BUILDING RESILIENCE IN THE MARYLAND COASTAL BAYS

2022

Source material for this booklet is derived the 2014 Comprehensive Conservation Management Plan (https://mdcoastalbays.org/app/uploads/2020/05/2015-comprehensive-conservation-amp-management-plan.pdf) and the 2016 Ecosystem Health Assessment—both available at http://mdcoastalbays.org/publications. Data used in this publication is through 2021.

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PHOTO CREDITS

Photos courtesy of Maryland Coastal Bays Program unless specified.
Front and back cover photos: Nathan Miller.

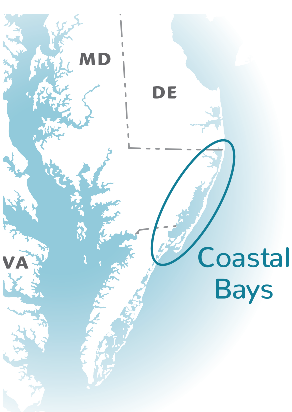
FOREWORD

Reporting on the State of the Maryland Coastal Bays is an opportunity to step back and reflect on the status and trends of key environmental features in this iconic region. These State of the Maryland Coastal Bays assessments have occurred previously, resulting in public-friendly documents: a) *State of the Maryland Coastal Bays* in 2004, b) *Shifting Sands: Environmental and cultural change in Maryland's Coastal Bays* (2009), and c) *Maryland Coastal Bays in 2016: Land and Bay Perspectives*. The previous State of the Bays have been accompanied by annual report cards since 2008, and various scientific and technical publications. The major distinguishing feature of State of the Bays reporting is that it is an opportunity to synthesize key scientific advances and to highlight emerging issues.

The theme of this State of the Coastal Bays is building ecological resilience in the region. This focus on resilience is due to the convergence of several factors: 1) the realization that accelerating climate change impacts are being manifested throughout the Coastal Bays, 2) the increased human footprint in the region, and 3) the slow progress on reducing nutrient over-enrichment compared to nearby Chesapeake Bay.

The Maryland Coastal Bays were coined the "Forgotten Bays" in the 1990s, but the increased scientific and public attention that they received led us to consider them "discovered." Sadly, the global pandemic and increased attention on Chesapeake Bay restoration has caused the Maryland Coastal Bays to once again fall at the back of the line regarding funding and scientific scrutiny. A goal of this State of the Coastal Bays is to avoid them becoming "forgotten" again. The structure of the State of the Coastal Bays is to 1) establish the challenge of climate change, 2) discuss various aspects of ecosystem health, 3) conceptualize key features and major threats and highlight features that increase health and resilience, and 4) discuss various aspects of resilience.

A long partnership between Maryland Coastal Bays Program, Maryland Department of Natural Resources, National Park Service, and the University of Maryland Center for Environmental Science has made this assessment possible.

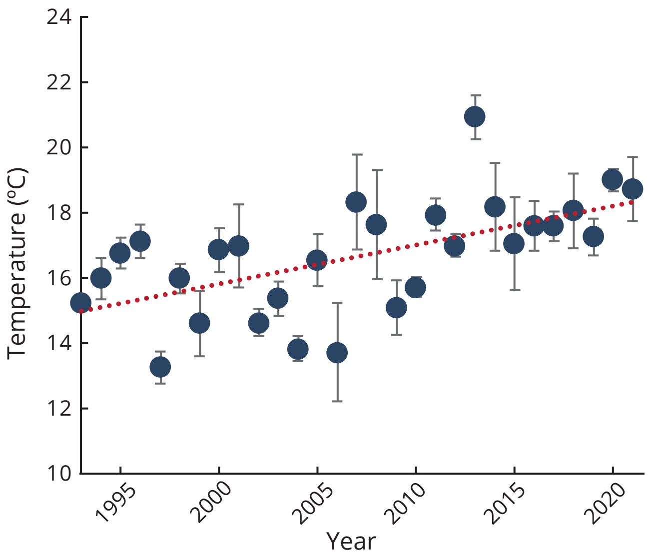


A locator map of the Maryland Coastal Bays.

CLIMATE CHANGE CHALLENGES RESILIENCE OF MARYLAND COASTAL BAYS

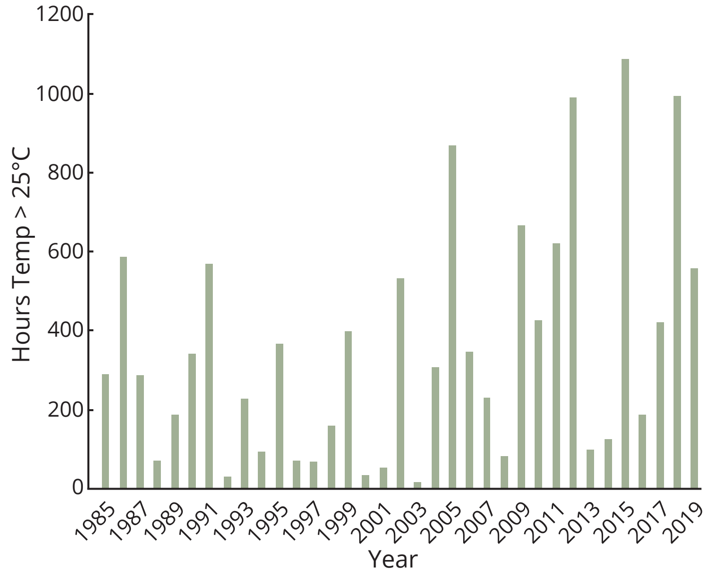
Climate change is impacting every part of the planet. The Maryland Coastal Bays, at the interface of the Delmarva Peninsula and the Mid-Atlantic Bight of the Atlantic Ocean, are particularly vulnerable. Sea level rise, changes in river discharge from precipitation extremes, increased water temperatures, and potential acidification are the major threats.

INCREASING OCTOBER TEMPERATURES RESULT IN EXPANDED SUMMER SEASON



Data show significant interannual variation and increasing trend in surface water temperatures in the Coastal Bays in October from 1993–2021 (n=560, R^2=0.59; 20 sites per month from the Delaware to Virginia state boundaries) (MD DNR Coastal Fisheries Trawl Survey).

NUMBER OF HOURS WITH OFFSHORE TEMPERATURES ABOVE 25°C



Number of hours that water temperature was 25°C or greater calculated from the NOAA buoy 44009, 23 miles offshore from Ocean City, MD. 2015 data were not available during July, and 2016 data starts at July 22. Data source: https://www.ndbc.noaa.gov/station_history.php?station=44009

Relative sea level rise affects the barrier islands, the exchange of water through inlets, and impacts marshes, islands, and embayments in the coastal lagoons. Another climate change impact along the Atlantic coastline is related to the frequency and severity of storms. Storms like tropical hurricanes or nor'easters can affect the geomorphology of the barrier islands and inlets, which affects the ecology of coastal lagoons.

Precipitation is expected to increase, particularly in the winter and spring. The frequency and intensity of extreme precipitation events are also expected to increase, which could increase the risk of flooding. Sea level rise is expected to continue in Maryland with a two to four ft increase expected by 2100.

Due to the geographic location of the Maryland Coastal Bays, the jet stream is often located near the state, particularly in the late fall, winter, and spring. Precipitation is frequent because of low-pressure storms associated with the jet stream. In winter, the contrasting influences of cold air masses from the interior and moist air masses from the Atlantic provide the energy for occasional intense storms like nor’easters.

Increasing temperatures, which in Maryland have risen 1.4°C (2.5°F) since the beginning of the 20th century, affect the biota and chemistry of the Coastal Bays, especially in the Mid-Atlantic region where warm and cool temperate species are intermingled. Marine heat waves are becoming more common, and loss of eelgrass has occurred at least twice in the past couple of decades, presumably due to extreme heat events. Populations of winter flounder are also moving north due to rising temperatures.

These changes will impact the ecosystems that straddle the northern and southern ranges of many species. The response to extreme events like storm surges or marine heat waves will be related to the resilience of the biota of the Coastal Bays. To keep pace with sea level rise, management actions that can promote ecological resilience, such as maintaining migration corridors for salt marshes and SAV beds, are needed. Reductions in nutrient inputs also provide for resilience, facilitating recovery from extreme events.

WATER QUALITY DEGRADING IN NORTHERN COASTAL BAYS BUT IMPROVING IN SOUTHERN COASTAL BAYS

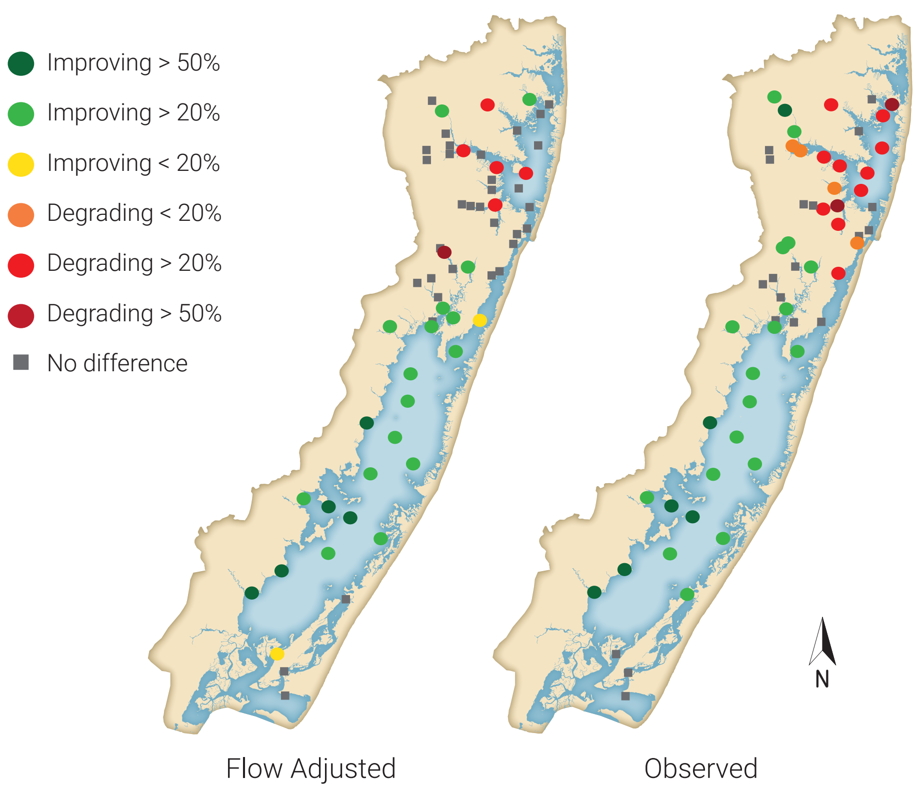
Nutrient over-enrichment is a major threat to the Maryland Coastal Bays. Nutrients enter the water column from a wide range of point and non-point sources. Non-point sources include runoff from urban areas, agriculture, septic systems, legacy groundwater, atmospheric deposition, and natural sources (wetlands, marshes, and forests). Nutrients fuel algal (phytoplankton) growth, which is needed to help feed fish and other organisms. However, too many nutrients cause high concentrations of algae, which can lead to a reduction in water clarity and dissolved oxygen, creating unsuitable conditions for living resources (fish, shellfish, and seagrasses).

