Coastal Bays watershed may take decades to reach the bays themselves. Source: Sanford et al. 2012.

Ecological lag times in response to environmental changes also contribute to inertia in ecosystem processes. A build-up of organic matter can lead to nutrient remineralization where the organic matter is slowly decomposed, releasing nutrients and consuming oxygen. The microbial community in sediments and soils will reflect the history of organic and nutrient loading for an undetermined period.

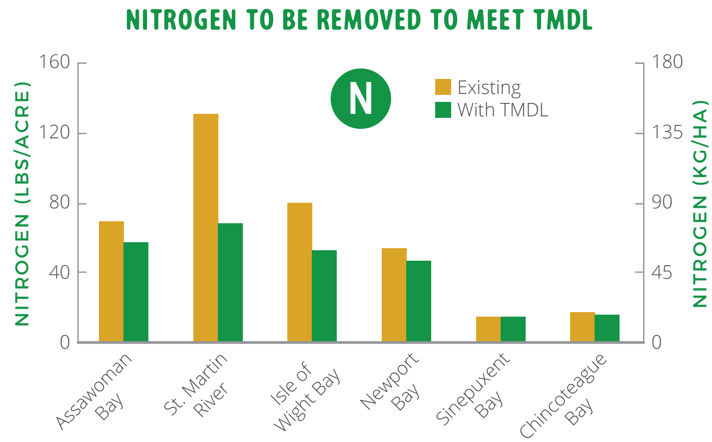
In summary, we cannot expect rapid responses to some of our management actions so patience and persistence will need to be exercised.

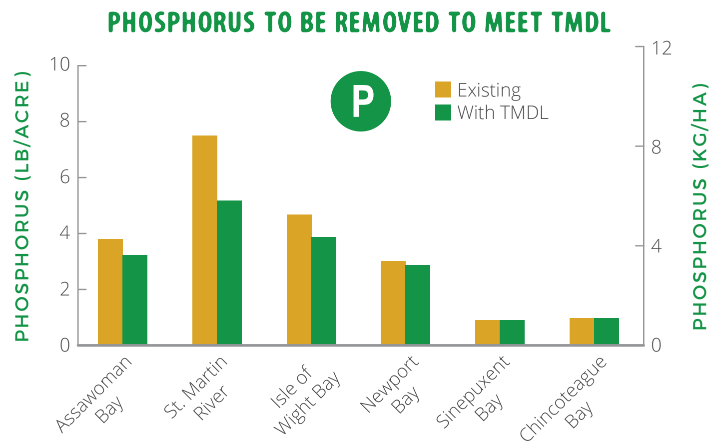
THE WATERSHED IS ON A NUTRIENT DIET

Waterways in the United States that are listed as impaired under the federal Clean Water Act have an opportunity for voluntary clean-up. Following a period of voluntary efforts, if the waterways are still listed as impaired, the U.S. Environmental Protection Agency is authorized to impose a regulatory clean-up. For nutrient impairments, like in the Maryland Coastal Bays, the regulatory clean up is known as a Total Maximum Daily Load, or TMDL. The TMDL does not prescribe how the nutrient reductions are achieved, but it sets the limit on the total amount of nitrogen and phosphorus that can enter the waterways. The TMDL is also known as a 'nutrient diet'. The TMDL targets and allocations are set by a hydrodynamic and eutrophication model developed with consultation with the research and monitoring scientists.

Nutrient targets are set by the relevant state agencies (e.g., Maryland Department of Environment), who are delegated the authority to impose the TMDL through their Watershed Implementation Plans (WIPs). The Maryland Coastal Bays have watershed area in three states: Maryland, Virginia, and Delaware. Thus, the TMDL applies to these portions of those states and the relevant state agencies for implementation. The TMDL sets the geographic and jurisdictional nutrient loads through the WIPs, which must be approved by the U.S. Environmental Protection Agency. The TMDL also has a timetable for nutrient reductions, with interim and end-point goals.

In practice, the federal TMDL agency—the U.S. EPA—delegates the authority to the relevant state agencies, who in turn mandate the local jurisdictions to implement the WIPs. So the counties, towns, and cities are required to come up with solutions, often without funding allocations. This can cause conflict due to 'unfunded mandates'. At the local level, there is considerable opportunity for innovation and creative solutions.





These graphs show the amount by which nitrogen (top) and phosphorus (bottom) loads would need to be reduced to meet the Total Maximum Daily Load requirements.

It is helpful to visualize the provisions of the Clean Water Act as a train, with water quality standards as the 'engine' and each car dependent on the one preceding it. Modified from Georgia Legal Watch.

ADAPTATIONS TO STORM SURGE AND SEA LEVEL RISE ARE NECESSARY

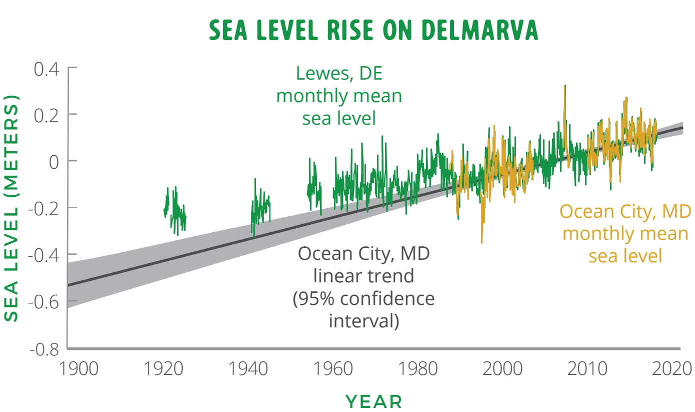
The mid-Atlantic Bight region is subject to rapid rates of relative sea level rise. Relative sea level rise accounts for both subsidence of land as well as gains in elevation of the ocean surface. Long-term rebound from the continental glaciers of North America results in land subsidence in Delmarva, which can be exacerbated by groundwater extraction. Global sea level rise is particularly acute in the North Atlantic Ocean due to greenhouse gas-related surface water warming. In addition, the weakening of the Gulf Stream offshore results in accelerated rates of sea level rise.

Given the pressing nature of relative sea level rise in this region, there is an urgency to develop strategies to adapt to these accelerated rates. Inundation maps reveal the vulnerability of the human infrastructure in the region. In addition, Assateague Island has been temporarily breached in recent storm events. A direct hit by a storm of the magnitude of Hurricane Sandy in 2012 could be devastating to the region.

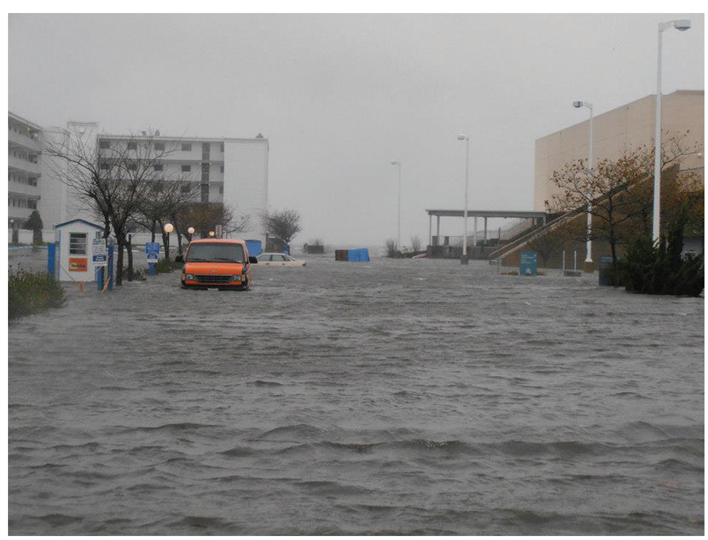
Currently, beach replenishment from offshore sand dredging is conducted north of Ocean City inlet to maintain swimming beaches, but also to protect Ocean City from storm surge. Assateague Island National Seashore transports sand to maintain the north end of the island from washing away due to storm surges and erosion. Additionally, the National Park Service is experimenting with sand berms and sand dune stabilization to protect the island from storm surge.

Maryland escaped major damage during Hurricane Sandy. However, we recognize that the greatest change to the bays could occur during an intense storm event that lasts only a few days, but changes the shape and function of the system for several decades. The ongoing impacts in other areas from Hurricane Sandy are just a glimpse into how climate change and sea level rise alter ecosystem processes and coastal communities. To face these challenges, the Maryland Coastal Bays Program will continue to use the best available science to work towards restoring and protecting this unique ecosystem that we all treasure.

The top photo shows an intact southern end of Assateague Island prior to the blizzard of 22–24 January 2016. That storm breached Assateague Island in several places, as seen in the bottom photo. Photos by Patrick J. Hendrickson/Highcamera.com



Shown here is mean sea level at the Ocean City inlet, MD and Lewes, DE. Sea level at Ocean City is rising at a rate of 5.6 mm (nearly a quarter-inch) per year which is equivalent to a change of 1.84 feet in 100 years. Source: NOAA.



Ocean City suffered severe flooding during Hurricane Sandy, which impacted Maryland on October 29–30, 2012. Photo by Ricky Kerrigan.

DAM REMOVAL RESTORES STREAM HABITATS

The goal of the Bishopville Stream Corridor Enhancement Project was to replace the existing dam with a nature-like fish passageway, consisting of a series of shallow step pools, to allow fish to move upstream. The removal of the Bishopville Dam allows access to more than seven miles of freshwater spawning habitat for anadromous fish species such as alewife (*Alosa pseudoharengus*), blueback herring (*A. aestivalis*), and white perch (*Morone americana*)—these species live in salt water but require fresh water to reproduce. Herring populations are of special concern throughout the East Coast due to loss and degradation of habitat. The project maintained a portion of the existing pond, at the request of local residents, while creating fish passage through a series of step pools that serve as a gently sloping stream corridor to transition from non-tidal to tidal waters.

The non-tidal portion of the project was completed in December 2014, making spring 2015 the first time the area has been accessible to anadromous fish since 1959. The project was deemed successful with alewife, white perch, American eel (*Anguilla rostrata*), and gizzard shad (*Dorosoma cepedianum*) passing upstream in its first season. In addition to fish passage, the project provides increased contact time with bacteria and vegetation to allow for nutrient removal as water flows over the series of vegetated weirs and shallow pools.

From top right, this series of photographs shows the Bishopville Dam before its removal; the restoration project under construction; and the final restored stream with three rock weirs. Photos by Roman Jesien/Maryland Coastal Bays Program.

