National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Assateague Island National Seashore Natural Resource Condition Assessment

Maryland, Virginia

Natural Resource Report NPS/ASIS/NRR—2011/405

ON THE COVER

Aerial view of Assateague Island showing marshes, ditches, and seagrass.
Assateague Island National Seashore.
Photo: Jane Thomas, IAN Image Library

Assateague Island National Seashore
Natural Resource Condition Assessment

Maryland, Virginia

Natural Resource Report NPS/ASIS/NRR—2011/405

Tim Carruthers, Kris Beckert, Bill Dennison, Jane Thomas, Tracey Saxby, Mike Williams
Integration & Application Network
University of Maryland Center for Environmental Science
PO Box 775
Cambridge, MD 21613

Tom Fisher
Horn Point Laboratory
University of Maryland Center for Environmental Science
PO Box 775
Cambridge, MD 21613

Jack Kumer, Courtney Schupp, Brian Sturgis, Carl Zimmerman
Assateague Island National Seashore
National Park Service
7206 National Seashore Lane
Berlin, MD 21811

June 2011

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the Northeast Coastal and Barrier Network, Northeast Region (http://www.nps.gov/nero/science/final/finalreps.htm) and the Natural Resource Publications Management Web site (http://www.nature.nps.gov/publications/nrpm) on the Internet.

Please cite this publication as:

Carruthers, T., K. Beckert, B. Dennison, J. Thomas, T. Saxby, M. Williams, T. Fisher, J. Kumer, C. Schupp, B. Sturgis, and C. Zimmerman. 2011. Assateague Island National Seashore natural resource condition assessment: Maryland, Virginia. Natural Resource Report NPS/ASIS/NRR—2011/405. National Park Service, Fort Collins, Colorado.

TIC Number: 622/107814

NPS 622/107814 , June 2011

Contents

Figures

Tables

Appendices

Executive Summary

BACKGROUND AND CONTEXT

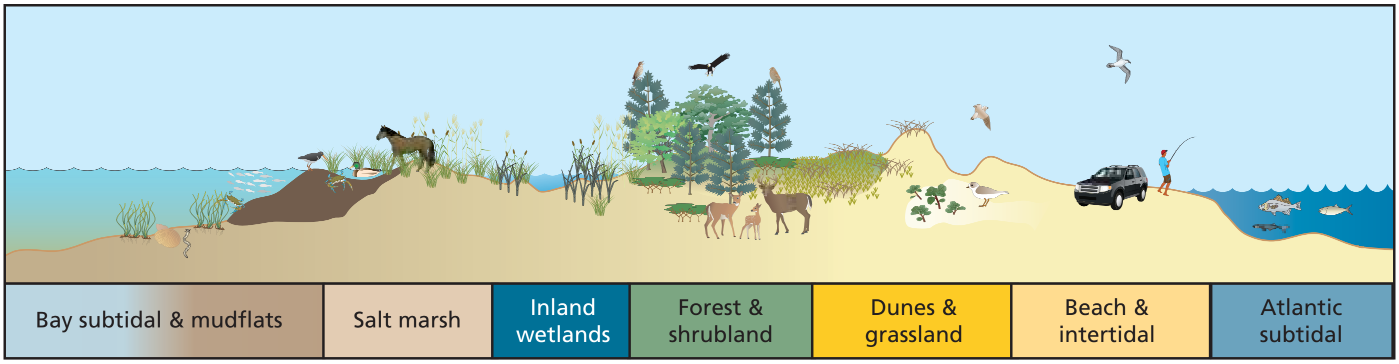
Assateague Island National Seashore, established in 1965, includes 11,571 ha (28,584 acres) of lands and waters in Maryland and 4,813 ha (11,902 acres) of lands and waters in Virginia. Assateague Island also contains protected lands under the jurisdiction of the Maryland Park Service (Assateague State park) and U.S. Fish and Wildlife Service (Chincoteague National Wildlife Refuge). The Seashore receives some two million visitors per year, most of whom are beach day visitors from mid-Atlantic states, but other activities include back country camping, and permitted hunting of deer, upland game, and waterfowl, within season.