Assawoman Bay, St. Martin River, tributaries to Isle of Wight Bay, and Newport Bay were severely enriched with nitrogen, while Sinepuxent and Chincoteague Bays had the lowest total nitrogen concentrations. Phosphorus enrichment was widespread. Nitrogen levels met the seagrass threshold at 59% of stations, while phosphorus only met the seagrass threshold at 36% of stations.

Many tributaries with failing nutrient thresholds had elevated algae levels (measured as chlorophyll), while the open bays generally had lower algae levels more suitable for seagrasses. Phytoplankton abundance in Assawoman, Isle of Wight, Sinepuxent, and Chincoteague Bays was generally low enough to allow for seagrass growth during 2007–2013. The St. Martin River and tributaries of Newport Bay demonstrated high chlorophyll levels (21% of sites) and failed the thresholds established for seagrass growth and dissolved oxygen.

Trends

Improving nutrient trends are a sign the system is heading in the right direction. Nitrogen levels improved (71% of stations) but there was less improvement in phosphorus (29% of stations). Flow adjusted trends are an indicator of management success. Additionally, improving trends in chlorophyll *a* occurred mostly in Chincoteague Bay (33% of stations), leading scientists to anticipate that seagrasses will respond positively in time. Degrading chlorophyll *a* trends (increased algae) in Isle of Wight and Assawoman Bays are not a positive sign for seagrass.



Chlorophyll trends show differences between northern and southern bays. Seagrass growing season (March–November) flow adjusted and observed trends for chlorophyll *a*. Only stations with at least 80% of monthly data available were tested.

CHRONIC HARMFUL ALGAL BLOOMS)THREATEN ECOSYSTEMS OF COASTAL BAYS

Although algal blooms (including those considered to be toxic) are a natural phenomenon, the geographic distribution and abundance of harmful algal blooms (HABs) are increasing. Over 20 potentially harmful algae species are found in the Maryland Coastal Bays and several may produce toxins that can be harmful to humans.

Factors that are believed to play a role in promoting harmful algae blooms are nutrient concentrations and ratios, freshwater input, temperature, salinity, and grazing. Sites with higher nutrients (closer to the mouths of tributaries) favored the development of dinoflagellates and very small phytoplankton compared to sites closer to the inlets. Selective grazing occurs by zooplankton, planktivorous fish, jellyfish, and shellfish.

Brown tides are caused by the algae *Aureococcus anophagefferens*. Blooms turn the water a deep coffee color and can have significant impacts on seagrasses (shading) and shellfish (starvation). Brown tide blooms have been found in all coastal bays segments; however, an area in the southern bays from Newport Bay to Public Landing across to Tingles Island consistently has the highest levels. Blooms peak between late May and mid-June and decline as bay water temperatures rise above their optimum growth range.

Under certain conditions, this algae species can produce okadaic acid, which causes diarrhetic shellfish poisoning. While blooms have been documented in offshore waters and the Maryland Coastal Bays, there is low toxin production in the bay. Only one exceedance of FDA threshold has been detected to date in a no-shellfish area. The increase of bloom prevalence and toxins on every U.S. coast in recent years, demonstrates the need to monitor this problematic species.

Alexandrium cf. minutum was first detected in the St. Martin River (a no-shellfish area) in 2015. This species has the potential to produce paralytic shellfish poisoning toxins. To date, no toxins have been detected.

Monitoring for potential HABs is ongoing. Samples are tested for toxins if cell count thresholds are exceeded.

Foam accumulation in Isle of Wight Bay as a result of a mahogany tide.

In 2018, a winter bloom of *Prorocentrum minimum* occurred in Isle of Wight and Assawoman Bays. This bloom is also known as a mahogany tide because it turns the water a distinct reddish-brown color, decreasing light available to seagrasses. The unusual winter bloom is believed to have been caused by higher nutrients resulting from the record setting rainfall along with elevated winter water temperatures. A record level of chlorophyll was recorded in the St. Martin River (953 µg/L), the highest observed level in the state in the past 30 years. The abundance of algae died back in early 2019, leading to large accumulations of sea foam in some areas of the bays (one source of sea foam is from the agitation of saltwater containing high organic matter).

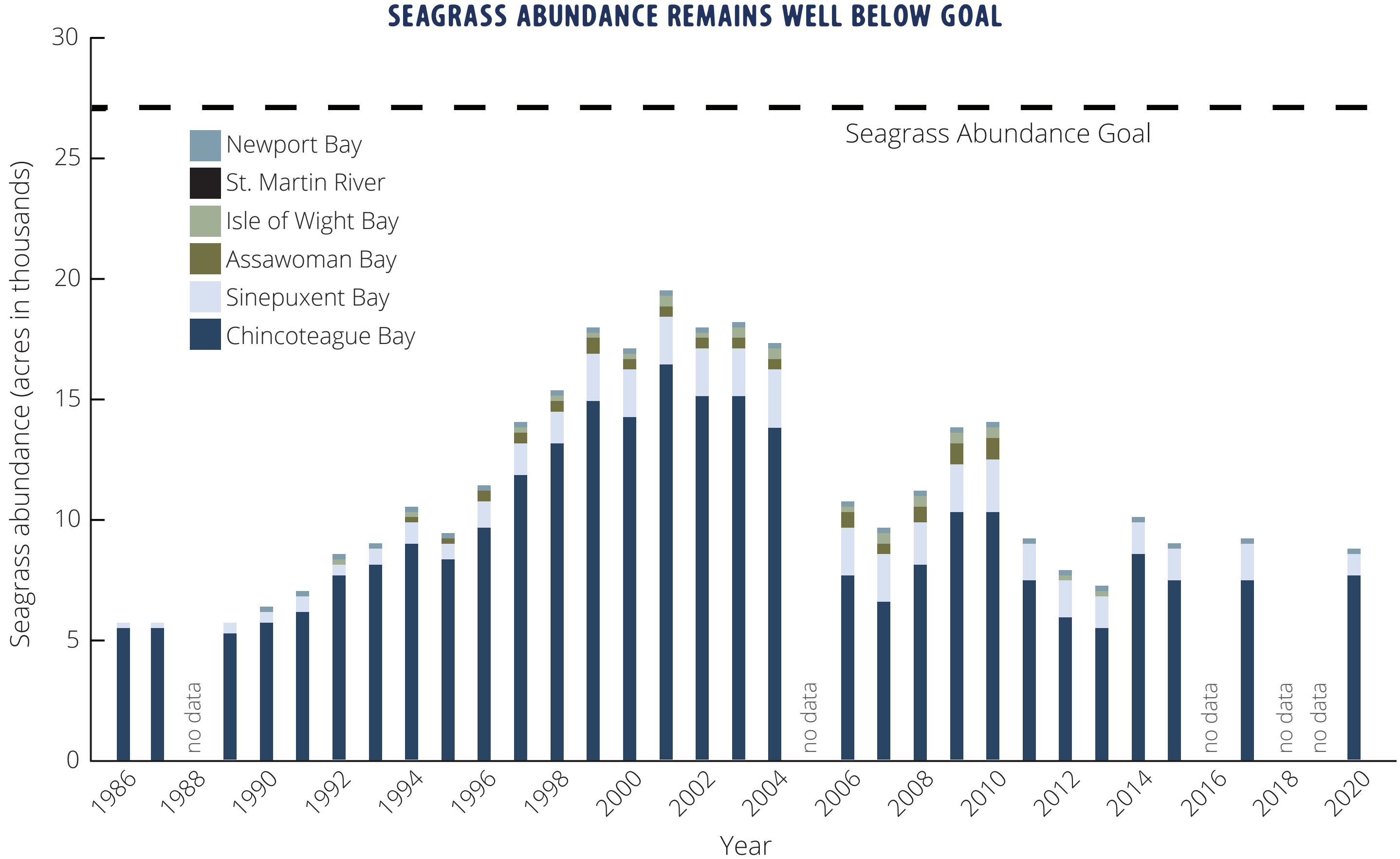
SEAGRASSES MISSING IN NORTHERN COASTAL BAYS, POISED FOR COMEBACK IN SOUTHERN COASTAL BAYS

Seagrasses, also known as Submerged Aquatic Vegetation (SAV), provide essential habitat for fish, crabs, and other ecologically, commercially, and recreationally important fish and shellfish species in the Coastal Bays. Seagrass beds serve as nurseries, protection, and feeding areas for aquatic life. A total of 48 fishes have been collected in the SAV Habitat Survey. The most abundant were Atlantic silverside, black sea bass, halfbeak, sheepshead, silver perch, and tautog. Black sea bass, sheepshead, and tautog abundance has increased since 2015, while silver perch relative abundance has decreased. The most abundant crustaceans were blue crabs, brown shrimp, and grass shrimp. The SAV survey shows that this habitat is critical for the early life stages of fish species of management concern including tautog, sheepshead, and black sea bass. Seagrasses improve water quality by producing oxygen, absorbing excess nutrients, and removing sediment from the water. They also buffer waves and can reduce shoreline erosion.

Restoring seagrass abundance and maintaining acceptable habitat conditions within the Coastal Bays are critical management objectives. Important seagrass habitat factors include limits on sediment organic content (<5%) and water temperature (<30°C). The two main species of seagrass in the bays are widgeon grass and the dominant eelgrass. In the early 1930s, an eelgrass wasting disease virtually eliminated eelgrass along the East Coast, including areas in the southern Coastal Bays. However, seagrass had recovered to 74% of its historical abundance by 2001. Since then, seagrasses have significantly decreased in the Maryland Coastal Bays. Seagrasses suffered large losses in 2005 and are currently half what they were at their peak. Seagrasses have disappeared north of the Ocean City inlet and have been replaced by seaweeds that are more tolerant of poor water quality and low light. Current seagrass abundance is just over 9,000 acres, 33% of the 27,041 acre goal.

Increasing water temperatures and decreased light from reduced water quality have led to decreasing eelgrass populations throughout the Mid-Atlantic region. Locally, eelgrass populations are projected to decrease even further as water temperatures continue to increase. While widgeon grass may fill the niche in most areas, there will be ecological consequences. Management efforts to reduce nitrogen and phosphorus will facilitate recovery of SAV, despite climate stressors (e.g. temperature, CO_2 concentrations, and sea-level rise), by improving water clarity.

SEAGRASS ABUNDANCE REMAINS WELL BELOW GOAL



Annual seagrass abundance (acres) vs. seagrass goal. Data from Virginia Institute of Marine Science survey. Recent weather events and poor water clarity have prevented the aerial survey from occurring in 2016, 2018, and 2019.