IMPROVEMENTS TO SEPTIC AND SEWAGE DISCHARGES ARE ONGOING

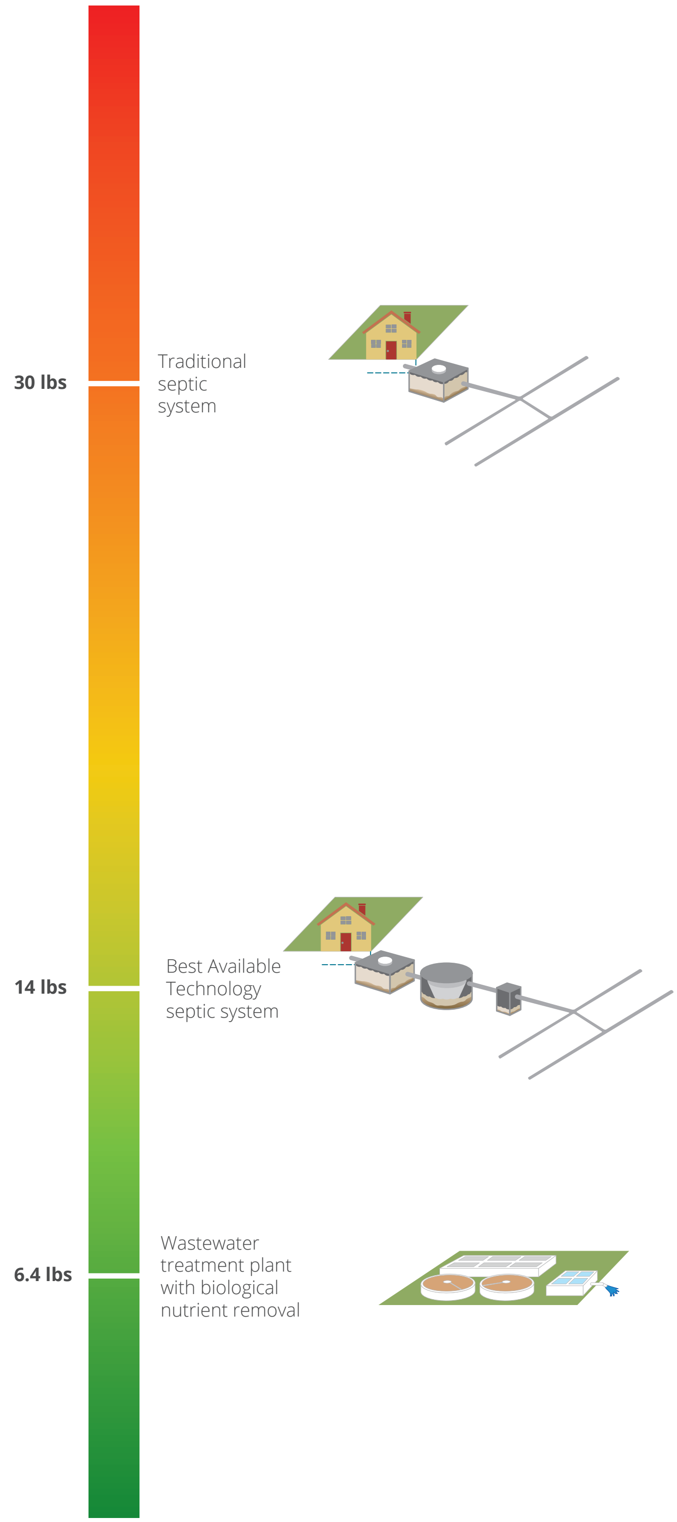
Through the Bay Restoration Fund in Maryland, a $60 annual fee is collected from each home served by an on-site septic system. The total estimated program income is $27 million per year. Sixty percent of these funds are used for septic system upgrades and 40 percent are used for cover crops. There are 420,000 on-site septic systems in Maryland. With priority given to failing septic systems in the Critical Area (all land within 1,000 feet of Maryland's tidal waters and tidal wetlands), Bay Restoration funds can be provided for upgrades of existing septic systems to best available technology for nitrogen removal.

Similarly, a $5 monthly fee is collected from each home served by a wastewater treatment plant, with funds reaching an estimated $100 million per year. These funds are directed towards upgrading wastewater treatment plants to enhanced nutrient removal (ENR) technologies.

The average properly functioning septic system delivers about 30 lbs of nitrogen per year to groundwater. Septic systems that have been upgraded to the best available technology for nitrogen removal contribute about 14 lbs of nitrogen per household per year to groundwater. Wastewater treatment plants with biological nutrient removal contribute about 6.4 lbs per household. In the Maryland Coastal Bays watershed, there are 4,484 septic systems, most of which are in the Critical Area. In the Coastal Bays, 454 new septic systems are proposed to be added by 2025 with an additional 683 systems connected to existing wastewater treatment plants by 2025.

The town of Berlin has diverted all of the effluent from its sewage treatment plant from stream discharge to land application. Trees, shrubs, and grasses take up the nutrients from the treated effluent. Photo by Roman Jesien.

POUNDS OF NITROGEN DELIVERED TO GROUNDWATER ANNUALLY PER HOUSEHOLD



Wastewater treatment plants with biological nutrient removal contribute the least amount of nitrogen to groundwater annually per household—less than 25% of the nitrogen that traditional septic systems contribute to groundwater.

STRATEGIES ARE BEING DEVELOPED FOR CHICKEN WASTE DISPOSAL

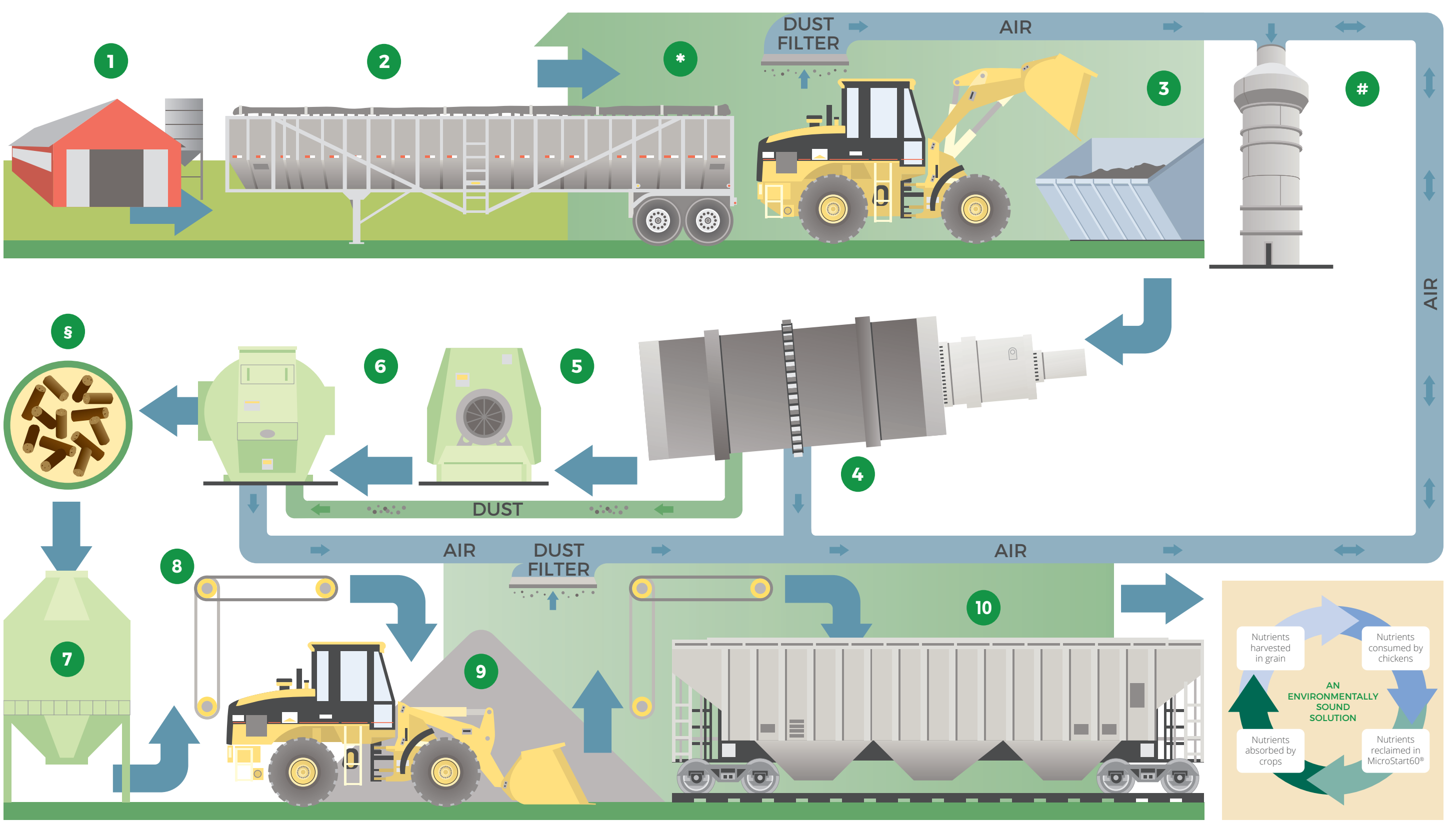
To combat the excess of chicken waste on the Eastern Shore, alternative disposal methods are being developed. A pilot program developed by Planet Found Energy Development LLC began in 2014 at Millennium Farms in Pocomoke, Maryland. The program is designed to transform chicken waste into usable energy while removing excess nutrients through three anaerobic digesters. The chicken manure is heated up inside concrete towers where bacteria begin to decompose the waste, releasing methane in the process. The collected methane can provide enough energy to power the digesters; excess energy will help generate electricity for the farm. Dissolved nutrients are reduced from the manure byproduct before it is applied to the fields as fertilizer. If successful, this program is projected to remove more than 18 tons of phosphorus per year from poultry waste.

Since 2001, Perdue's AgriRecycle plant has been transforming chicken waste into organic fertilizer. Raw manure is transported to the plant and heated to kill any bacteria and seeds remaining in the waste. The treated manure is processed through a pelletizing machine to produce slow-release fertilizer. The fertilizer is then sold to organic farms and home fertilizer companies such as Espoma and Scott's. About half of the fertilizer is exported out of the Coastal Bays and Chesapeake Bay watersheds.

Two other methods are reducing the amount of phosphorus reaching the Coastal Bays. One is to transport the manure out of the Coastal Bays watershed for disposal. The other is to feed the enzyme, phytase, to the chickens to increase their ability to absorb phosphorus, reducing the amount available in the manure and thus applied to fields.

From left to right, Amanda Poskaitis (Maryland Coastal Bays Program), Jeff Smith (Perdue), Jennifer Rafter, Roman Jesien (Maryland Coastal Bays Program), and Wayne Hudson (Perdue) at the Perdue AgriRecycle plant. Photo by Katherine Phillips.

STEP BY STEP THROUGH THE PELLETIZATION PROCESS



1. **ON THE FARM.** Perdue AgriRecycle has signed contracts with poultry producers to remove surplus litter from their farms.
2. **TRANSPORTING LITTER.** Litter is loaded into specially designed, covered, and leak-proof 23-ton capacity aluminum trailers dedicated for transport to the 68,000-square-foot pellet plant, which is the length of 2.5 football fields.
3. **SEPARATING LITTER.** Wet and dry litter is segregated into designated feed hoppers with a front-end loader before moving to the dryer.
4. **DRYER.** The litter, heated from 180 to 225 degrees Fahrenheit to destroy bacteria and weed seed.

INNOVATIONS IN STORMWATER MANAGEMENT ARE BEING IMPLEMENTED

BERLIN INITIATIVES

The town of Berlin passed historic legislation in January 2013 that helps reduce flooding and clean up local rivers and streams. The new ordinance created a stormwater utility that divided the cost of managing stormwater among the town's property owners and helps the town leverage federal and state grants for additional, related enhancements. It is expected that the utility would generate $570,000 annually for capital projects to help curb flooding, reduce erosion and polluted runoff, and combat property damage. Maryland Department of Natural Resources (DNR) and its partners recognized that some jurisdictions don't have the capacity to create large-scale, non-point source restoration and protection efforts. DNR, along with other state and federal agencies, created the Watershed Assistance Collaborative in 2008 to provide services and technical assistance to communities to advance restoration activities and projects. Projects have been identified and prioritized. Upcoming projects include culvert replacement and an offline wetland along Flower Street.