An important context for this resource condition assessment, is that barrier islands are naturally dynamic ecosystems, potentially migrating meters on an annual basis, with longshore drift resulting in a continual sand erosion and deposition cycle. Barrier islands are also subject to major changes from storms that cause island overwash, and by major storms, and hurricanes, that can cause island breaching or form new inlets. These dynamic processes create the unique habitats, flora and fauna that are the key features of Assateague Island (including overwash areas, piping plover and seabeach amaranth); however, they also have the potential to dramatically change fundamental aspects of the island.

The unique history of Assateague Island, preceding the establishment of the National Park, also provides important context to an assessment of natural resource condition. In terms of the geomorphology of the island, significant impacts include the hard stabilization of Ocean City inlet, which was opened by the 1933 storm, the strengthening of a protective dune along much of the island following the 'Ash Wednesday Storm' in 1962, and the creation of an emergency storm berm at the north end of the island after two extra-tropical cyclones in 1998 threatened to breach the island. Two significant biological introductions, horses and sika deer, while non-native species to the area, have become significant park resources in their own right. Accordingly, this assessment includes these metrics in the context of stressors when they are extreme, but in recognition that maintaining a naturally dynamic system with sustainable populations of horses and deer is also the desired condition.

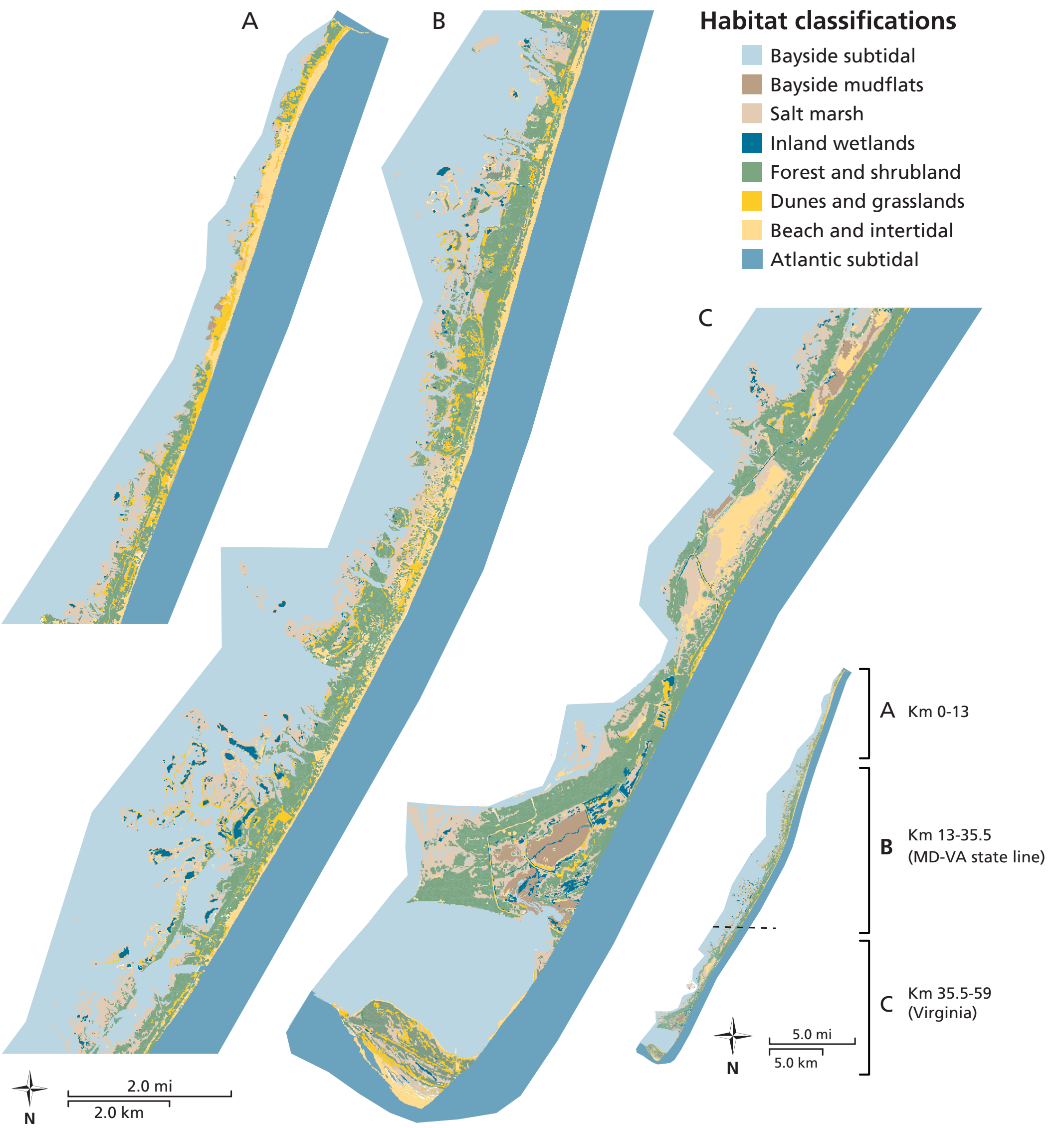
Photo: NPS ASIS

Assateague Island horses are both a feature and a stressor.



APPROACH