COASTAL BAYS SUPPORT A LARGE DIVERSITY OF FINFISH

The Coastal Bays are essential fish habitat for many species at multiple life stages, many of which support local fisheries. Since 1972, Maryland Department of Natural Resources (MD DNR) has sampled the Coastal Bays through the trawl and beach seine surveys.

Results of these annual surveys show the presence of over 140 species of finfish. Abundance and species diversity observed in these surveys indicates stability, with no significant trend since 1989. Several species, like summer flounder, Atlantic croaker, Atlantic menhaden, black sea bass, and tautog, which are relatively abundant in the Coastal Bays, are also of commercial and recreational importance to the area.

Increasing water temperature affects species composition

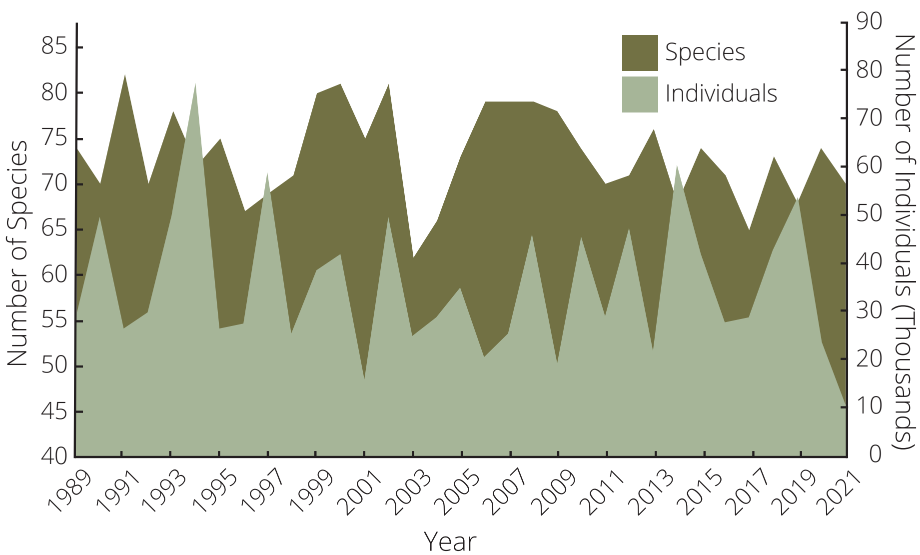
Survey data indicate that annual surface water temperature has been increasing since 1995 (see graph, p. 4). The annual upward temperature trend was most influenced by the increasing temperatures in September and October. This increase in surface water temperature will affect species composition of the fish stocks in the Coastal Bays.

Fish populations are stable, but the future is uncertain

SAV is a critical habitat for fisheries. Increasing water temperature negatively impacts SAV growth, which, in turn, adversely impacts fish habitat and populations. While current populations of fish are stable in the Coastal Bays, continued SAV loss will likely result in a decrease in fish populations and species diversity.

Summer flounder support a commercial fishery offshore Ocean City. Pictured are Captain Albert Dennis (right), biologists Steve Doctor (left), and Angel Willey (back). Photo by Steve Doctor.

NUMBER OF FISH INDIVIDUALS AND SPECIES CAUGHT PER YEAR INDICATES STABILITY



Count of fish species (dark color) and total number of fish (light color) collected annually by the MD DNR trawl and beach seine surveys conducted in Maryland's Coastal Bays.

Most abundant species from MD DNR surveys, 1989–2021

Shallow water (beach seine):

- Atlantic menhaden
- Bay anchovy
- Mummichog
- Spot

Deeper water (trawl):

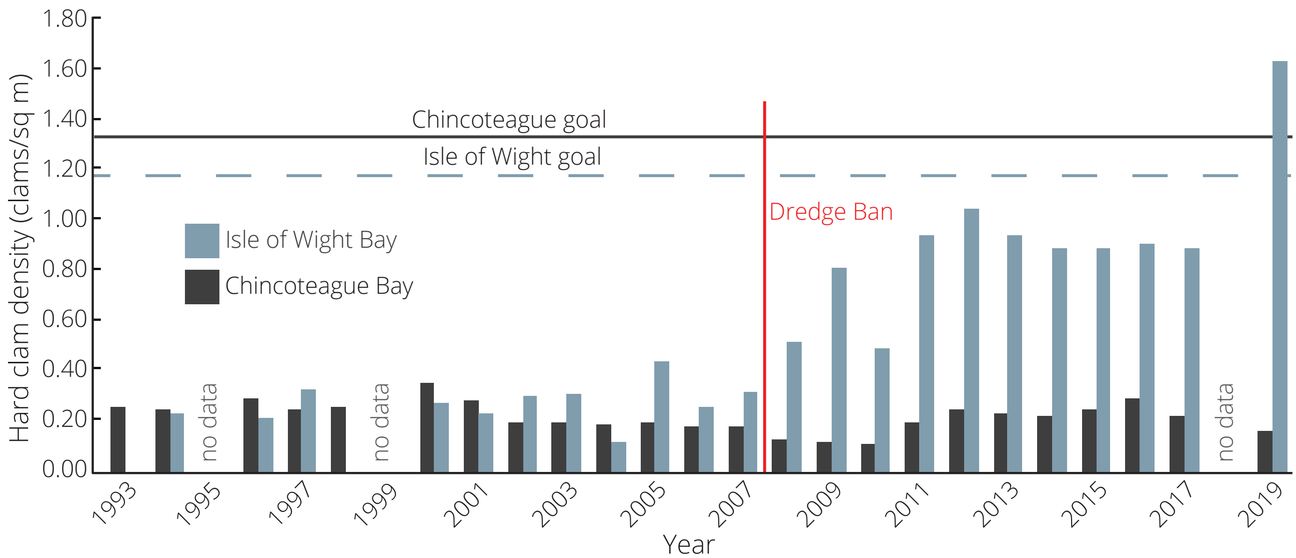
- Atlantic croaker
- Silver perch
- Spot
- Summer flounder
- Weakfish

WILD SHELLFISH POPULATIONS LACKING EXCEPT FOR HARD CLAMS IN NORTHERN BAYS; AQUACULTURE ON THE RISE

Hard clams are improving in northern bays, but struggle in Chincoteague Bay

For years, densities of commercially important hard clams in the Coastal Bays were well below the benchmarks established in 1952–1953. In 2008, mechanical harvesting of shellfish was legislatively prohibited in the Coastal Bays. Since then, population numbers have increased, but the degree of recovery varies, with most of the bays still below their baseline values. Clam densities have risen sharply from Sinepuxent Bay northward. Isle of Wight Bay has been the only major clam population to exceed its 1953 baseline. In Chincoteague Bay, historically the primary focus of the hard clam fishery, clam densities remain a fraction of the historic benchmark. Despite the near absence of harvest pressure, recovery of this species requires an extended period of time, on the order of a decade or more. It may take up to several decades for this population to return to its benchmark density.

HARD CLAM DENSITY HAS IMPROVED SINCE THE DREDGING BAN



Chincoteague and Isle of Wight Bay hard clam densities before and after the dredging ban (red bar) and the historic benchmark densities (black and blue lines). Data courtesy of MD DNR.

There are still no viable oyster populations in the Coastal Bays

Populations of the eastern oyster in the Coastal Bays have historically been relatively small. The practice of "salting" oysters that were brought from the Chesapeake Bay and allowed to take on a saltier flavor in Chincoteague Bay was a livelihood and a source of pride for bayside communities at the turn of the century. Today, native populations of the eastern oyster are primarily present in the intertidal zone and on anthropogenic structures like pilings and riprap mostly in the Sinepuxent and Isle of Wight Bays.

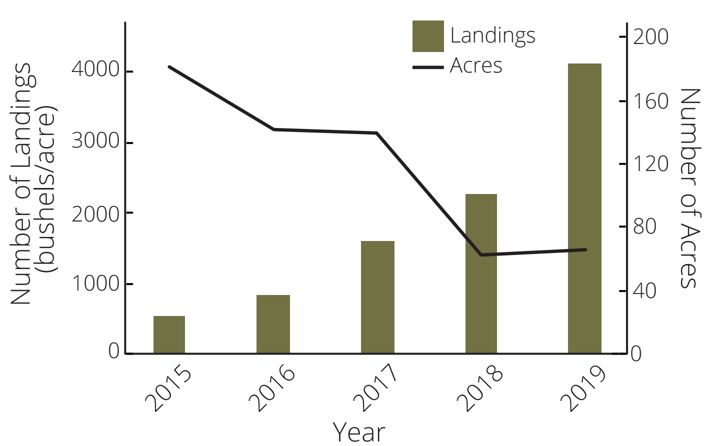
Bay scallops populations still at risk

The status of bay scallop populations remains tenuous following a reintroduction by MD DNR during the late 1990s. Extremely low densities over the past 15 years, diminishing habitat, and declining water quality suggest that the long-term viability of the bay scallop population is in question.

Shellfish aquaculture is on the rise

The trend in shellfish aquaculture has been one of steady annual increases in landings. Production has increased from 525 bushels in 2015 to 4,111 bushels in 2019. Initially both hard clams and oysters were being raised, but this has shifted to only oysters in recent years.

AQUACULTURE LANDINGS INCREASING



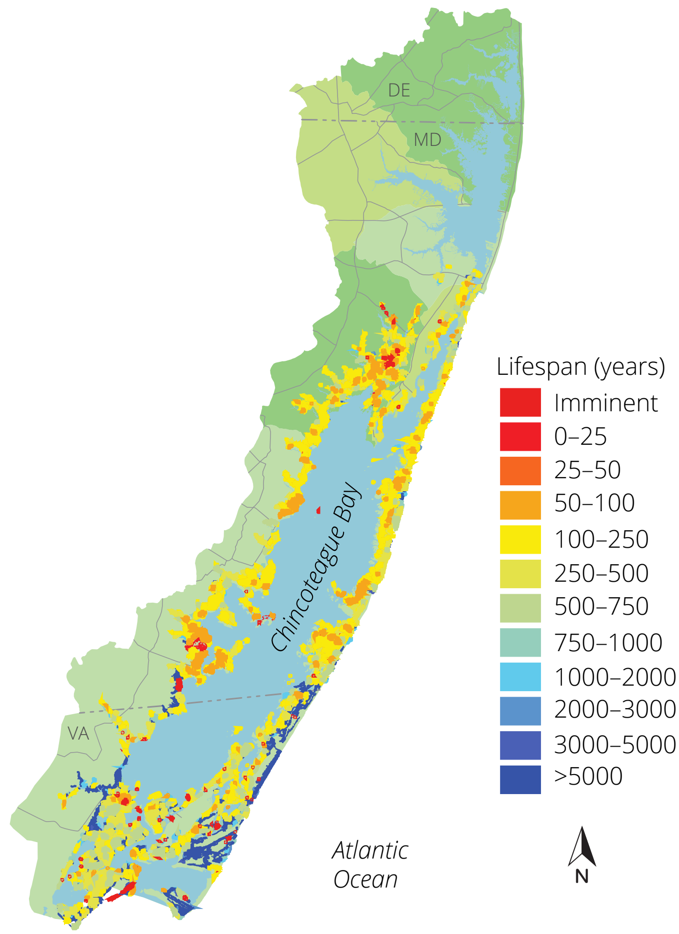
Maryland Coastal Bays aquaculture landings and acreage under active lease, 2015–2019. Data courtesy of MD DNR.