This sequence of photos shows the before (top) and after (bottom) refitting a stormwater culvert in Berlin. The rocks help to slow down the flow of stormwater while plants among the rocks help to reduce the amount of nutrients in the stormwater. Photos by Roman Jesien.

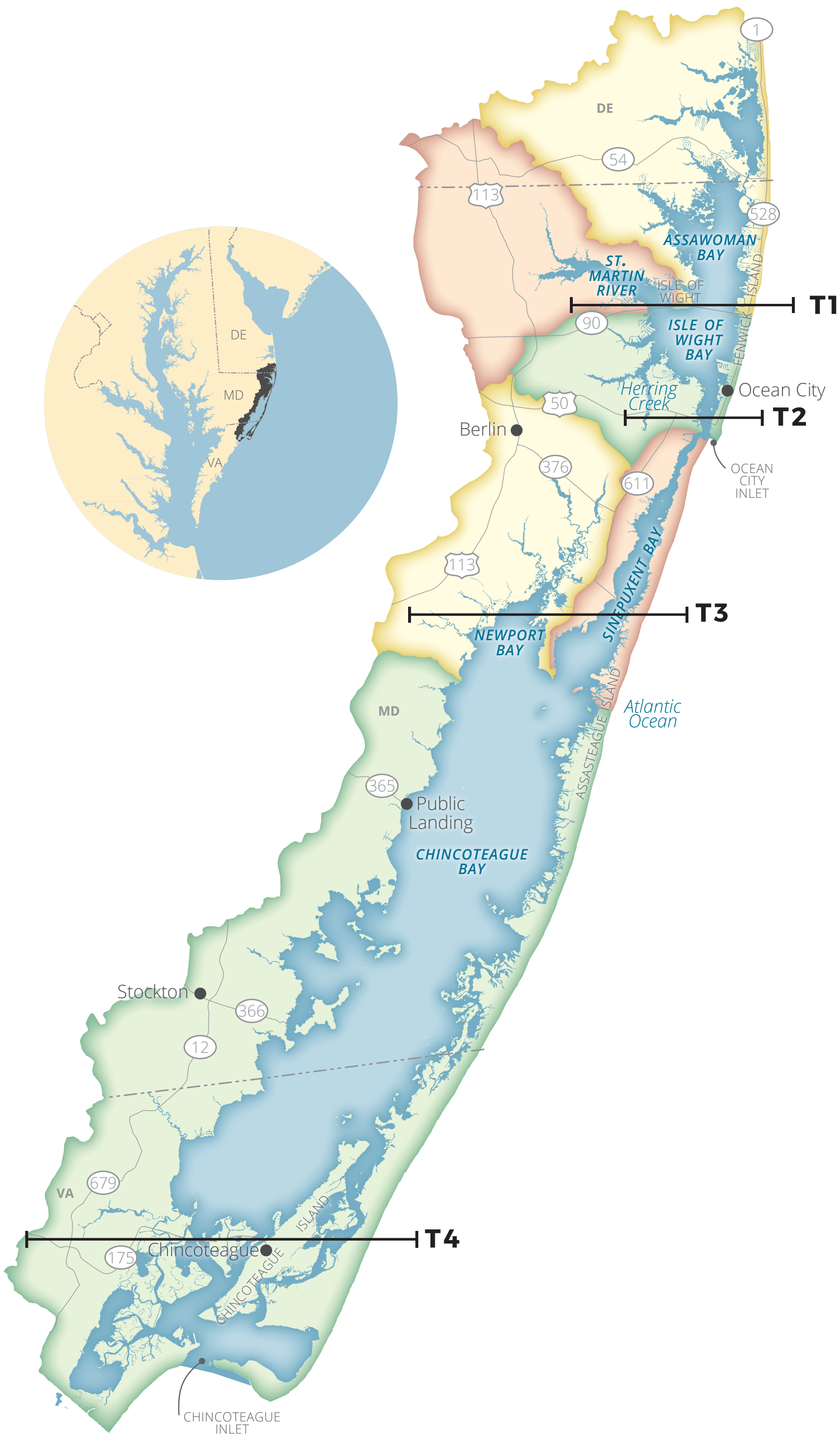
OCEAN CITY INITIATIVES

The Town of Ocean City is delegated the review authority for the State's stormwater and critical area regulations. The entire town is under the re-development umbrella and therefore has the ability to require mitigation and fee-in-lieu on projects not meeting the full intent of the regulations. Considering the existing development, hydrology, and geology of the barrier island, full compliance on-site would not be as beneficial as using the mitigation fees collected to install stormwater Best Management Practices elsewhere throughout the Town.

The mitigation fees have been used to include pervious surfaces on Town projects. Funds have been used to retrofit the storm drain system and outfalls with inserts, baffle boxes, and outfall improvements. The Town also uses the funds to offer programs in order to install native landscaping. The Beach District and BayScape programs have been going on for 11 years—beach plants and grasses are given to residents to help with water quality, habitat, and erosion control in the beach block areas where the environment is harsh and hardier plants are needed. Rain barrels are also subsidized using these mitigation fees.

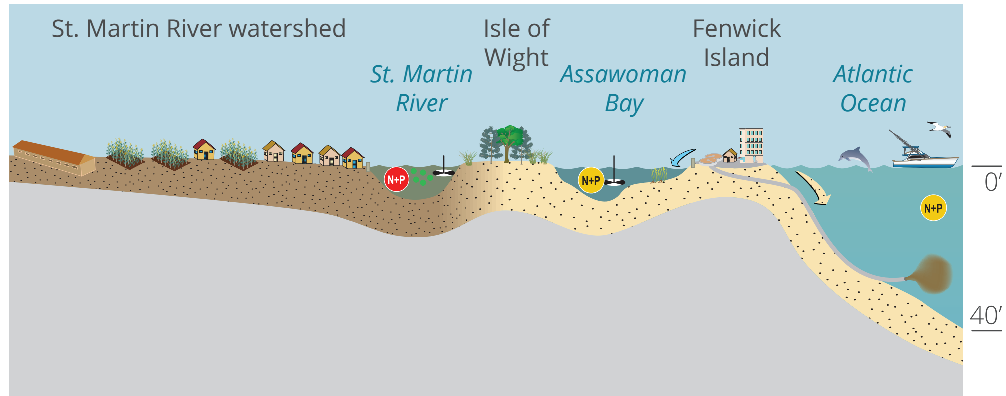
Dune Patrol has been active in Ocean City for over 20 years, with supplies provided by the Town. In addition, the Town hosts two clean-ups a year—one in April around Earth Day and the other in September for the International Coastal Clean-Up. Trash bags, gloves, t-shirts, and other supplies are provided to the volunteers.

A stormwater baffle box being installed in Ocean City. The primary function of baffle boxes is to remove trash, sediment, suspended particles, and associated pollutants from stormwater. Photo by Town of Ocean City.



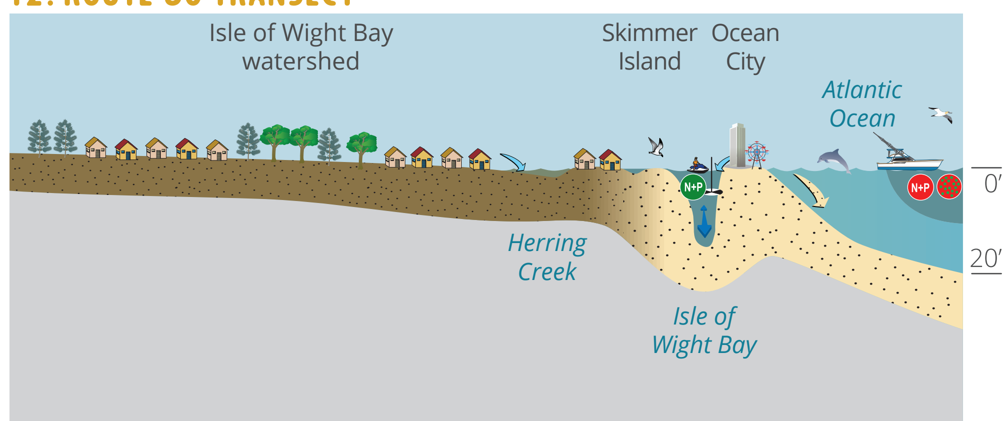
A LOOK ACROSS THE COASTAL BAYS

T1: ROUTE 90 TRANSECT



- St. Martin River watershed is highly developed leading to degraded water quality in St. Martin River.
- Ocean City sewage treatment effluent discharges offshore (~30′ water depth).
- Assawoman Bay has moderate water quality with remnant seagrasses.

T2: ROUTE 50 TRANSECT

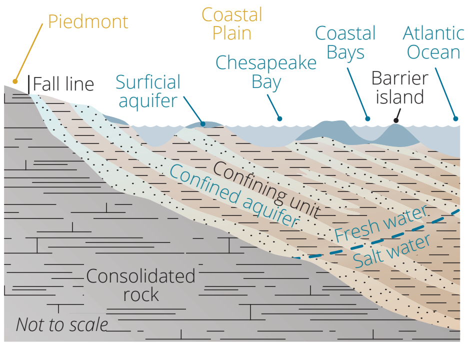


- Isle of Wight Bay watershed is residential and commercial; Isle of Wight Bay is well flushed with clams and fishing, Skimmer Island supports waterfowl.
- Ocean City inlet is maintained by dredging and tidal scouring.
- Ocean City is highly urbanized for summer tourism with impervious surfaces and stormwater runoff.

Four parallel east–west transects were established to provide insights into the features of the Maryland Coastal Bays. From north to south, these transects were the following:

T1: Route 90 bridge transect
T2: Route 50 bridge transect
T3: Verrazano Bridge transect
T4: Chincoteague Island transect

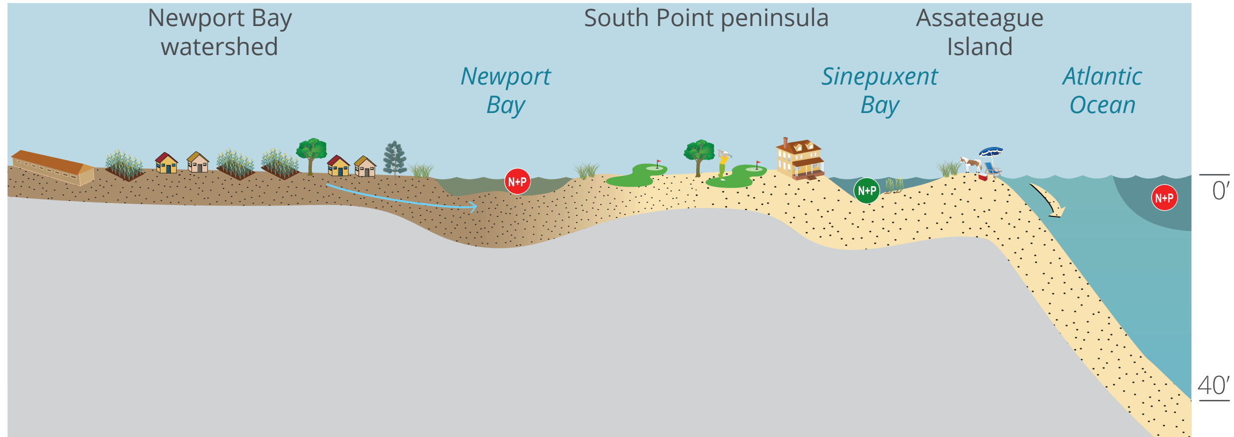
CROSS SECTION OF THE ATLANTIC COASTAL PLAIN