A habitat framework was used to assess natural resource condition within the Seashore. After determining key habitats on Assateague Island, potential indicators to inform the current condition of these habitats were identified and data sourced. Reference conditions were determined based on published scientific literature, federal guidelines, and historic data as appropriate. Attainment of reference condition was assessed for each metric and summarized by habitat and ultimately for the whole park. Based on these key findings, management recommendations were developed.



FEATURES OF ASSATEAGUE ISLAND NATIONAL SEASHORE

Photo: istockphoto.com

More than two million people visit the seashore every year including these bay side salt marshes.

The abundant resources of Assateague Island National Seashore include physical features of the Island, ecosystem features and human use features. Assateague Island is a naturally dynamic coastal barrier island, structured by storm activity. These storms cause island overwash by large waves resulting in sand erosion and accretion, including inlet formation and closure. Assateague Island has an independent groundwater system, with a fresh lens 6-7 m (20-23 ft) deep in the center of the island and less than 1 m (3 ft) near both shores. Globally rare sand overwash habitat provides nesting sites for the threatened shorebird, *Charadrius melodus* (piping plover). The dune annual, *Amaranthus pumilus* (sea-beach amaranth) is only found in these habitats between the high tide line and the base of the primary dune. The Seashore is an important site for many migratory bird species, and supports populations of the native white tail deer (*Odocoileus virginianus*) as well as the historically introduced sika deer (*Cervus nippon*) and horses (*Equus caballus*). The aesthetic appeal, beach, and unique fauna (including the feral horses) are key reasons for visiting the Seashore, and therefore important human use features. The National Park Service is committed to monitoring and preserving natural night sky conditions, and the Seashore is one of the longest sections of undeveloped coastline on the mid-Atlantic US coast, providing a rare dark sky experience.

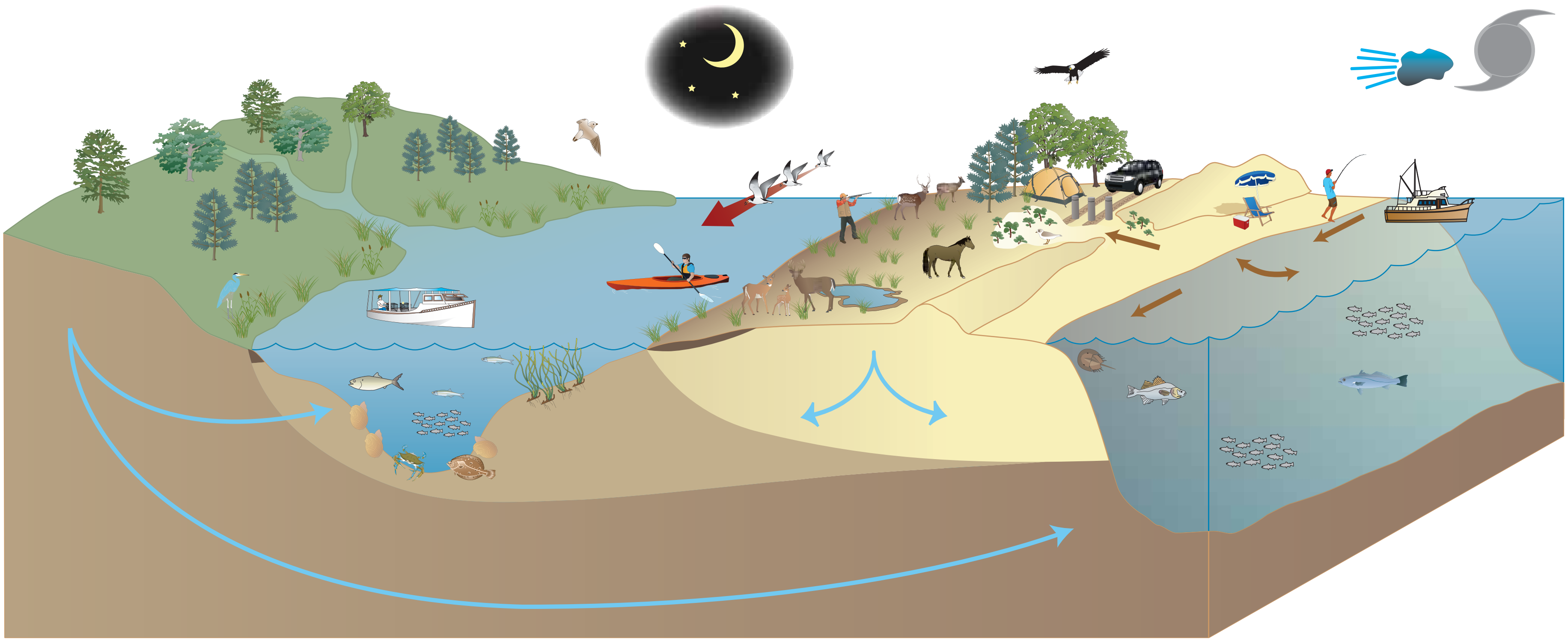
THREATS TO ASSATEAGUE ISLAND NATIONAL SEASHORE