HISTORIC MARSH DITCHING LED TO MARSH LOSS; EFFORTS TO AMELIORATE DITCHING IMPACTS UNDERWAY

Approximately 90% of salt marshes from Maine to Virginia are ditched, and most coastal marshes in the U.S. are degraded by marsh filling, diking, or draining. These historic impacts greatly exacerbate the impact of sea level rise, causing negative feedback loops that lead to vegetation loss, expansion of open water on the marsh surface, marsh subsidence, and saturation of the marsh platform. In the same geography, highly altered marshes have greatly reduced lifespans, whereas marshes without human impacts and under the same sea level rise influence have much longer lifespan estimates of 1,000–5,000 years.

These human-induced impacts are particularly pronounced in the Mid-Atlantic, where marsh ditching is pervasive and relative sea level rise is occurring at rates twice the global average. On the western shore of Chincoteague Bay in Maryland, the marshes are extensively ditched with significant ponding and megapool formation between the ditches. This system is also microtidal, with tide ranges never exceeding one foot, so mineral sediment delivery is low, making it difficult for degraded marshes to accrete quickly enough to offset marsh subsidence and sea level rise. Like most marshes throughout the Northeast, the Chincoteague Bay marshes need extensive management to prevent the complete collapse of marsh processes.

Restoring the natural physical processes within a marsh, such as hydrology and marsh surface elevation, is paramount to recovery. Filling linear man-made ditches and channels, while establishing an interconnected channel network, will allow marshes to build function and resiliency.



Despite a similar landscape and SLR scenarios, the highly altered marshes of MD have projected lifespans of just 0-250 years (warm colors) while the unimpacted and largely intact marshes of VA have lifespans of 1,000 to >5,000 years (cool colors). Data source: Ganju, NK, Defne, Z., 2022.

Aerial image taken in 2019 of E. A. Vaugh Wildlife Management area showing how marshes in the Coastal Bays are degrading and drowning due to ditching and vegetation die-back. Photo by Roman Jesien.

HABITAT LOSS DECIMATING COLONIAL WATERBIRD POPULATIONS

Common tern adults on raft. Photo by Kim Abplanalp.

Common tern adult and chick with fish. Photo by Kim Abplanalp.

Bird populations have declined for species that nest on bare sand, such as beaches. Forster's terns are slowly declining because of inundation events following storms that clear nests. Common terns, black skimmers, and royal terns have also lost all the barren sand habitat as Skimmer Island, the last major island providing natural habitat, has lost its potential for nesting because of flooding. Other threats include great horned owls that feed on tern chicks and adults.

To counteract the drastic decline in habitat, a two-pronged approach was developed. One phase is to continue planning to manage sand in a beneficial manner by restoring islands wherever possible. Groups such as the U.S. Army Corps of Engineers, Department of Natural Resources, and Audubon Mid-Atlantic have banded together with the Maryland Coastal Bays Program to see how and where dredge material can be best used for beneficial purposes. The other phase is to construct an artificial island to quickly provide the critical habitat. The artificial island is a floating platform that was deployed in a remote area in Chincoteague Bay in 2021. Patterned after several similar artificial nesting islands in Ontario, Minnesota, and Ohio, the 32ft × 32ft platform was constructed in March/April 2021 and deployed May 6, 2021. Common terns were the only bare sand colonial nesting birds that occupied the platform in 2021. A total of 23 pairs of common terns hatched 36 chicks, 22 of which fledged. This was the largest common tern colony in the Coastal Bays in 2021.

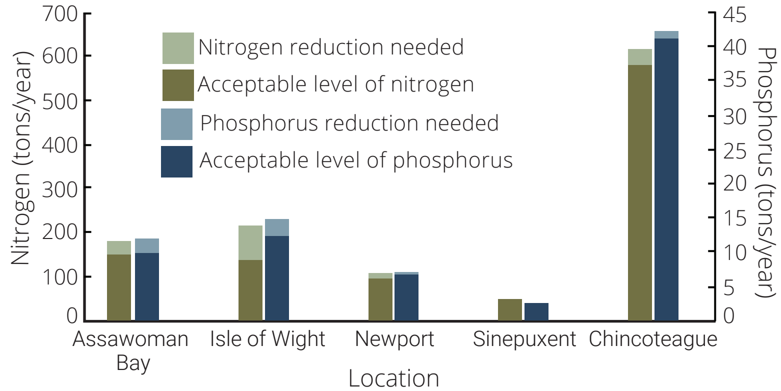
Nesting platform deployed May 2021. This was the largest common tern colony in the Coastal Bays with 23 pairs. Photo by Roman Jesien.

Not all bird populations are declining. With climate change, some coastal birds are benefiting from longer summers. For example, young brown pelicans, which have successfully nested in South Point Spoils Island, in Chincoteague Bay, start flying after 13 weeks, so longer summers have helped increase numbers as survival increases. Black-backed gull populations have increased because there are no predators on the existing salt marsh islands where they nest.

INCREASED COMMITMENT TO "NUTRIENT DIET" NEEDED

Under the federal Clean Water Act (CWA), the state of Maryland is required to assess all waters against any and all applicable water quality criteria and develop a Total Maximum Daily Load (TMDL) for waters identified as impaired for a given pollutant. A TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet water quality criteria. TMDLs have often been referred to as "pollution diets." The Maryland Coastal Bays have been identified as impaired for nutrients on Maryland's Integrated Report.

NUTRIENT LEVELS MUST DECREASE IN THE COASTAL BAYS



Nitrogen and phosphorus reductions needed to meet water quality goals.

TMDLs for nitrogen and phosphorus were developed by Maryland Department of the Environment (MDE) and approved by EPA in 2014. The TMDLs set limits on the total amount of nitrogen and phosphorus that can enter the waterways. They also assign allocations and reductions to both permitted and non-permitted sources. The TMDL targets and allocations are set by a hydrodynamic and eutrophication model used to simulate the impacts of various nutrient loadings on water quality within the Maryland Coastal Bays.

Within the Coastal Bays TMDLs, MDE sets nutrient targets for permitted and non-permitted sources. Permitted sources include municipal and industrial wastewater, industrial stormwater, and concentrated animal feeding operations. Non-permitted sources include municipal urban stormwater, agriculture, atmospheric deposition, shoreline erosion, and natural background sources such as forests. In most instances, TMDLs are implemented via incorporation of TMDL allocations into permits. In the case of the Coastal Bays TMDLs, most of the loads are from non-regulated sources, so most of the implementation will be voluntary. MDE is working with Worcester County and the Maryland Coastal Bays Program and coordinating with the state of Delaware to develop watershed plans that will open up grant funding opportunities to implement restoration projects in these non-regulated source sectors.

A watershed plan for the Assawoman Bay watershed to address the non-permitted sources in the TMDLs was conditionally approved by EPA's CWA Section 319 Non-point Source Program in September 2019. The plan identifies the implementation actions that the applicable entities intend to implement to achieve the nitrogen and phosphorus reductions from non-point sources. The Assawoman Bay plan calls for 370 acres of best management practices (BMPs) and 1,700 ft. of stream and shoreline restoration that would mainly occur on agricultural land. Participation and buy-in from the agricultural community will be a major factor in the success of this plan and TMDL achievement. MDE and its partners are still working on plans for the other Maryland Coastal Bays TMDL watersheds.

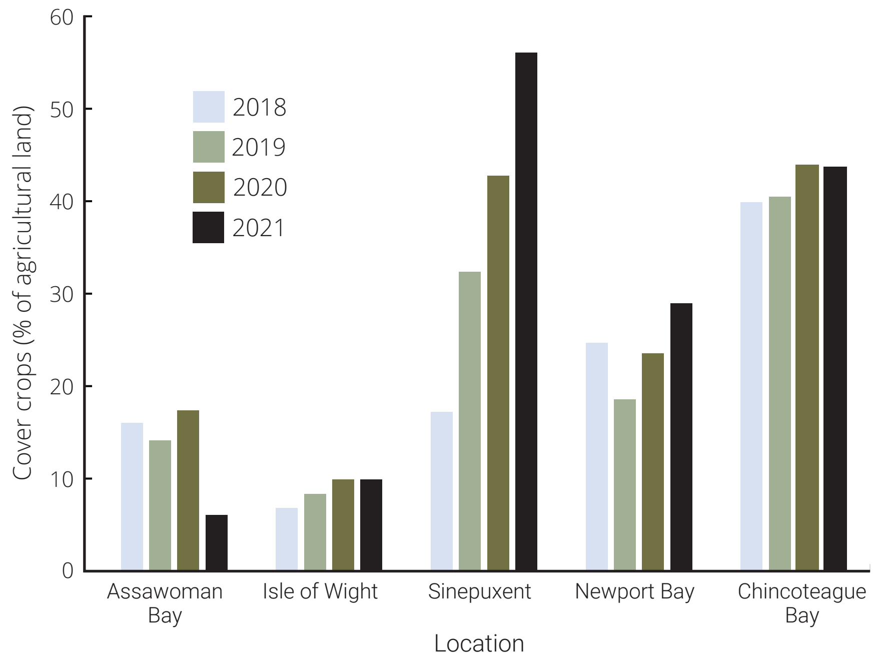
Assawoman Bay Watershed Plan Short and Long Term Goals.

		Component			
		Watershed assessment and plan refinement	**Project implementation**	**Load reductions**	**Monitoring**
Measurable Goals	Short Term (2020–2024)	Assawoman Bay/Isle of Wight Bay assessment completed	103 septic conversions; 86.5 acres with SCWQMPs, 54.26 acres with core NMPs; and 3 demonstration BMPs in Assawoman Bay	25% of load reductions achieved in Assawoman Bay; 25% of load reductions achieved in Isle of Wight Bay	Continued monitoring is needed to track progress
	Mid Term (2025–2029)	Newport Bay and Chincoteague Bay assessments completed	Continue work on implementation in Assawoman Bay; begin work on implementation in Isle of Wight Bay	75% of load reductions achieved in Assawoman Bay; 25% of load reductions achieved in Isle of Wight Bay	Continued monitoring is needed to track progress
	Long Term (2030–2040)	N/A	Complete implementation in Assawoman Bay; continue work on implementation in Isle of Wight Bay; begin work on implementation in Newport Bay and Chincoteague Bay	100% of load reductions achieved in Assawoman Bay, Isle of Wight Bay, Newport Bay, and Chincoteague Bay.	