LEGEND

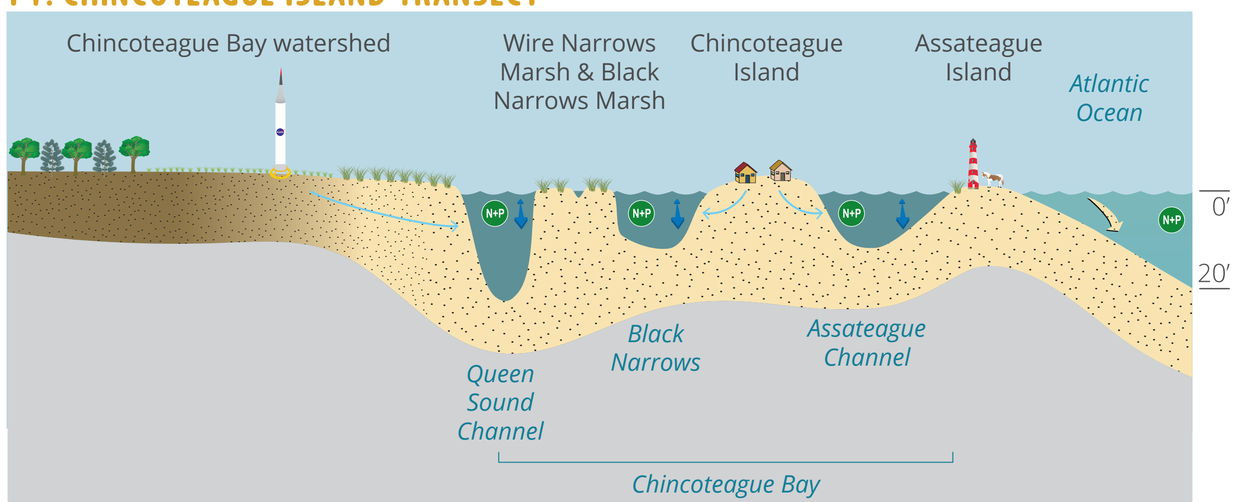
- Sandy bottom
- Muddy bottom
- Water clarity
- Nutrient concentration—low
- Nutrient concentration—moderate
- Nutrient concentration—high
- Chlorophyll concentration—high
- Algal bloom
- Seagrass
- Stormwater runoff
- Longshore sediment transport
- Tidal flushing
- Groundwater flow
- Hardened shoreline

T3: VERRAZANO BRIDGE TRANSECT



- Newport Bay watershed is rural with forest and agriculture leading to nutrient runoff into poorly flushed Newport Bay.
- Sinepuxent Bay is shallow and well flushed, supporting extensive seagrass meadows.
- Assateague Island is managed with the National Park Service for natural geomorphological processes, with herds of iconic feral ponies.

T4: CHINCOTEAGUE ISLAND TRANSECT



- Southern Chincoteague Bay watershed includes housing developments and Wallops Island Flight Center, as well as forest and agriculture.
- Southern Chincoteague bay is well flushed with low ambient nutrient concentrations.
- Chincoteague Island supports the town of Chincoteague which is on septic systems on sandy soil which leads to nutrient discharge to Southern Chincoteague Bay via groundwater.

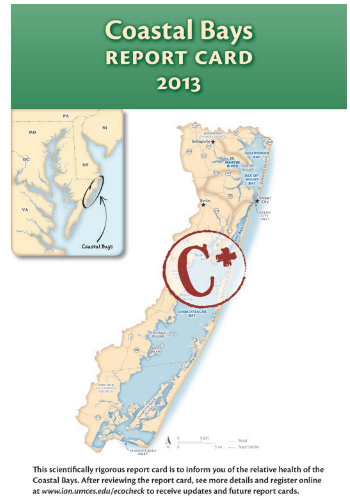
FREQUENT COMMUNICATION AND SYNTHESIS IMPROVES MANAGEMENT AND UNDERSTANDING

Monitoring data and scientific research can be hard to interpret. But frequent and easy-to-understand reporting, that is supported by quantitative measures and results, help identify the main messages that the data and research contain—they help us see the big picture, as well as the most important details.

Frequent communications like annual Report Cards, books, and reports remind us of the things we value in the Coastal Bays ecosystems. They also remind us about how the ecosystem supports these values. For example, poor water quality and loss of seagrass create poor habitat for fish and crabs. But, decisions to reduce pollution and stormwater runoff into the Coastal Bays, along with good fishery management can lead to improved habitat and improved fishing and crabbing opportunities.

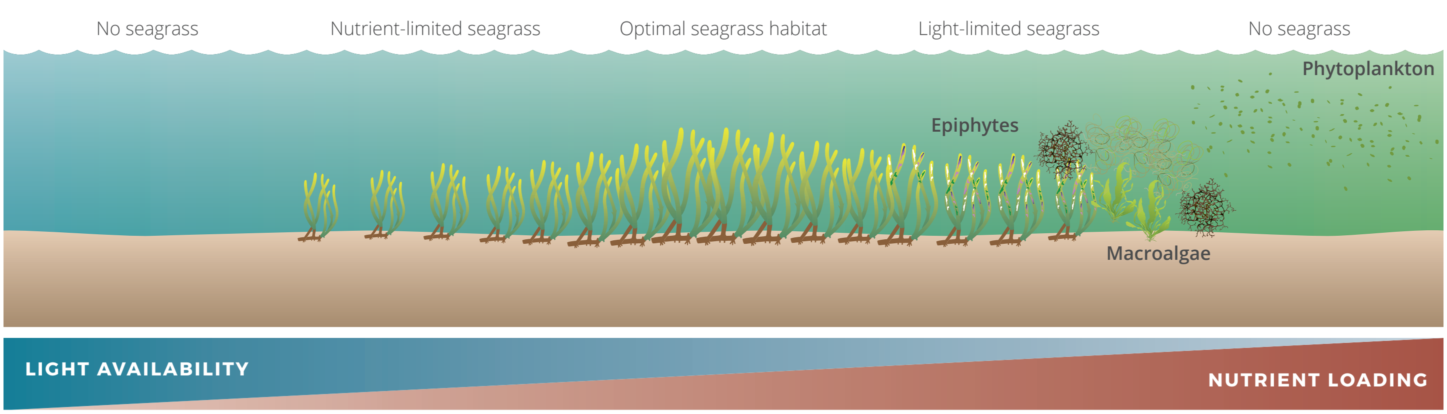
Highlighting these issues with frequent communication can also help us identify recurring themes or problems, and can keep them in the public eye. This also reinforces our understanding of the way ecosystems work and the things we can do to improve them. This type of public discourse can lead to better management and sustainable decisions. A more informed public creates pressure to protect the things we value.

Local residents provide input on Coastal Bays' direction and activities through the Citizens Advisory Committee, which meets frequently for citizens to provide input. The Science and Technical Advisory Committee provides sound science-based input on Coastal Bays issues.



Communication products of the Maryland Coastal Bays include the 2009 book *Shifting Sands: Environmental and cultural change in Maryland's Coastal Bays* (top left) as well as annual ecosystem health report cards (top right). The annual report cards are officially released during a media event held on the shores of the bays. Photo by Jane Thomas.

EFFECT OF INCREASING NUTRIENTS ON SEAGRASSES AND OTHER PLANTS



Conceptual diagrams such as this one are an effective way to communicate complex processes to a wide audience. This diagram depicts how increasing nutrients affect seagrasses by reducing light availability. This iconic figure has been used in many different communication products for the Coastal Bays.

INNOVATIVE MONITORING HELPS IDENTIFY NUTRIENT SOURCES

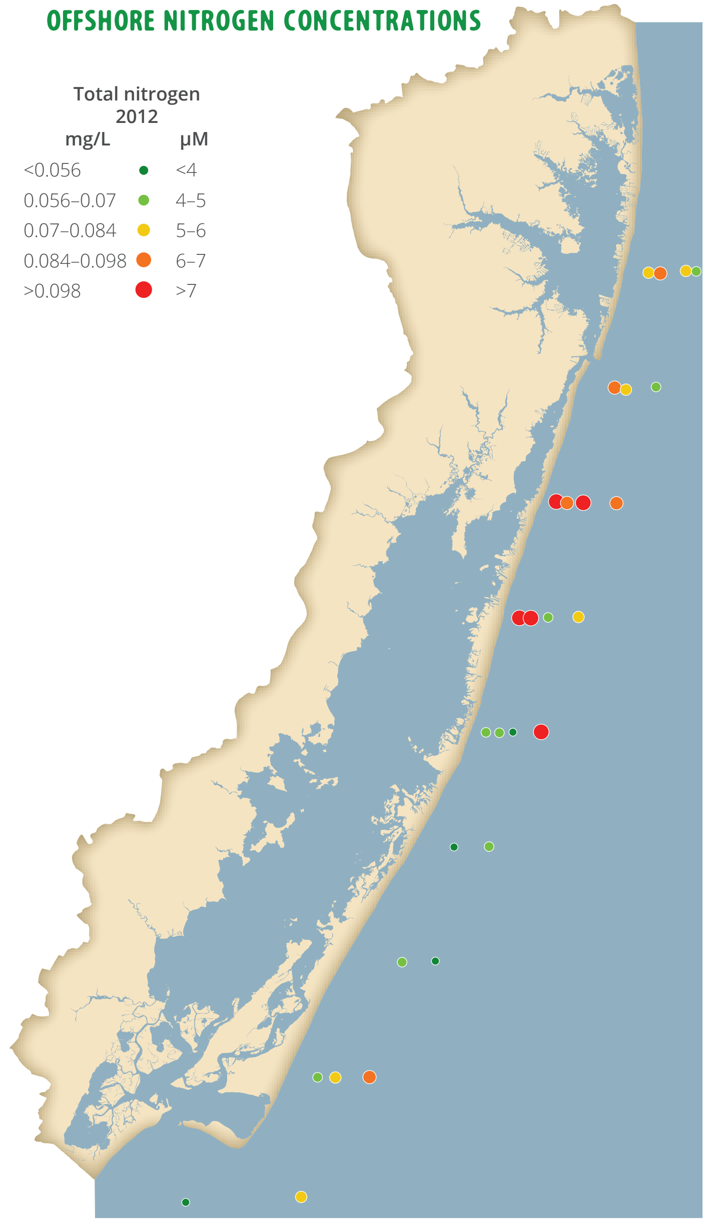
When the *State of the Bays* was published in 2004 and Shifting Sands was published in 2009, scientists and resource managers were puzzled by the degrading ecosystem health of Chincoteague Bay. The development pressures were largely confined to north of the Ocean City inlet, yet water quality improvements were observed in these regions while Chincoteague Bay water quality was inexplicably declining. The Maryland Coastal Bays Program has funded targeted research projects during the past 10 years which have provided insights into important long-standing questions about potential nutrient sources.

One project used a novel technique of measuring nitrogen stable isotopes in macroalgae as bioindicators throughout the Coastal Bays. This technique identified sewage nitrogen sources in the vicinity of Chincoteague Island. Chincoteague Island is a porous sand island with 4,300 permanent residents and over one million visitors annually relying on septic systems. Traditional septic systems do not remove nutrients which was evident from the sewage nitrogen plume observed.