Photo: Jane Thomas, IAN Image Library

Aerial view of Assateague Island, showing proximity to Ocean City Inlet and development.

Threats and stressors to the natural resources of Assateague Island National Seashore occur at three main scales, within the Seashore itself, within the surrounding watersheds and within the mid Atlantic region. Changes to vegetation structure and dune erosion have been observed as a result of the Seashore's feral horse, white tail and sika deer populations. Many invasive plant species, including the highly invasive strain of *Phragmites australis*, occur within the Seashore. Over-sand vehicles impact the beaches, and have historically impacted dunes areas. Historic mosquito ditches remain, potentially impacting wading and shorebirds as well as estuarine water quality. The coastal bays within and adjacent to the Seashore are impacted by development, agriculture, and concentrated animal feeding operations throughout the adjoining watersheds, and are showing evidence of degrading water quality and loss of seagrass meadows. The mid-Atlantic region includes some of the highest population densities in north America, resulting in regional scale stressors, such as poor air quality. The mid-Atlantic region of the US has experienced almost twice the global mean rate of relative sea level rise over the past century (3-4 mm yr^{-1}), which is predicted to increase a further 19 cm by 2030, resulting in increased coastal flooding and changes to coastal geomorphological processes.

Conceptual diagram showing the key features of Assateague Island.



Physical features

- Storms result in inlet formation, closure, and island overwash.
- Dynamic geomorphology includes longshore sand transport, island "rollover," and net westerly migration.
- Mainland groundwater discharges to the coastal bays and the ocean. Assateague groundwater is isolated.
- Removal of artificial structures is restoring natural processes such as dune building and overwash.