COVER CROP IMPLEMENTATION HELPS ALLEVIATE NUTRIENT RUNOFF INTO COASTAL BAYS

Cover crops provide farmers with a strong defense against nutrient runoff and soil erosion during the winter months when farm fields would otherwise lie bare. Maryland's Cover Crop Program is administered by Maryland Department of Agriculture (MDA) and the state's 24 soil conservation districts through the Maryland Agricultural Water Quality Cost-Share (MACS) Program. The program's current budget is largely provided by the Chesapeake and Atlantic Coastal Bays 2010 Trust Fund and the Chesapeake Bay Restoration Fund. Applicants must be in good standing with MACS to participate and must be in compliance with the Nutrient Management Program.

USE OF COVER CROPS INCREASING IN COASTAL BAYS



Cover crop application varies in the Coastal Bays due to weather, crop type, and timing of harvest.

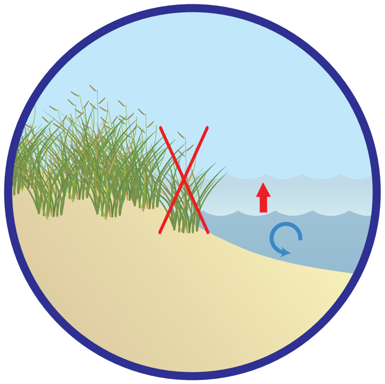
Cover crops have been used for centuries, but recent research has confirmed their benefits. Since not all nitrogen fertilizer that is applied during the primary growing season is used by the target crop, the remaining nitrogen is transformed into nitrate that moves through the soil with water. Cover crops can step in to take that excess nitrogen out of the soil and stop it from moving out of the soil and into the water. To investigate this more thoroughly, scientists from the University of Maryland Wye Research and Education Center studied winter rye cover crops planted after corn harvest. They found cover crops consistently reduced annual nitrate leaching losses by approximately 80% compared to bare fields. Under long-term continuous corn production, shallow groundwater nitrate-nitrogen concentrations decreased by at least half after seven years of winter cover cropping. This encouraged state legislators to provide monetary incentives to ensure as widespread use of cover crops as possible in Chesapeake Bay and the Coastal Bays.

Sign-up for the cover crop grants is held in early summer and coordinated through soil conservation districts. Cost-share rates vary from year to year; however, in recent years farmers have received up to $45 an acre for incorporated seed and $50 an acre for aerial seed or aerial ground seeding. Additional incentive payments are available for highly valued planting practices. Farmers in the Coastal Bays watershed have consistently taken advantage of the cover crop program.

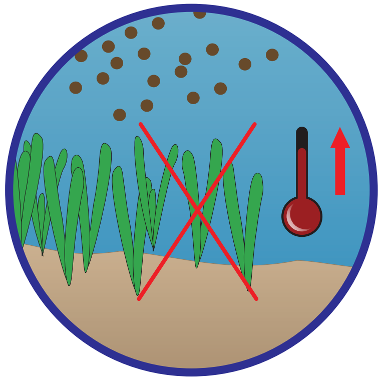
Cover crops may be planted after corn, soy, beans, sorghum, or vegetables. Barley, canola, rapeseed, kale, rye, ryegrass, spring oats, triticale, forage radish, and wheat may be used as cover crops. Photo by Roman Jesien.

MAJOR THREATS TO COASTAL BAYS HEALTH

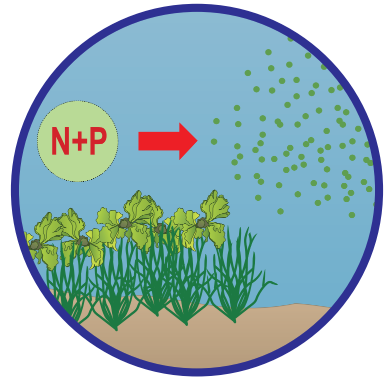
Erosion and relative sea level rise leading to salt marsh and island loss



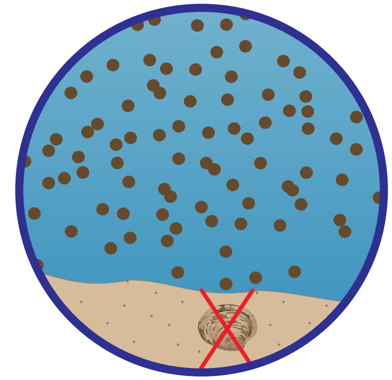
Heat stress and poor water quality leading to seagrass loss

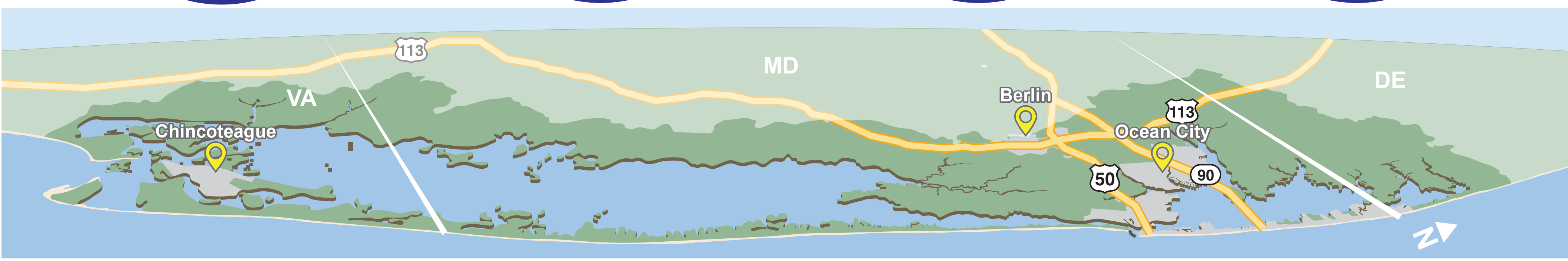


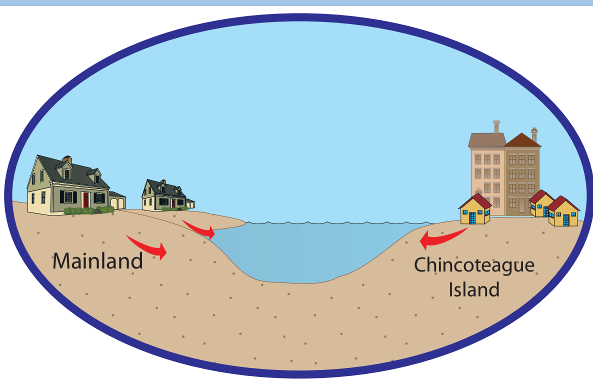
Increased nutrients leading to algal blooms



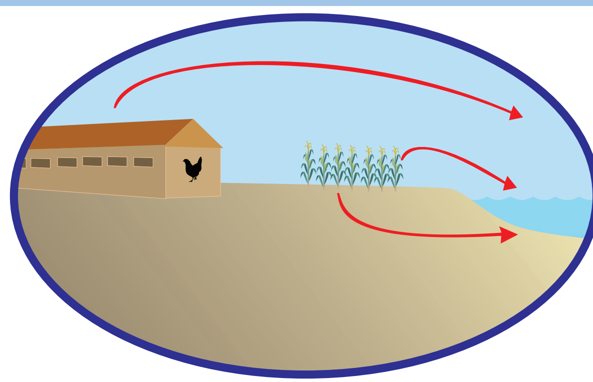
Chronic brown tide blooms degrading water quality



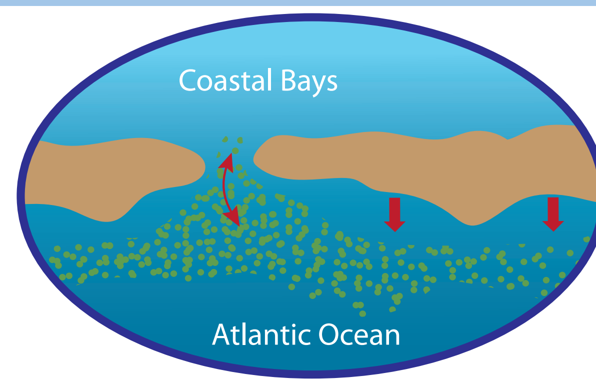




Nutrient inputs from septic systems via groundwater percolation



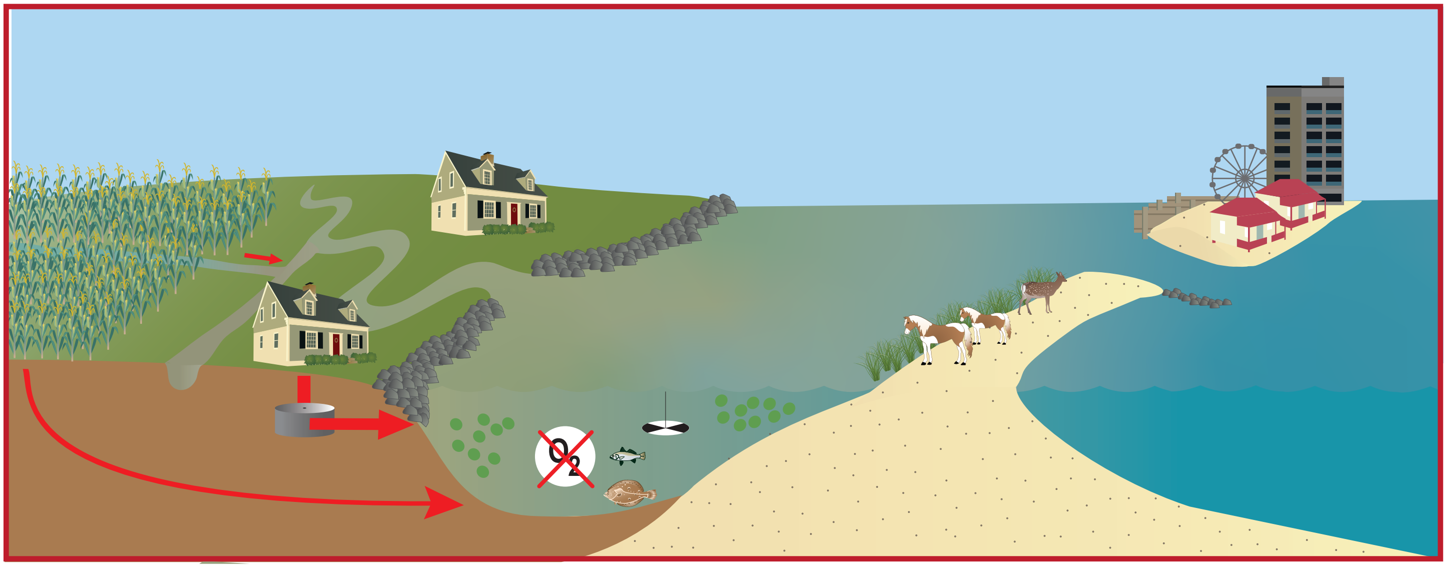
Agriculture nutrient inputs via atmospheric, surface runoff, and groundwater pathways



Offshore nutrients from upwelling, Delaware Bay, and sewage discharge can enter the bays via tidal exchange; nutrients from the bay can also flush out to the ocean

BEST MANAGEMENT PRACTICES CAN IMPROVE HEALTH AND RESILIENCY

UNHEALTHY AND NON-RESILIENT SYSTEM



In this scenario, nutrient sources from agriculture , houses with septic systems , and atmospheric deposition are unabated. In addition, upland migration of salt marshes and seagrasses is impeded by hardened shorelines and degraded by animal grazing . Poor water quality leads to harmful algal blooms , low dissolved oxygen , turbid water , and sparse fish .