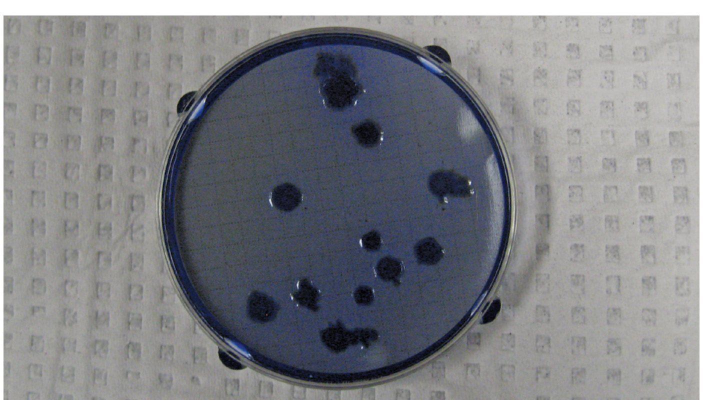
Two offshore sampling cruises in the nearshore Atlantic Ocean in 2012 found areas of elevated nitrogen, phosphorus, and chlorophyll, as well as some harmful algae species. Elevated nutrients may be from Delaware Bay outflow, upwelling, and/or emanating from the offshore discharge of the Ocean City sewage treatment plant in the summertime (increased tourist population may impact the bay at its most vulnerable time). Entrainment of these high nutrient ocean waters into the Coastal Bays via the Ocean City inlet is a possible nutrient source. Additional study is warranted to help understand the causes and potential impacts of oceanic nutrient loads.

Enterococcus bacteria are found in animal guts, including humans. If *Enterococcus* bacteria make their way into water bodies, the contaminated water is unfit for human contact. People infected with *Enterococcus* bacteria are often treated with antibiotics, which has led to various strains of *Enterococcus* bacteria developing a resistance to antibiotics. The resistance of *Enterococcus* bacteria to various antibiotics can be measured and compared to different sources of *Enterococcus*. This provides an indication of different potential sources of organic material contamination. This technique was employed using *Enterococcus* bacteria collected from streams flowing into Chincoteague Bay in the vicinity of Johnson Bay. The antibiotic resistance in *Enterococcus* bacteria from Scarboro Creek were most similar in a cluster analysis to poultry runoff and poultry litter. The antibiotic resistance in samples from Powell and Boxiron Creeks were most similar to biosolids, which are derived from sludge generated at sewage treatment plants. These results, combined with observations of high levels of nutrients measured in the steams, indicate that chicken and human waste applied to agricultural land is making its way into Chincoteague Bay.

OFFSHORE NITROGEN CONCENTRATIONS



There are elevated levels of nitrogen in the nearshore Atlantic Ocean, particularly offshore from Ocean City and northern Assateague Island.



Presence of *Enteroccocus* bacteria in streams and bays can indicate fecal contamination, from either human or animal sources. Photo by Katie Studholme.

WETLAND REHABILITATION RESTORES NEEDED FUNCTIONS

The salt marshes of the Maryland Coastal Bays were ditched in the 1930s as a mosquito control measure, using the Civilian Conservation Corps. In addition, impoundments were created in marshes to attract waterfowl in the 1950s. These marsh modifications changed the natural water flow of the salt marshes, and the scars have persisted to the current time. In addition to altered hydrology, the ditched marshes have different salt marsh species diversity and altered habitat value. Both State and Federal agencies have been working to restore marshes by plugging and filling the ditches.

The National Park Service has been restoring Assateague Island marshes since 2008. Marsh restoration is conducted during winter months. The top layer of beach sand is scraped off, transported to a staging area, then hauled to the ditches using a temporary corrugated oak logging mat. The mouth of the ditch is plugged with non-treated plywood that will decay over time. There are over 2,300 acres of ditched salt marshes on Assateague Island and restoration has been conducted on 800–900 acres to date. The ditches are not visible just a few years after restoration. Restored ditches attract shrimp, crabs, wading birds, breeding black ducks, and other waterfowl. Enhanced vegetative marsh growth is evident in marshes with restored natural hydrology. In addition, marsh accretion rates measured with Surface Elevation Tables appear higher in restored marshes, which will allow them more opportunity to keep pace with relative sea level rise.

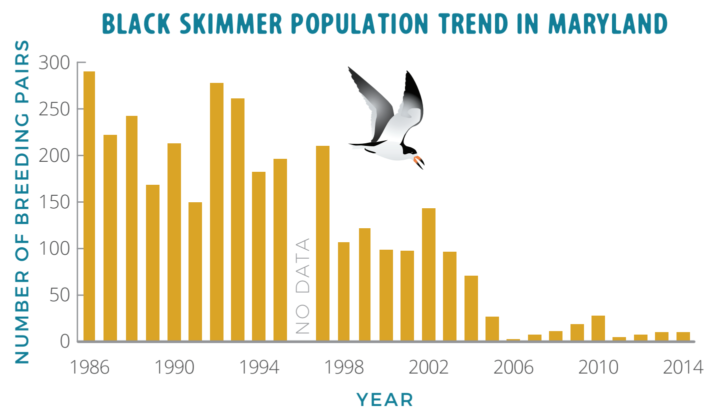
Maryland Department of Natural Resources has been plugging ditches using polycarbonate dams and fiberglass plugs in locations like the E.A. Vaughn Wildlife Management Area and on the Isle of Wight. Without ready access to beach sand, these restoration projects do not use fill material, relying on marsh accretion to eventually fill in the ditches. In Delaware, some marshes have had a thin layer of sediments from dredging applied to the marsh surface, and this technique may be a way to mitigate marsh loss due to relative sea level rise.

Clockwise from top left: an unrestored mosquito ditch; filling the ditch with sand to restore hydrological function; a ditch immediately after being filled with sand; a plugged ditch 18 months after restoration. Photos by Brian Sturgis/ Assateague Island National Seashore.

ISLAND RESTORATION RECOVERS CRITICAL BIRD HABITAT

Several species of threatened or endangered colonial nesting birds make the Maryland Coastal Bays their home. In the state of Maryland, least terns (*Sternula antillarum*) are listed as threatened, while black skimmers (*Rynchops niger*), common terns (*Sterna hirundo*), and royal terns (*Thalasseus maximus*) are listed as endangered. These birds rely on sandy beaches on which to build their nests; however, this habitat is becoming harder to come by. Development, erosion, and sea-level rise are all factors that have taken away valuable nesting area. The islands that dot our Coastal Bays are the last remaining refuges for these birds because they are ideal habitats. Mostly devoid of possible predators such as foxes and raccoons, islands provide the sandy beaches that are essential to these birds. Since 1989, almost 300 acres of islands have eroded away.

The Army Corps of Engineers created four islands throughout the Coastal Bays, with the project reaching completion in the fall of 2015. The project added 10 acres of habitat for colonial nesting birds. The islands are considered natural resources of the state of Maryland and are under management of the Department of Natural Resources as wildlife management areas. The islands have restricted access from April 1 to September 15 to protect vulnerable nests and chicks from direct harm, and to prevent parent birds from being frightened away and unable to defend their eggs and chicks from predatory gulls and crows. It is essential for boaters to avoid landing on these islands during this time.



The black skimmer population of the Coastal Bays has been declining for the past several decades.

This photo shows Tern Island in Isle of Wight Bay in the foreground, one of four constructed islands in the Coastal Bays that are providing new habitat for colonial nesting birds. The approximate location of these four islands are shown with arrows. Photo by Kathy Phillips/Assateague Coastal Trust.

FISHERIES MANAGEMENT STRATEGIES NEED TO CONSIDER ALL USERS

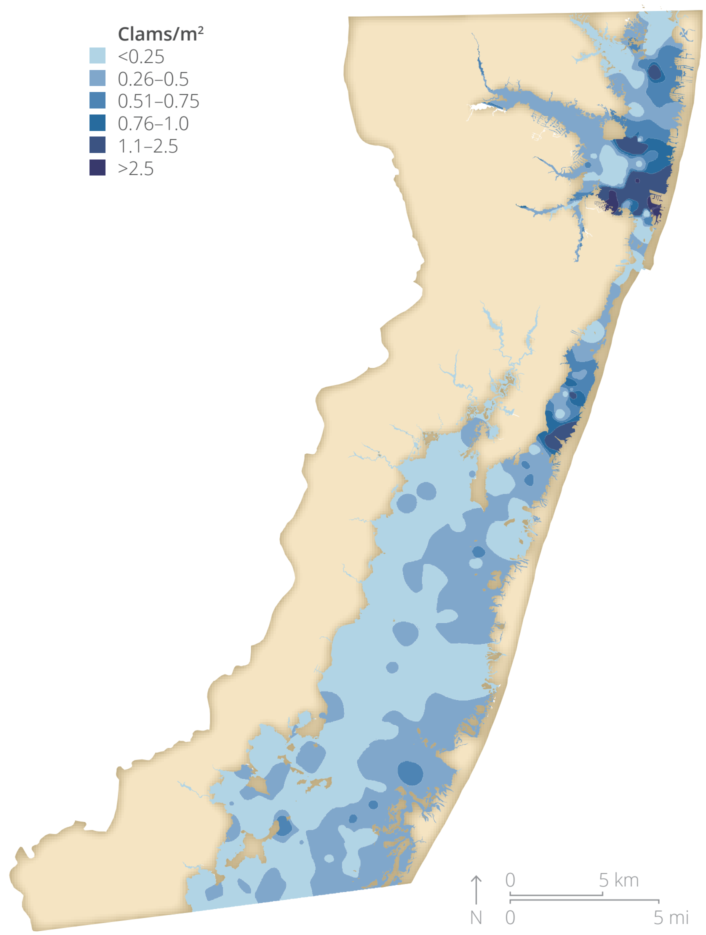
Fish populations are ecologically and economically important to the Coastal Bays. Harvests of fish and shellfish must be balanced between recreational and commercial users, while maintaining populations that support ecosystem needs (food source for other fish and bird species, filtering the bay, shoreline protection, habitat). Fishery management plans have been developed for blue crabs and hard clams that balance the needs of multiple users. The northern bays have significantly higher densities of finfish than the southern bays. Temporal changes in abundance of many species are mostly the result of stock-wide recruitment processes in Atlantic coastal populations. Therefore, the harvest of many finfish species is managed on a coastwide basis.

Despite a ban on mechanical harvesting for shellfish in the Coastal Bays beginning in 2008, current hard clam densities in all of the bays remain lower than historical levels. Density trends in the northern bays have been improving, with the Isle of Wight Bay clam population approaching the 60-year benchmark. Observed mortalities have been negligible throughout the bays. The Coastal Bays populations are dominated by older, larger clams, with recruitment generally low and sporadic in the lower bays. Parts of Sinepuxent, Isle of Wight, and Assawoman Bays experienced a strong recruitment period during the late 2000s which accounted for the boost in clam densities, but has tailed off since then. Poor recruitment may be a factor of the small and patchy clam population. Shellfish aquaculture is beginning to expand in the State and may help boost wild populations in some areas. Recreational clamming has long been popular in the Coastal Bays.

Extremely low densities of bay scallops over the past four years, diminishing habitat, and declining water quality suggest that the long-term viability of the bay scallop population is in question.

Shellfish sampling in the Coastal Bays. Photo by Robert Bussell/MD DNR.

2013 HARD CLAM DENSITY



This map shows the density of hard clams in the Coastal Bays in 2013.