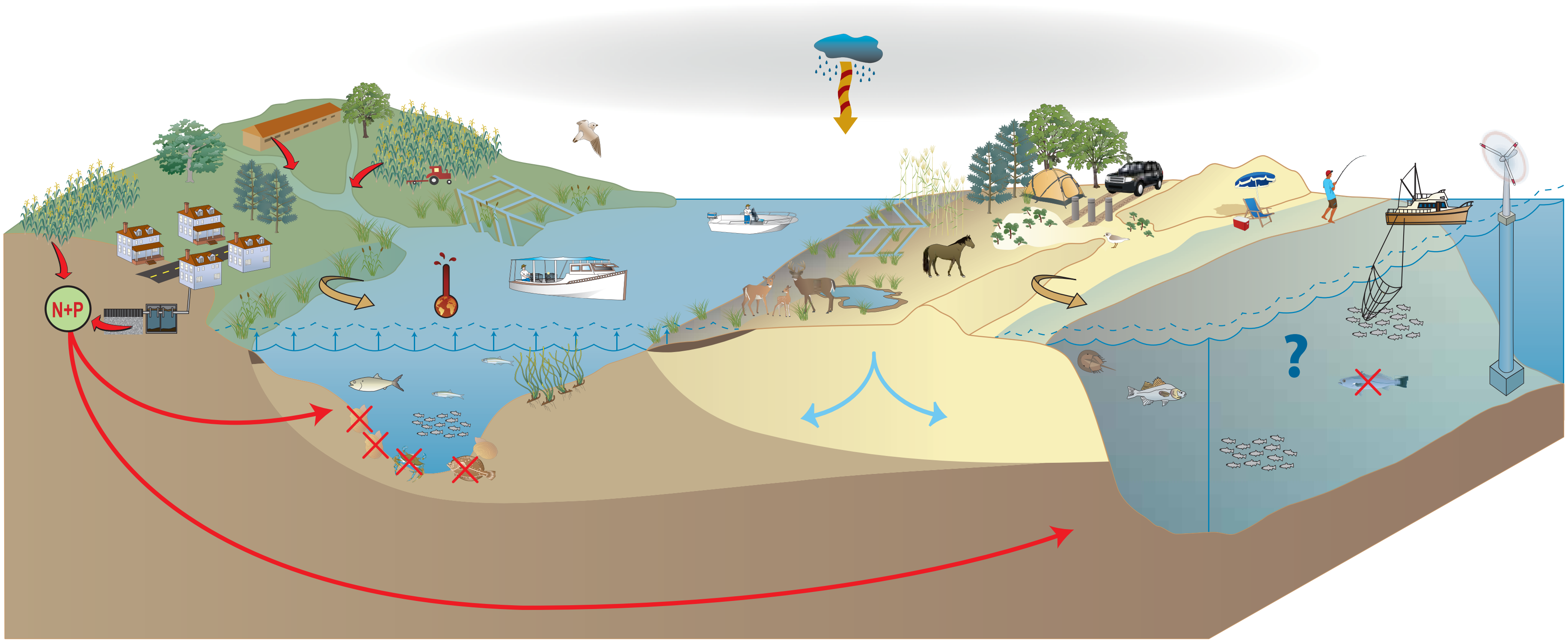
Ecosystem features

- Rare overwash habitat supports specialized and rare species such as piping plover and seabeach amaranth.
- Birds use the island for overwintering and a stop along a major Atlantic migration corridor.
- The absence of ambient noise allows for sensitive species to be unimpacted by human activity.
- Native white-tail deer and historically introduced horses and sika deer.

Human use features

- The bays and ocean provide important habitat for commercial and recreational fisheries.
- Aesthetic appeal and observation of unique fauna attracts millions of visitors every year.
- Increasingly rare on the US Atlantic coast, night darkness characterizes the sky.
- Hunting of native white-tail deer and introduced sika deer help control population size.

Conceptual diagram showing the key threats to Assateague Island.



Internal park threats

Overgrazing and trampling by deer and horses reduces biodiversity and disrupts dune formation and stabilization.

Introduced invasive plant species such as *Phragmites* displace native vegetation.

Park visitors increase habitat disturbance.

Mosquito ditches have potentially adverse effects on salt marshes.

Watershed threats

Agriculture and concentrated feeding operations in the Coastal Bays watershed increase nutrient inputs.

Increasing human population results in greater impervious surfaces and more nutrient inputs.

Historical overfishing impacts the abundance of forage fish and clams.

Nutrients are transported to the bay and ocean via groundwater.