HEALTHY AND RESILIENT SYSTEM

In this scenario, nutrient sources from agriculture and houses with sewer systems are mitigated. In addition, upland migration of salt marshes and seagrasses is facilitated . Good water quality leads to abundant fish , birds , clams , and clear water .

IN ADDITION TO MANAGING FOR CURRENT CONDITIONS, ACTIONS TO ENHANCE RESILIENCE NEEDED FOR THE FUTURE

The Maryland Coastal Bays watershed is positioned on the front lines of current and future climate change impacts, including sea level rise, increased temperatures, and more frequent and extreme weather events. Consequently, climate resilience—the capacity to prepare for, respond to, and recover from climate change impacts—has been one of Maryland Coastal Bays Program's (MCBP) highest priorities over the past five years.

The current Comprehensive Conservation and Management Plan (CCMP) has a chapter on Coastal Resilience citing 50 actions relating to climate change, and climate resilience is certainly a predominant focus of the upcoming CCMP revision process scheduled to be completed in 2024. The Program has conducted a Climate Change Vulnerability Assessment that identifies and prioritizes risks that climate change stressors pose for effective implementation of the CCMP, and a corresponding Climate Change Action Plan is near completion.

The living shoreline project near the Assateague State Park boat ramp. Eroding shoreline was enhanced with headlands and beaches that dissipate wave energy and a freshwater wetland that intercepts storm water. Photo by Roman Jesien.

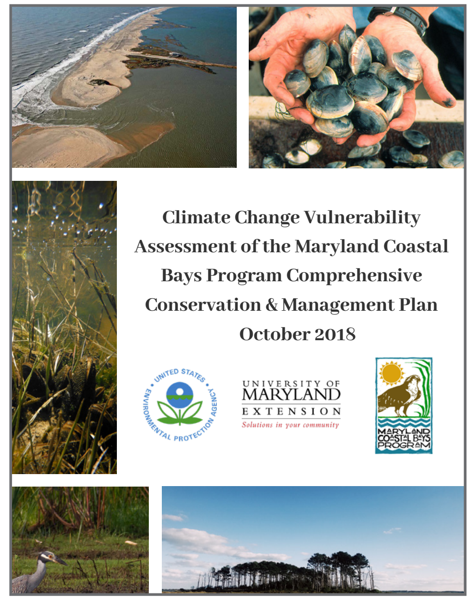
DEVELOPING A CLIMATE ACTION PLAN VITAL TO BUILD RESILIENCE

The EPA Climate Ready Estuaries (CRE) program works with the National Estuary Programs and the Coastal Management Community to: (1) assess climate change vulnerabilities, (2) develop and implement adaptation strategies, and (3) engage and educate stakeholders.

In 2018, the MCBP completed the first five steps of EPA's "Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans." This Climate Change Vulnerability Assessment (CCVA) was conducted to learn about and prepare for the ways climate change stressors might affect MCBP's ability to reach the 14 goals of the 2015–2025 Comprehensive Conservation and Management Plan (CCMP). The outcome of this assessment is the identification and prioritization of 168 risks that could limit MCBP's ability to reach those goals. Chief among the priorities to address are the impacts climate change will have on the Water Quality goals and Fish and Wildlife goals of the CCMP.

MCBP is currently in the final stages of developing a Climate Change Action Plan (CCAP) guided by the concluding steps in the EPA workbook. This CCAP includes the identification of those risks from the CCVA that can be mitigated, and the development of proposed adaptation actions to advance the targeted mitigation goals. A final report should be available by the end of 2023.

It has become increasingly clear that climate-related impacts have a real and significant effect on the quality of life, water, and habitat in Maryland's Coastal Bays. MCBP will be engaging citizens and other stakeholders in the revision of our CCMP for 2025 to adequately address these issues.



The Climate Change Vulnerability Assessment is the first phase of the EPA Climate Ready Estuaries process completed by MCBP in 2018. Credit: MCBP and University of Maryland Extension.

This table identifies and prioritizes risks to the effective implementation of the MCBP CCMP posed by projected climate change stressors. Goals fall into one of four categories: Water Quality (WQ), Fish and Wildlife (FW), Recreation and Navigation (RN), or Community and Economic Development (CE). Credit: MCBP and University of Maryland Extension.

Goals	Number of Risks		
	Red	Yellow	Green
Decrease nutrient loading throughout the watershed (WQ1)	17	7	2
Decrease inputs of toxic contaminants (WQ2)	2	3	15
Implement a strategy to meet TMDL restrictions (WQ3)	4	0	2
Characterize, monitor, and manage fishery resources and habitats (FW1)	21	9	6
Characterize, monitor, and manage estuarine resources and habitats (FW2)	10	3	1
Characterize, monitor, and manage terrestrial resources and habitats (FW3)	14	1	1
Expand upon the coordinated effort to collect and report on Coastal Bays geomorphic and biometric info (FW4)	1	0	0
Improve recreational opportunities and access to the Coastal Bays and tributaries (RN1)	0	2	2
Balance resource protection with recreational use (RN2)	5	0	2
Continue to implement the Ocean City Water Resources Study recommendations (RN3)	3	2	1
Manage sediment alterations in a manner beneficial to the local economy and natural resources (RN4)	2	0	1
Manage the watershed to maximize economic benefits while minimizing negative resource impacts (CE1)	5	7	3
Enhance the level of sustainability in land-use decision making (CE2)	1	3	8
Educate and inform the population so it can make knowledgeable decisions for the community and its future (CE3)	0	1	0
Total: 168 Risks	86	38	44

RESTORATION PROJECTS LIKE TIZZARD ISLAND AND BISHOPVILLE DAM REMOVAL ENHANCE RESILIENCE

Ensuring healthy and robust natural systems is essential to building a more resilient and stalwart coast. Recent restoration activities have focused on enhancing critical wildlife habitat and providing protection for communities and infrastructure. Recent projects include the living shoreline near Assateague State Park boat ramp, the Bishopville Dam Removal and the Bainbridge Pond stormwater management retrofit. Future restoration and resiliency projects such as the shoreline and marsh restoration projects on Tizzard and Reedy Islands, the dam modification and fish passage project at Swans Gut and the Jenkins Point Peninsula resiliency project in Isle of Wight Bay continue to focus on habitat enhancement as well as providing for long-term resiliency and protection to account for storm surge, sea level rise and high intensity rainfall events.

The Bainbridge Stormwater Retrofit after shortly after completion. This project helps to address flooding and improve water quality in ocean Pines. Photo by Kevin Smith.

Marsh degradation and loss is of particular concern as acres of vegetated tidal marsh are shrinking in the Coastal Bays. MCBP is partnering with the U.S. Fish and Wildlife Service to assess the extent of marsh loss and target critical marsh habitat for restoration. A planned project at Rum Pointe in Sinepuxent Bay is an example where rebuilding marsh elevation and reducing tidal flooding using new techniques such as “runnels” will be tried for the first time in the Maryland Coastal Bays.

Climate resilience is also an important element in reducing nutrient and sediment pollutant loading into the bays, as increased precipitation exacerbates stormwater runoff, and shoreline erosion and marsh loss threaten critical buffer and filtering assets. Countering these impacts was a key consideration in recent watershed-wide assessments focused on identifying and prioritizing non-point source nutrient reduction project opportunities.

The removal of the Bishopville Dam provided opportunities for anadromous fish passage and provided a more ecologically robust and resilient stream and riparian corridor. Photo by Keith Pivonski.

INCREASED STORMS REQUIRE BETTER STORMWATER MANAGEMENT

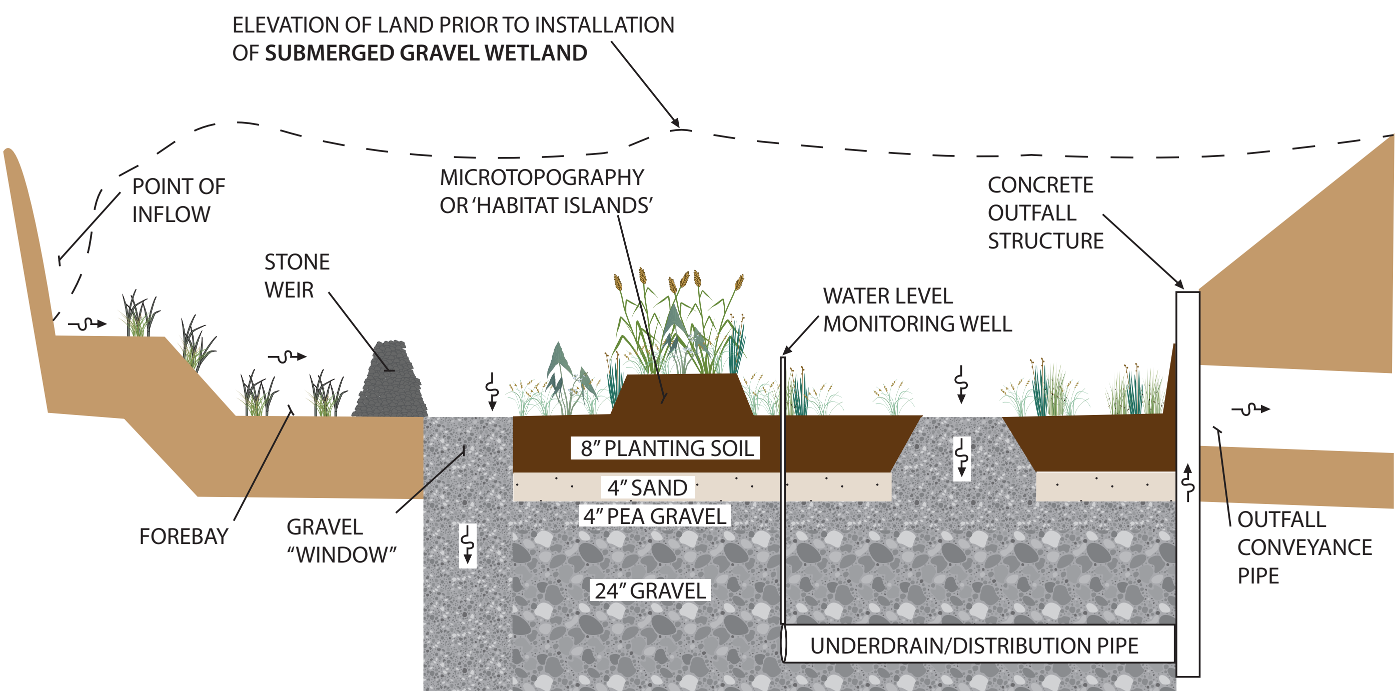
Effective stormwater management continues to be a priority challenge in the Coastal Bays watershed, not only as a means to prevent or mitigate the impacts of coastal flooding, but also to decrease non-point nutrient and sediment pollution loading into the bays. Both aspects of this stormwater challenge are only exacerbated by the impacts of climate change, particularly the increased frequency and severity of storms.