CLIMATE EFFECTS CHALLENGE MANAGEMENT OF BAY RESOURCES

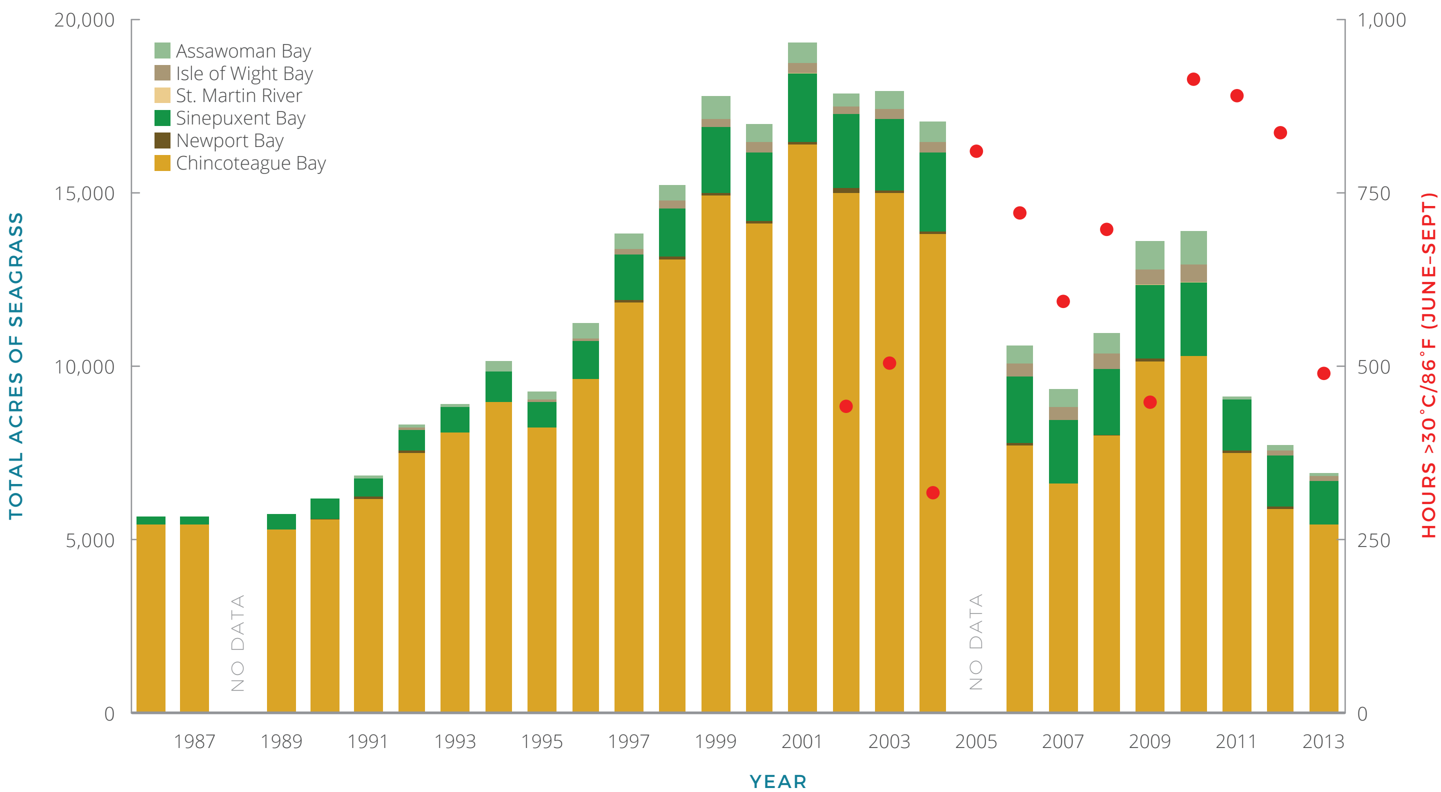
Maryland is one of the states most susceptible to sea level rise, due to its 3,100 miles of tidal shoreline and low-lying and rural areas. The Maryland Coastal Bays' geography and geology make this region one of the most vulnerable areas of the state. Historic tidal records show that sea levels have risen approximately one foot during the last century. Maryland is projected to have between 2.7 to 3.4 feet (0.8–1.0 meters) of sea level rise over the next 100 years.

In many cases, the Maryland Coastal Bays are already experiencing these problems. For example, seagrasses (specifically eelgrass) have experienced major declines since 2001 as a function of a) water quality degradation, b) temperature stress in 2005 and 2010, c) chronic harmful algae blooms, and d) loss of marshes. Climate change makes it even more difficult to manage these issues by changing the extent, frequency, intensity, and magnitude of the various problems that are occurring.

There are many ways in which climate change may affect the Maryland Coastal Bays including:

- **Accelerated barrier island migration toward mainland, increased dune and beach erosion, and increased island breaches/inlets or property damage in Ocean City.**
- **Decreased eelgrass population (possibly replaced by more southern species).**
- **Increased Coastal Bays depth and stronger tidal forces, causing more erosion and increased tidal prism .**
- **Increased nuisance flooding due to elevation changes**
- **Decline in marsh acreage (no retreat).**
- **More frequent and expansive low oxygen events (dead zones).**
- **Declining water quality, decreased water clarity, and increases in harmful algal blooms.**
- **Changing species composition.**
- **Hotter summers—up to 60 additional days/year of temperatures >90°F, milder winters, and more precipitation in winter and spring; less in summer.**
- **Increased storm frequency and intensity.**

HIGH TEMPERATURES AFFECT SEAGRASS ABUNDANCE



Seagrass coverage in the Coastal Bays increased until 2001, after which it has been declining and variable. This may be related to the temperature stress to seagrass that occurs when the water temperature exceeds 30°C/86°F. Years with lower water temperature correspond to years with higher seagrass abundance, and vice versa. Data courtesy of Virginia Institute of Marine Science and Maryland DNR.

BAY FISHERIES DEPEND ON OCEAN AND BAY HEALTH

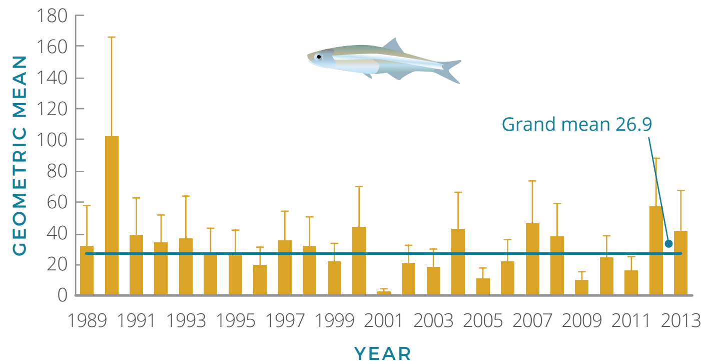
Maryland's Coastal Bays are important finfish nursery grounds. These shallow estuaries, at the interface between fresh and saltwater, provide habitat for a wide range of aquatic life. But like many coastal systems, they face threats from intense development, nutrients, sediments, and other stressors associated with human activities.

Most finfish species found within Maryland's Coastal Bays are coastal spawners, illustrating the importance of the Coastal Bays as finfish nursery grounds. Summer flounder (*Paralichthys dentatus*) and black sea bass (*Centropristis striata*) are longer-lived species of recreational and commercial importance, while bay anchovy (*Anchoa hepsetus*) and silver perch (*Bairdiella chrysoura*) have shorter life spans and serve as food for larger fish.

Bay anchovy are often the most abundant species in the bays. They are a preferred forage species for larger game fish. They are equally abundant in all areas of the Coastal Bays. Being short–lived, they exhibit rather consistent recruitment and abundance. There has been more variability in their abundance in recent years compared to earlier surveys. However, abundances have been both above and below the long-term average and not indicative of a trend.

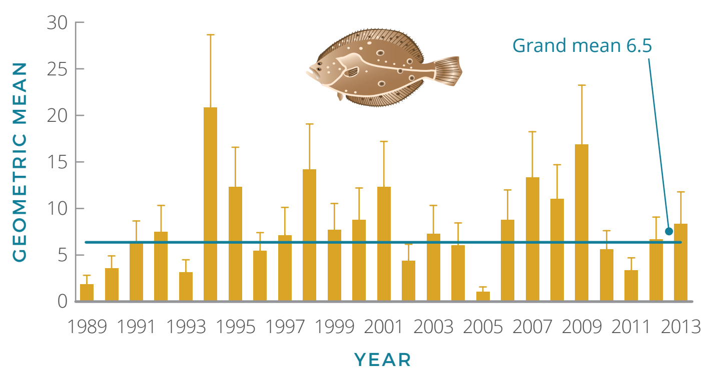
Summer flounder are the most sought-after recreational game fish in the Coastal Bays. The Summer Flounder Index reflects annual recruitment in the bays, and consequently also reflects nursery habitat. Summer flounder are abundant in all the Coastal Bays except for Sinepuxent Bay. The more extreme currents found in Sinepuxent Bay may inhibit its habitat value to juvenile summer flounder.

BAY ANCHOVY ABUNDANCE IN THE COASTAL BAYS



Bay anchovy (*Anchoa hepsetus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989–2015). Protocols of the Coastal Bays Fisheries Investigation Trawl and Seine Survey were standardized in 1989 (n=140/year).

SUMMER FLOUNDER ABUNDANCE IN THE COASTAL BAYS



Summer flounder (*Paralichthys dentatus*) trawl index of relative abundance (geometric mean) with 95% confidence intervals (1989–2015). Protocols of the Coastal Bays Fisheries Investigation Trawl and Seine Survey were standardized in 1989 (n=140/year).

Seining is one of the sampling methods used by the Maryand Department of Natural Resources to estimate fish populations in the Coastal Bays. Photo by Maryland Department of Natural Resources.

Blue crabs (*Callinectes sapidis*), an important fisheries resource throughout the bays, are dependent on ocean conditions. Although there is evidence that some internal recruitment may occur, the majority of young crabs that take up residence in the bays are transported by ocean currents from the mouth of the Chesapeake and Delaware Bays. Climate change, ocean acidification, and altered circulation patterns can directly affect blue crab abundance in the bays. Blue crabs support both a commercial and recreational fishery in the bays. Commercial harvest of hard, soft, and peeler crabs is around 1 million pounds per year and has fluctuated from a low of 0.5 million in 1998 to a high in 2010 when almost 2.5 million pounds were harvested.

WATER QUALITY IMPROVEMENTS OFFER HOPE FOR SEAGRASS RECOVERY

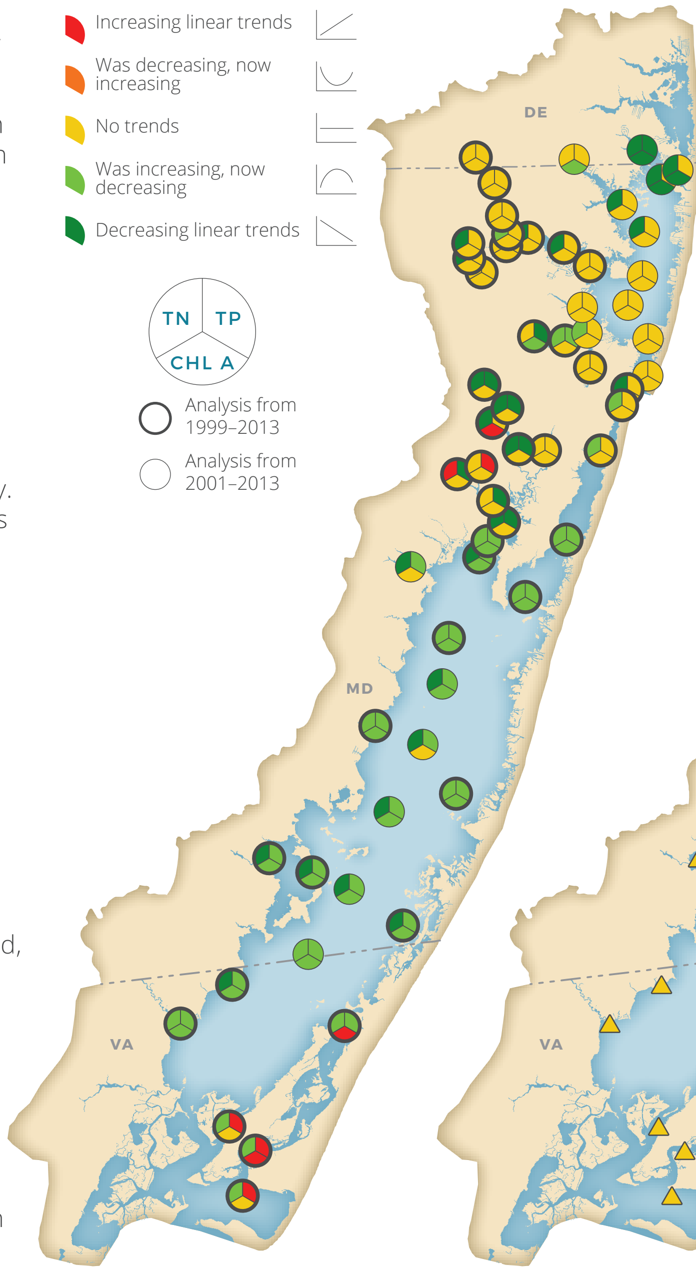
WATER QUALITY INDEX STATUS

The water quality index is comprised of chlorophyll *a*, total nitrogen, total phosphorus, and dissolved oxygen. Strong gradients in water quality index occur in the Coastal Bays, averaged over three years (2011–2013). The most degraded regions were St. Martin River, Newport Bay, and Assawoman Bay. The highest water quality was near the Ocean City inlet in Isle of Wight Bay, Sinepuxent Bay, and northern Chincoteague Bay. Moderate water quality was observed in southern and central Chincoteague Bay.

WATER QUALITY CHANGE OVER TIME

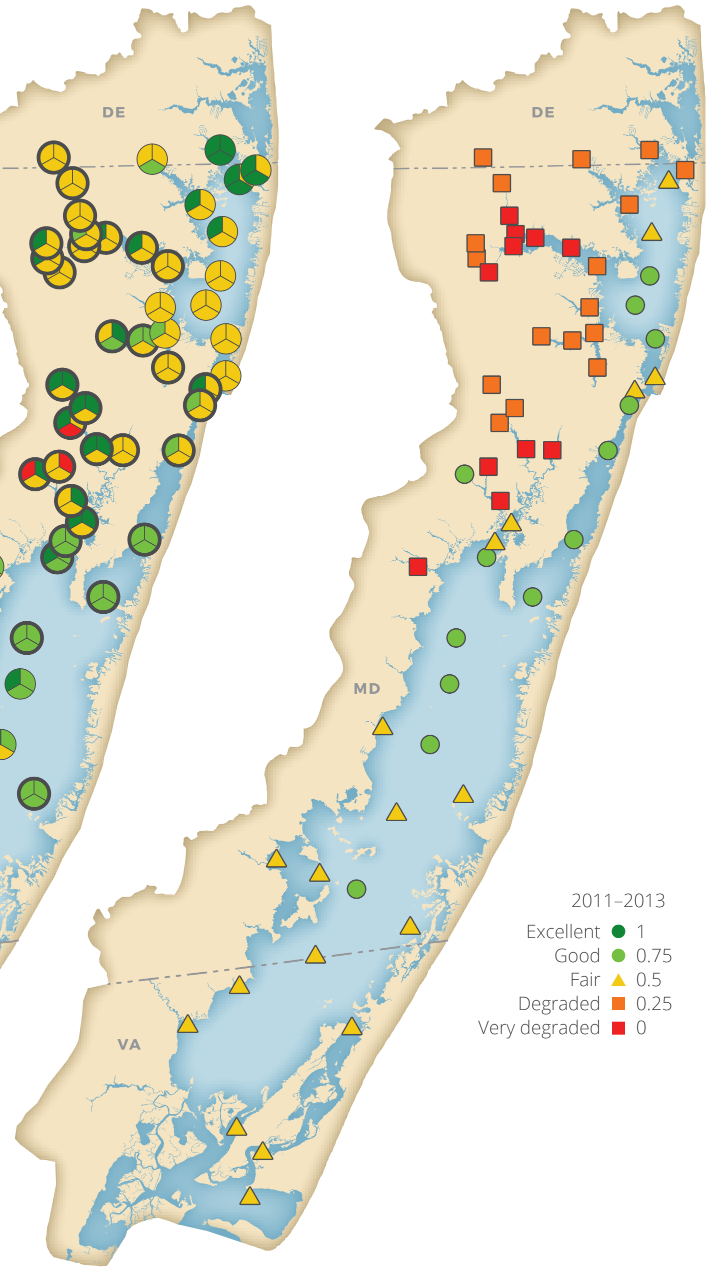
Trends in three water quality parameters were calculated for the periods 1999–2013 or for 2001–2013. Total nitrogen, total phosphorus and chlorophyll *a* trends were generally similar—when one improved or decreased, the others followed suit. Improving trends were evident in Chincoteague Bay, except for sites near Chincoteague Island where a number of declining trends were observed. No trends were evident in most sites north of the Ocean City inlet. Sinepuxent Bay had improving trends or no trend, but no degrading trends.

WATER QUALITY CHANGE OVER TIME



Long-term trends in total nitrogen, total phosphorus, and chlorophyll a show improving conditions in many areas.

WATER QUALITY INDEX STATUS



The Water Quality Index synthesizes the status of the four water quality indicators—chlorophyll *a* (algae), total nitrogen, total phosphorus, and dissolved oxygen—into a single indicator of water quality.

STATUS AND TRENDS

The overall picture emerging from this analysis is that water quality is improving or at least not degrading in most locations. Poor water quality in the north Coastal Bays is not getting worse, but also not getting better. However, water quality in Newport Bay and most of Chincoteague Bay is improving. The region around Chincoteague Island is markedly problematic, even with its proximity to the Chincoteague inlet.

SHIFTING STRESSORS INFLUENCE BAY HEALTH

The bays are home to a diversity of species including marine mammals, seabirds and shorebirds, sea turtles, fishes, crabs and other invertebrates, seagrasses, and marine algae. Activities that put pressure on bay resources are also diverse. Some of the most prominent pressures include vessel traffic, commercial and recreational fishing, agriculture, residential and septic system runoff, coastal development, sea-level rise, and climate change. These pressures associated with human activities increase nutrient and sediment inputs, which in turn change the food webs in the bays and lead to harmful algal blooms. Some linkages with the land are observed more quickly, such as when new inlets are formed.

Human population is expected to climb steadily, with more permanent residents compared to summer visitors. Resulting changes in landscape, especially as farmland is converted to residential development in the greater watershed, will bring added stressors to the Coastal Bays (increased runoff, flooding, wastewater). The watershed has already lost over 55,000 acres of forests and wetlands. Proactive management of development, along with improvements in wastewater and run-off projects, will be necessary to preserve the integrity of this ecosystem.

Long-term, gradual changes, such as changes in water quality and bay sediments within seagrass beds, lead to shifts in species composition. Runoff from land leads to changes in the bay sediment, covering sandy bottom with silty-clay deposits that are inhospitable to seagrasses. Species composition of the seagrass community may be impacted by rising temperatures. As sea level rises and wetlands cannot migrate inland, wetlands acreage will decline and distribution will be altered. The type of fertilizers used in the watershed has shifted from inorganic to organic forms of nitrogen, leading to water quality conditions that are more suited to harmful algal species.

Larger, more global issues, such as climate change and ocean acidification, are significant areas of concern. Some regional impacts are being detected already but long-term effects are not well understood. Effects brought about by climate changes (increased temperature, frequency of storms) will impact bay resources and likely lead to shifts in bay wildlife populations (southern species expanding northward and northern species receding).

The Coastal Bays community, both ecological and human, will certainly continue to change over time. The capacity to respond and adapt to this change over time should be preserved.

This juxtaposition of the heavily developed Ocean City/Fenwick Island and the undeveloped Assateague Island National Seashore captures the variety of stressors facing the Coastal Bays. Photo by Jane Thomas

COASTAL LAGOONS ARE INFLUENCED BY PHYSICAL AND HUMAN FACTORS

The Delmarva (Delaware–Maryland–Virginia) lagoonal system is remarkably similar to the New Jersey and Long Island coastal lagoon complexes. The narrow barrier islands of all three regions are largely undeveloped, but the Long Island and New Jersey short drumstick barrier islands are extensively developed, unlike the uninhabited southern Delmarva barrier islands.

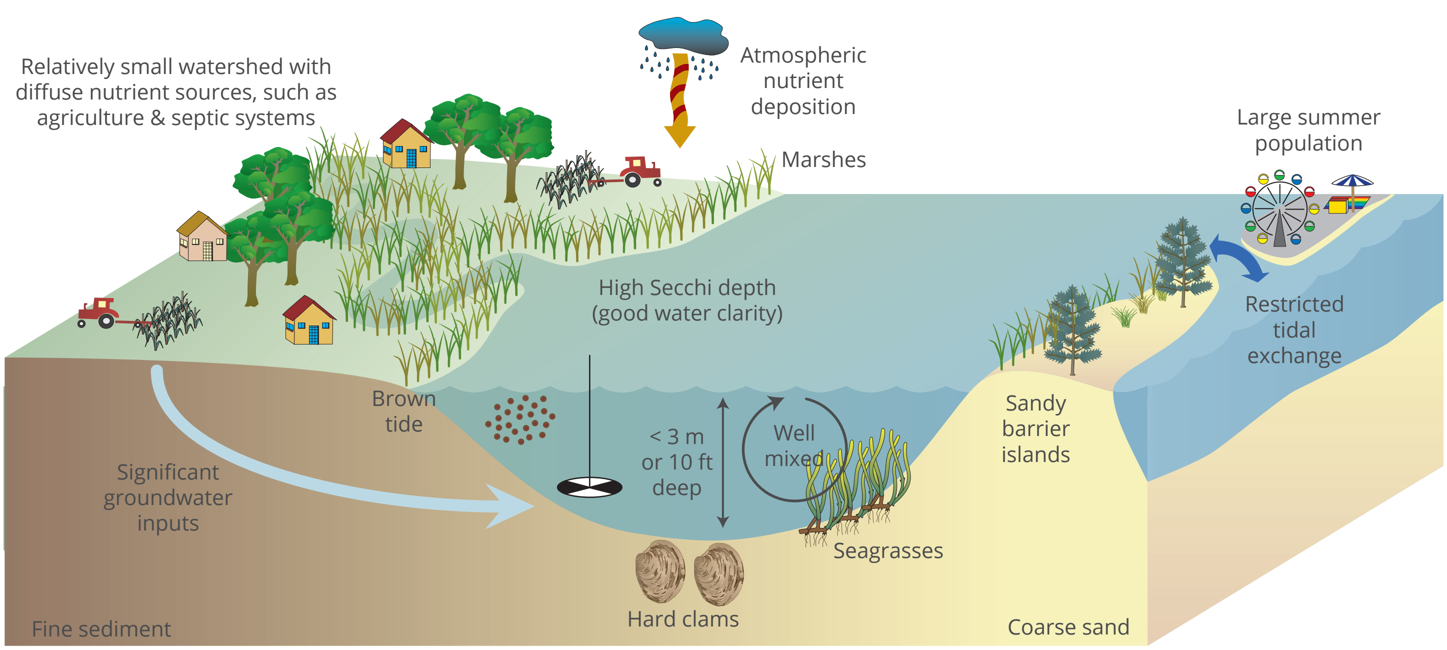
The Delmarva coastal embayments are heavily influenced by tides and currents. Except for a few short tidal rivers, freshwater inputs are dominated by groundwater percolating into streams. There are also differences among the Delmarva Bays in flushing rates (due to number and size of inlets) and development. In this continuum, the total nitrogen loadings and concentrations are highest in the Delaware Inland Bays, lowest in the Virginia Seaside Bays and in-between in the Maryland Coastal Bays.