Over the past five years, MCBP has conducted a series of assessments in the watershed to identify and prioritize opportunities to address non-point source nutrient loading, including the targeting of specific sites for the installation of cost-effective best management practices, many of which focus on stormwater management. These assessments have yielded a robust pipeline of ranked opportunities for which to seek design and implementation funding.

An old electrical transfer station was converted into a sand gravel wetland to collect and treat stormwater in a Berlin neighborhood prone to flooding. Photo by Roman Jesien.

MCBP has also been engaged with partners in the watershed to facilitate and participate in on-the-ground projects to enhance stormwater management to reduce flooding and improve water quality. This includes the installation of a submerged gravel wetland in the Town of Berlin and the retrofit of Bainbridge Pond in Ocean Pines. Both of these projects are examples of green infrastructure, an approach to stormwater management that uses natural or nature-based systems—as opposed to pipes—to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters.

Stormwater runoff from agricultural lands is one of the most significant sources of non-point source pollution in the watershed. MCBP is engaging with a number of property owners to address this issue through wetland restoration and managing stormwater to improve water quality and enhance wildlife habitat.



A submerged gravel wetland serves to store stormwater runoff and provides a small-scale filter using wetland plants in a rock media to provide water quality treatment. This green infrastructure approach was used for a project in the town of Berlin, installed in 2019. Diagram modified from EA Engineering, Science and Technology.

LIVING SHORELINES PROTECT PROPERTY AND PROVIDE CRITICAL HABITAT

Traditional methods of erosion protection along the shorelines of Maryland's Coastal Bays have typically consisted of bulkheads and rock revetments. These methods can be effective at stopping erosion but have a negative impact on the fish, fowl, and plants that inhabit these areas.

The Assateague Island State Park living shoreline 2 years after construction. Vegetated headlands diffuse and refract wave energy which maintain the quiescent coves. This shoreline project attracts nesting horseshoe crabs, diamondback terrapins, and marsh nesting birds such as willets. Photo by Roman Jesien.

Shorelines are the transition area between open water and upland habitat. This transition area is critically important to the life cycle of many of tidewater creatures, such as horseshoe crabs, diamondback terrapins, shorebirds, and fish.

Erosion and deposition along shorelines is a natural phenomenon and a result of the dynamic environment where they exist. It is also vitally important to the health of the ecosystems. Erosion is also exacerbated by boat wakes, lack of SAVs, and lack of oyster reefs in the nearshore area. Reducing erosion to protect infrastructure and critical habitat is desired in some areas. But is it possible to do that and still maintain the dynamic and vital role that these shorelines play in the overall ecology of the Coastal Bays?

Living shorelines replicate natural features to reduce erosion, sustain habitat, and allow for dynamic natural processes to continue. These processes include the daily flushing of tidal waters and the movement of sediment.

Living shoreline treatments can include marsh plantings, installing low-profile sills, headland structures, coir logs, sand, tree trunks, cobbles, or any number of other natural materials which replicate natural processes and help stabilize the shoreline. Every shoreline is different, therefore the design of each living shoreline should be tailored to that specific location.

In cases where artificial shore erosion structures, like bulkheads, already exist, they can be modified. One of these practices is the installation of green bulkheads. Green bulkheads are typically made of round PVC pipe, filled with sand, and attached to the side of the bulkhead. The tops of the PVC pipes are located below and above mean water levels so that plants that require different flooding regimes can be planted and allowed to grow. This provides habitat for fish and other aquatic species which prefer a more complex ecosystem.

Recently, the Maryland Coastal Bays Program worked with the Maryland Department of Natural Resources and Assateague State Park to design and install an innovative living shoreline near the Verrazano Bridge on Route 611. This project protected approximately 700 linear ft. of eroding shoreline and used vegetated headland control as the primary method for reducing erosion and enhancing the shoreline habitat. This project provides habitat for a variety of organisms that need shallow water, beach, and marsh habitat.

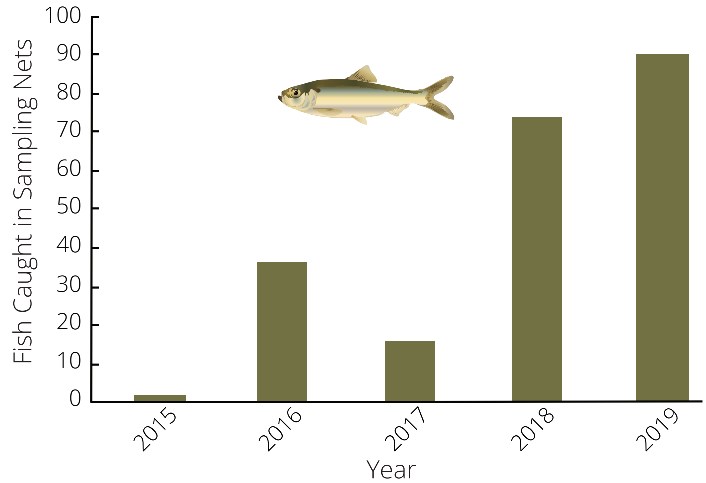
The completed installation of a green bulkhead in Ocean City. Grasses are planted in the top of these PVC pipes to provide additional habitat for fish and other aquatic species. Photo by Roman Jesien.

RESTORING WATERWAYS VIA DAM REMOVAL ENHANCES FISH PASSAGE

Modification of the dam at Bishopville in late 2014 provided a passage for migrating fishes to access over seven miles of headwater streams. The four-ft-high dam was replaced with four gently sloping steps and pools that were structured to allow fish to move upstream in one-ft increments. The steps were planted with native vegetation to establish a naturally-functioning stream corridor. The mill dam, originally built around the late 1870s, provided cheap power for lumber or grain production for the growing local communities. As other more reliable sources of power became available, the mill fell into disrepair and was removed, but the dam and mill pond remained and became cherished parts of the community. The passageway maintains the water level in the pond.

Considering the detrimental effects of dams on fish populations, and an estimated 80,000 dams in the U.S., this innovative technique has a wide range of applications. The approach provides the benefits of stream habitat while maintaining an historic mill pond with its associated benefits to water quality. Fish like alewife and white perch, which spawn in freshwater, are able to reach their spawning grounds. Alewife, an important forage species for many commercially important ocean species, has greatly reduced populations due to habitat loss from dams and poor water quality. The addition of a spawning stream along the Atlantic Coast benefits the population. Freshwater species, such as largemouth bass, white crappie, and several turtle species that might go over the dam, are able to return to their freshwater habitat.

ALEWIFE PASSAGE INCREASING FOLLOWING DAM REMOVAL



Index of fish passage. Number of alewife caught after the modification of the dam at Bishopville in late 2014. Data source: 2019 MCBP Monitoring Report.

The Bishopville Dam before its removal (top) and the final restored stream (bottom). Photos by Roman Jesien.

ISLAND LOSS HAS CAUSED COLLAPSE OF COLONIAL WATERBIRD POPULATIONS

Island formation is a natural occurrence in coastal lagoon systems. As storms and hurricanes pass, inlets are cut in the barrier island and typically close off after a while as sand continues to move. This process was severely diminished with the stabilization of the inlet after the 1933 storm, which opened a large channel through the barrier island. The inlet was quickly stabilized with rock, and the commercial harbor was dredged so that Ocean City had an ocean port. That stabilization caused major changes in the pattern of sand movement in and outside the bays. It starved the north end of Assateague Island from getting new sand, causing it to erode away. To accommodate boating traffic in the bays, the U.S. Army Corps of Engineers built and maintains a navigation channel to the north and south of the inlet. The material from the channel dredging was used to build islands in the bays. Similarly, islands were restored after the 1962 storm and again after Hurricane Sandy in 2012.

The importance of these islands for colonial nesting birds was acknowledged in the 1998 Ocean City Water Resources Study completed by the U.S. Army Corps of Engineers. Dredge material is a vital tool for providing habitat for coastal ground nesting birds. Birds, such as black skimmer, royal tern, common tern, and oyster catchers, need a vegetation-free beach on which to lay their eggs. With sea level rise brought about by climate change, increased boat traffic, and development pressures, suitable island habitat for these birds is almost gone. Between 1989 and 2007, the Maryland Coastal Bays lost 295 acres of islands, a 26% loss of acreage. Of the islands restored through dredging the federal navigation channel following Hurricane Sandy, only one still existed in 2021.

Skimmer Island, a haven for colonial waterbirds for decades, has recently lost so much sand that it has ceased to produce birds despite placement of beneficial material from 2011–2013. Photo by Roman Jesien.

Future island restoration efforts are certainly needed and can be accomplished through a cooperative effort among a variety of interested groups, including Worcester County, Town of Ocean City, state and federal resource, permitting and funding agencies, private and commercial shoreline landowners that have dredging needs, and bird-centered organizations such as Mid-Atlantic Audubon.

EFFORTS ARE BEING MADE TO RESTORE DEGRADED MARSHES

Most of the Maryland Coastal Bays marshes were grid ditched in the 1930s by the Civilian Conservation Corps, altering marsh hydrology and ultimately resulting in widespread interior marsh ponding and vegetation die-off. As an example, at the Croppers Island site, 25% of the marsh has been converted to open water megapools, a trend that is representative of many marshes in the area. There are currently four marsh restoration projects that are part of a larger strategy to restore 1,233 acres of degraded marshes.

Restoration goals are to create designs to restore historical human-induced impacts, build resiliency, and create habitat for marsh nesting birds, fish, and shellfish. This will be accomplished through the following techniques: (1) installation of runnels to drain water from megapools to foster marsh grass recolonization, (2) restoration of ditches back to meandering marsh channels, and (3) placement of sediment on the marsh to fill ditches and build elevation. The designs will be completed by an engineering/design firm with experience working locally implementing restoration projects in microtidal marsh systems using nature-based solution engineering. All of these restoration techniques have been implemented successfully in the Mid-Atlantic at project sites like Reeds Beach in New Jersey, Prime Hook National Wildlife Refuge in Delaware, Pepper Creek in Delaware, Blackwater National Wildlife Refuge in Maryland, and Assateague Island National Seashore in Maryland.

The saltmarsh sparrow is an endangered species and is considered a species of Greatest Conservation Need in Maryland in the Maryland State Wildlife Action Plan. It has suffered a steep population decline along the East Coast. The Fish and Wildlife Service has identified the Coastal Bays marshes as high priority habitat for the saltmarsh sparrow. They have identified areas containing salt marsh that are good candidates for restoration, enhancement, and/or conservation to provide persistent high-quality nesting habitat in the next 10 years in addition to long-term salt marsh resilience.

U.S. FWS, UMCES, and MCBP staff modify earthen and sheet pile plugs from mosquito ditches constructed in the early 1900's. Proper hydrology is critical to maintaining healthy and robust marsh ecosystems.

The saltmarsh sparrow is reliant on marshes in the Maryland Coastal Bays.

NUTRIENT PLUMES DETECTED OFFSHORE ARE A CONCERN FOR COASTAL BAYS

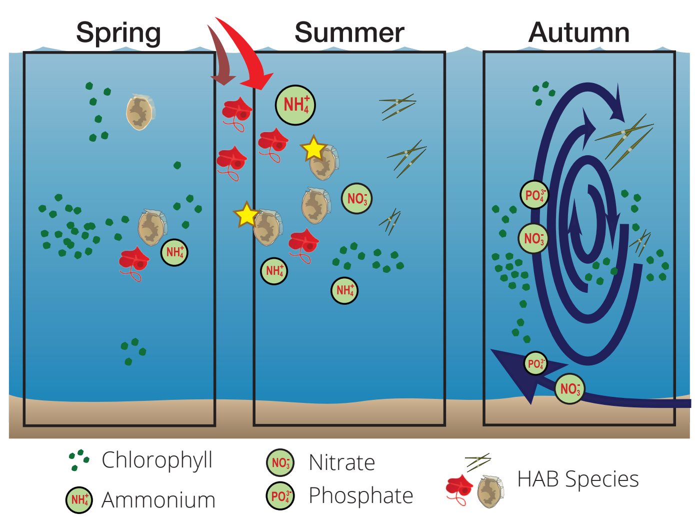
The coastal Mid-Atlantic Ocean, offshore of the Delmarva Peninsula, is undergoing ecological changes due to both anthropogenic climate change and eutrophication. The coastal zone is important since it is connected to the Coastal Bays of Maryland through both the Ocean City and Chincoteague Inlets. Entrainment of these ocean waters into the Coastal Bays may bring less polluted waters into the bays or be a possible nutrient source. Initial models assumed ocean waters were very low in nutrients. To better define nutrient concentrations in offshore waters, 10 transects were established and sampled in 2011 (May), 2012 (August), 2018 (June, July, and October), and 2019 (May and July).

Baseline condition assessments found areas of elevated nitrogen, phosphorus, and chlorophyll *a*. Small centric diatoms (< 10 µm) were the dominant diatom found throughout the survey area. This deviates from historic findings from 1976–2005 which documented *Skeletonema costatum*, a much larger species and better food source for zooplankton/fish, as the dominant diatom. Additionally, the presence of some emergent harmful algae species of concern *(Dinophysis, Karenia, and Pseudo-nitzschia)* were documented. In 2011, the state began routinely surveying offshore waters at 5 stations for HAB species of concern. While cell concentrations were generally found below bloom levels, an occasional bloom was detected. The presence of HABs were associated with nitrate and ammonium concentrations.

Continued eutrophication, climate change, and the impact of connected waterways present challenges for managing regional water quality issues in the coastal ocean. Elevated nutrients may be from Delaware Bay outflow, upwelling ocean currents, and/or offshore discharge of sewage treatment plants in the summer (increased tourist population). The plume from Delaware Bay reaches as far south as Assateague after high rain events. The high concentration of nutrients in the coastal plumes may also give rise to phytoplankton blooms which use up the oxygen in the area at night and lead to massive fish-kills. Anecdotal observations suggest that chlorophyll *a* in offshore waters has increased causing the water to be more turbid, leading fishermen to go further offshore for clearer water.

Nutrients and HAB species vary seasonally. The most significant factor of an emergent HAB was the presence of nitrate and ammonium. Higher nutrient and chlorophyll concentrations in autumn were due to mixing of resuspended phosphate and phytoplankton species. There was also nutrient upwelling from cooler, deeper waters in autumn. This research helps illuminate what species of HAB are present, in what numbers, and how they are influenced by environmental conditions.

Map of the study area with data collection sites, transects, sewage outflow locations, and MCB inlet locations.



Conceptual diagram outlining the chemical, biological, and physical processes that occur in the study region.

ENHANCED MONITORING AND INNOVATIVE RESEARCH NEEDED TO BUILD RESILIENCE

Water quality monitoring is conducted regularly in the Maryland Coastal Bays by Maryland Department of Natural Resources and the National Park Service.

Enhanced monitoring is needed to assess progress toward resilience. One of the critical monitoring needs is the reestablishment of continuous monitoring stations. Daily fluctuations in temperature and dissolved oxygen means regular monthly daytime sampling often misses the excursions in temperature (late afternoon) and dissolved oxygen (early morning). In addition, inlet flushing due to meteorological events is likely more important than astronomical tidal flushing and can be captured with continuous monitoring.

Rising water temperatures are a major concern for living resources in the Coastal Bays, and more frequent and widespread water temperature measures will help detect critical periods of elevated temperatures.

Monitoring HAB species is particularly important in the Coastal Bays, as HAB species of concern have been detected both in the Coastal Bays and offshore. For example, dense blooms of the brown tide and mahogany tide species have been observed.

Existing assessments of submerged aquatic vegetation (SAV), shellfish, birds, and water quality need to be continued as these parameters have been changing. Additional parameters to be considered include emerging contaminants and plastics.

Research needs in the Coastal Bays revolve around building an understanding of the factors that influence resilience. For example, the upland migration of salt marshes and SAV will be crucial in light of relative sea level rise, as is understanding the processes that control the successful migration of these critical habitats. Salt marsh enhancement through runnels and ditch filling requires research to test their effectiveness. In addition, interception of nutrient runoff from both agricultural and urban stormwater using innovative techniques, like denitrifying 'woodchip' bioreactors, phosphorus binding clays, or biofilm reactors, require research to test their efficacy for the Coastal Bays.

The issue of island loss that has led to the collapse of colonial waterbirds requires a better understanding of hydrodynamics and sediment movement in the Coastal Bays. Potential sediment placement from navigational or maintenance dredging would be enhanced with a better understanding of the sediment dynamics.

The eutrophication transition that the Coastal Bays is poised to undergo from a benthic-dominated ecosystem with SAV to a pelagic-dominated ecosystem with phytoplankton represents an ecological "tipping point." The dynamics that control this transition need to be better studied.

A risk assessment of toxicants is needed to structure a monitoring program that addresses emerging contaminants as well as existing contaminants.

EMERGING CONTAMINANTS THREATEN BAYS

Pesticides are a contaminant that threaten the bays. Photo by Jane Hawkey.

Contaminants of emerging concern are an issue of global alarm due to their potentially harmful effects on wildlife and human health. Examples include pharmaceuticals, personal care products, pesticides, natural and synthetic hormones, flame-retardants, and plastic products. These contaminants can enter the bays through land runoff, direct discharge (sewage treatment plants, septic systems, agricultural), and atmospheric deposition. They can dissolve in water, or they can bind onto fine-grained particles that eventually settle to the bottom of the bays. These contaminants can be harmful to organisms resulting in lower biodiversity and/or abundance and may become more concentrated as they move up the food chain (bioaccumulation). The effects of multiple toxins in the environment are unclear, but they are thought to work simultaneously and compound the stress of any individual toxin on aquatic organisms.

Increased knowledge on the adverse impacts of various compounds as well as improved methods of detection has led to better recognition of contaminants including Per and polyfluoroalkyl substances (PFAS; a group of toxins), endocrine disrupting chemicals, and pesticides. PFAS, dubbed "forever chemicals," were widely used in the construction industry, military, clothing, furniture, and firefighting. They do not break down over time readily and dissolve in water. A recent assessment of community drinking water systems included seven samples from the Coastal Bays watershed in 2021. PFAS were below detection or well below Maryland standards (four samples).

Recent research identified the presence of environmental estrogens, known as endocrine disruptors, in the water and sediments of the Coastal Bays. Endocrine disruptors are chemical compounds that mimic estrogen in organisms that produce eggs, which may affect reproductive ability and development. Expression of vitellogenin (VTG) in male fish has become a widely used biomarker of exposure to environmental estrogens. VTG is a hormone that is needed for egg production in females and should not be found in males. In a follow-up study in the Coastal Bays, researchers found VTG in almost all the male mummichog and striped killifish that were sampled. The presence of this hormone in male fish is disturbing and can lead to reproductive problems in a population. Highest levels were found in fish in Newport Bay and lowest near the Assateague Island National Park.

Breakdown of current contaminants of concern, their effects and impacts, and current management actions to address them.

Sources of Emerging Chemicals of Concern in the Coastal Bays

Toxicant	Primary Uses or Sources	Environmental Impacts	Current Management
Endocrine disruptors	Component of plastics and flame retardants	Developmental and reproduction problems	Screening and testing
PFAS (Per and polyfluoroalkyl substances)	Stain resistance and flame retardants	Immune system and child neurodevelopment	Proposed hazardous designation
Pesticides	Control plant and animal pests	Human and ecosystem health	Restricted use
Microplastics	Beauty products, clothing, breakdown of large plastics	Largely unknown	Micro-bead ban

PLASTIC POLLUTION HARMS AQUATIC LIFE IN THE BAYS

With increased global production of plastics since the 1950s, marine environments have experienced an increase in plastic pollution. Plastic pollution is now ubiquitous in the ocean. A floating garbage patch sits hundreds of miles off the coast in the Atlantic Ocean, covering a region roughly the distance from Cuba to Virginia (smaller than the Pacific trash vortex). Large plastics break down into pieces smaller than can be detected with the human eye (called microplastics) and enter the bays from urban runoff, agricultural runoff, and wastewater (treated or untreated septic/sewage). The most common plastics are drink bottles and grocery bags, while the most prevalent microplastic is fiber from fabrics, such as fleece. These very small particles have been found throughout the food web along with any adsorbed organic chemicals. Together, these have implications to aquatic food webs and potentially to humans that consume seafood.

The National Park Service beach survey showed that Assateague Bay had an average of 112 pieces of plastic/kg of sand (slightly above average amongst the 37 National Park Beaches tested). Fibers made up 97% of the microplastics found at these beaches. Microfibers, tiny synthetic pieces of plastic yarn from textiles and woven materials, are one of the biggest sources of plastic pollution in our oceans, and they are found virtually everywhere on the planet.

In 2021, NOAA released the Mid-Atlantic Marine Debris Action Plan. Action starts with limiting personal plastic use and increasing recycling and proper disposal. Area researchers are gearing up to take a closer look at the distribution of microplastics in the Coastal Bays, but efforts at source reduction and clean up have been going on for a number of years. Annual beach and road clean ups by volunteer groups have removed debris and plastics. An MCBP program called Marine Plunder has enlisted volunteers to remove tons of debris including plastics from the Coastal Bays. Significant decreases of plastic in the Coastal Bays are needed to prevent impacts to aquatic life.

Multiuse bags were donated to area businesses to distribute to reduce use of plastic bags. Photo by Mike Collins.

Benches made of recycled plastics from cigarette butts and placed on the board walk drive home the message that butts should be disposed of properly. Cigarette butts contain harmful chemicals. Photo by Sandi Smith.