The gradient in nutrient loading and concentration along the Delmarva lagoons is reflected in the abundance trajectories of seagrasses. A seagrass restoration project in the Virginia Seaside Bays has resulted in expanding seagrass acreage since 1999. Maryland Coastal Bays seagrasses expanded in the 1990s, but have peaked and declined since. The Delaware Inland Bays currently support only small remnant seagrass populations near inlets.

The Maryland Coastal Bays are a segment of the overall barrier island lagoonal system that extends along the Atlantic coast of the U.S.

All three lagoon complexes of the Mid-Atlantic Bight have high recreational value, strong water quality gradients, historic oyster and hard clam fisheries, and seagrass and salt marsh habitat. They face similar challenges like eutrophication and harmful algal blooms, particularly brown tide, habitat loss, and fisheries declines, particularly shellfish. They are all sensitive to climate change, sea level rise, storm surge, and tidal inundation. The human footprint on these lagoon complexes varies, and the Maryland Coastal Bays can use the Long Island and New Jersey lagoons as surrogates for future development scenarios.

CHARACTERISTICS OF COASTAL LAGOON SYSTEMS



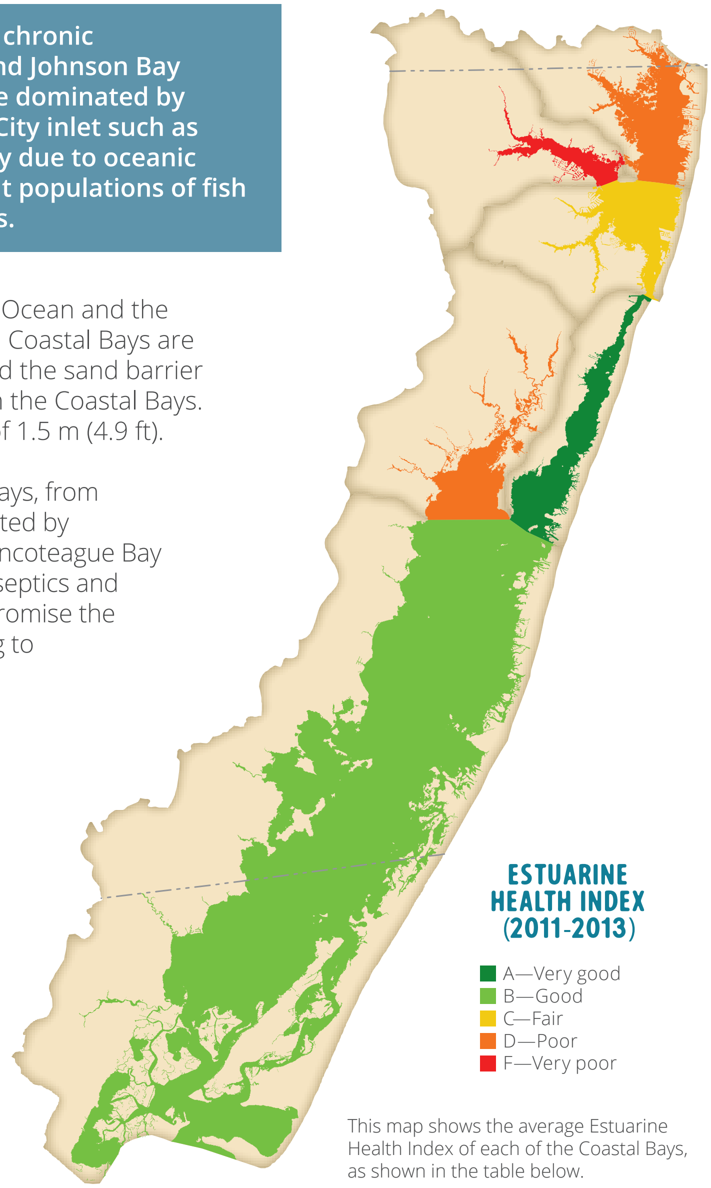
BAY HEALTH REFLECTS THE STATE OF THE LAND AND THE OCEAN

The ecosystem health of the Coastal Bays is variable, with chronic degradation occurring in St. Martin River, Newport Bay, and Johnson Bay (Chincoteague Bay)—areas that are poorly flushed and are dominated by watershed inputs of nutrients. The areas near the Ocean City inlet such as Sinepuxent Bay and Isle of Wight Bay are relatively healthy due to oceanic flushing. While the bays still support diverse and abundant populations of fish and shellfish, human activities are affecting their numbers.

The Maryland Coastal Bays are sandwiched between the Atlantic Ocean and the Delmarva (Delaware–Maryland–Virginia) Peninsula. The Maryland Coastal Bays are located adjacent to a narrow but highly developed watershed and the sand barrier islands (Fenwick and Assateague) which separate the ocean from the Coastal Bays. The Coastal Bays are very shallow, with an average water depth of 1.5 m (4.9 ft).

There are strong gradients in nutrient enrichment in the Coastal Bays, from well-flushed regions near the inlets to poorly flushed regions affected by watershed inputs and poor circulation. For example, southern Chincoteague Bay benefits from oceanic flushing, but nutrient inputs from streams (septics and agriculture) and from the unsewered town of Chincoteague compromise the effectiveness of flushing. We must continue to invest in monitoring to track key indicators and guide restoration of this complex system.

This report summarizes the current conditions of key indicators of bay health. Thanks to cooperation between our partners, we have completed two offshore cruises. These previously unassessed waters revealed high nutrients in areas and a possible new loading source to the bays. Summer discharge from the Ocean City wastewater treatment plant into the Atlantic Ocean may be one source of these high nutrients, as well as upwelling of nutrients as seen off the New Jersey coast. Research on groundwater has shown the significant role of ecological lag times on the impacts of best management practices on the Delmarva Peninsula. We have also documented blooms of the harmful algae that can cause diarrhetic shellfish poisoning and monitored shellfish to protect public health.



This map shows the average Estuarine Health Index of each of the Coastal Bays, as shown in the table below.

2011–2013 ESTUARINE HEALTH INDEX		Sinepuxent Bay	Chincoteague Bay	Isle of Wight Bay	Assawoman Bay	Newport Bay	St Martin River
WATER QUALITY	Water quality index	100	76	56	37	39	0
	Macroalgae	100	96	26	0	93	87
LIVING RESOURCES	Benthic index	100	65	33	45	13	0
	Hard clams	40	20	100	30	10	0
HABITAT	Seagrass area	100	72	32	54	22	0
	Wetland area	100	64	0	64	16	0
ESTUARINE HEALTH INDEX		**90**	**66**	**41**	**38**	**32**	**15**

This table shows the 2011–2013 Estuarine Health Index for each of the Coastal Bays. Each indicator is scored from 0–100, based on how close it is to achieving the goal for that indicator, where a score of 0 = 0% attainment and a score of 100 = 100% attainment.

This booklet provides an overview of the current science and management issues in the Maryland Coastal Bays and their watersheds in 2016. Previous assessments include the *2004 State of the Maryland Coastal Bays* and the 2009 book, *Shifting Sands: Environmental and cultural change in Maryland's Coastal Bays*. Both of these previous publications and this booklet, *Maryland Coastal Bays 2016: Land and bay perspectives* are available on IAN Press (*ian.umces.edu/press*).

Recognizing the importance of both a bay perspective and a land perspective, this booklet provides current data and insights into a) how bay health is influenced by ocean and land and b) how watershed health influences bay health. It includes two 'booklets' in one publication—one intended for those interested in the bay perspective, and the other for those interested in the land perspective. The two documents culminate in a summary centerfold which focuses on both watershed and bay issues.

Source material for this booklet is derived the 2015 Comprehensive Conservation Management Plan and the 2016 Ecosystem Health Assessment—both available at *http://mdcoastalbays.org/publications*. Data used in this publication is through 2013.

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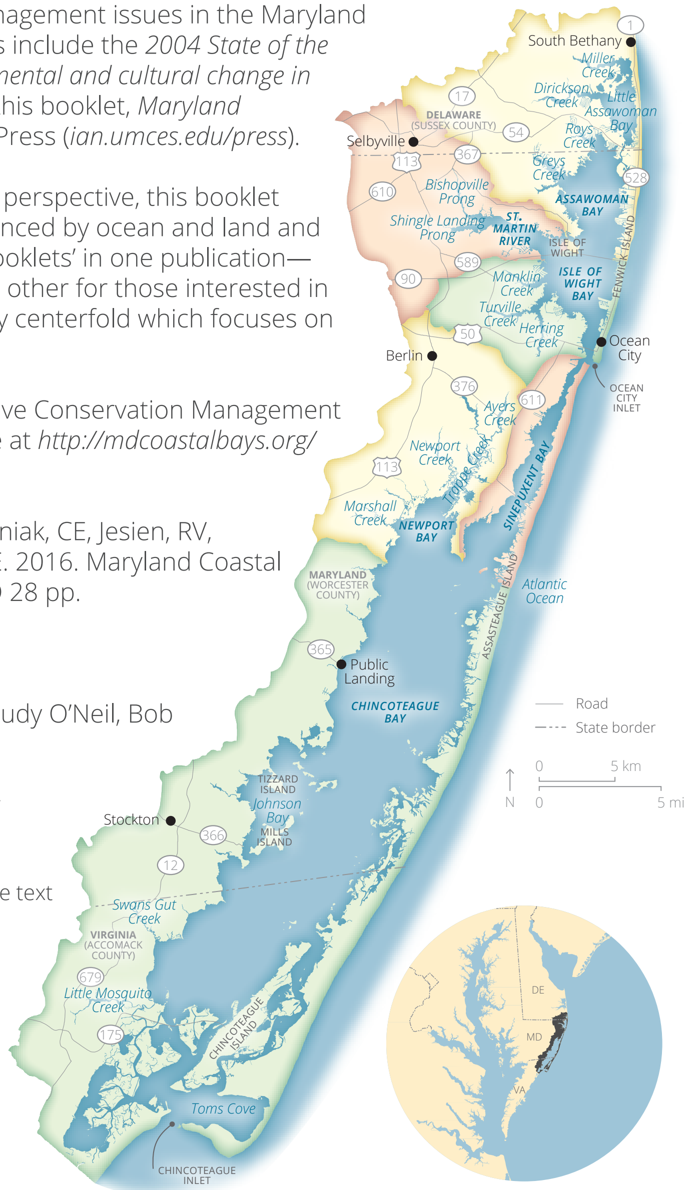

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THE BAYS PERSPECTIVE:

Bay health is influenced by ocean and land

THE MARYLAND COASTAL BAYS 2016