Regional threats

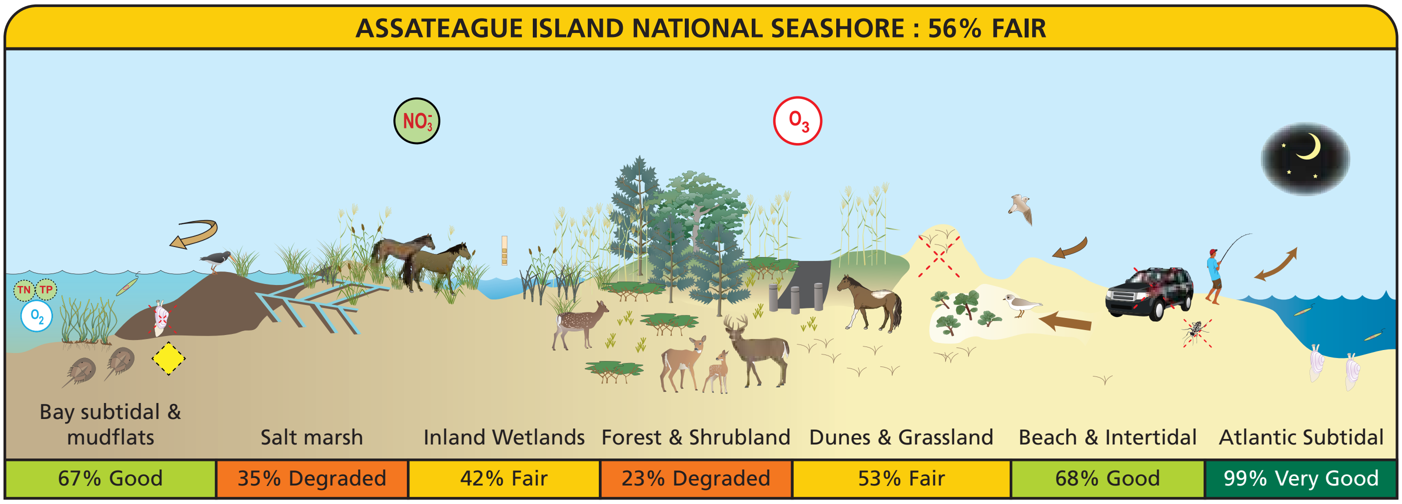
Air quality degradation and deposition of nitrate is a significant source of nitrogen input.

Climate change results in sea level rise, increased erosion, and species displacement.

Potential offshore energy development could affect viewshed, night sky, benthic habitat, birds, fish, and marine mammals.

A knowledge "gap" and lack of offshore data undermines management efforts and understanding of coastal processes.

CURRENT CONDITION OF NATURAL RESOURCES IN ASSATEAGUE ISLAND NATIONAL SEASHORE



Present in several habitats, invasive *Phragmites* is actively being reduced and abundant mosquito ditches are actively being filled. Rare, storm overwash habitat supports sustainable populations of the threatened beach annual, seabeach amaranth and the shorebird, piping plover. Increasingly rare, populations of tiger beetles are supported. Historically established to protect the island, artificial impediments are being removed to allow natural overwash processes. Low amounts of light pollution result in a dark night sky. Shoreline rate of change is equivalent to historic rates, as a result of active sand bypass across the ocean city inlet. Degraded air quality impacts vegetation and aquatic habitats. Coastal Bays water quality is currently good, but declining. Feral horse as well as native white tail, and introduced sika deer populations overgraze vegetation and trample fragile habitats.

Percent Attainment:	0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Habitat Condition:	Very Degraded	Degraded	Fair	Good	Very Good

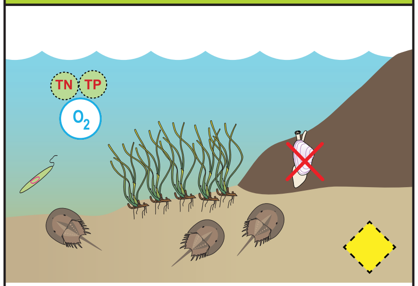
Habitat	Reference condition attainment	Current condition	Confidence in assessment
Bay subtidal and mudflats	67%	Good	High
Salt marsh	35%	Degraded	Fair
Forest and shrubland	23%	Degraded	Fair
Inland wetlands	42%	Fair	Limited
Dunes and grassland	53%	Fair	High
Beach and intertidal	73%	Good	High
Atlantic subtidal	99%	Very good	Very limited
Assateague Island National Seashore	**56%**	**Fair**	**Fair/high**

CURRENT CONDITION OF ASSATEAGUE ISLAND HABITATS

Overall, the natural resources of Assateague Island National Seashore were assessed to be in fair condition, with a fair to high confidence in this assessment. While salt marsh, forest and shrubland habitats were assessed to be in degraded condition, inland wetlands, dunes and grasslands were assessed as fair, bay subtidal and mudflats, beach and intertidal to be in good condition and Atlantic subtidal to be in very good condition. Confidence in the assessment of the different habitats varied, largely due to differences in data availability.

BAY SUBTIDAL AND MUDFLATS

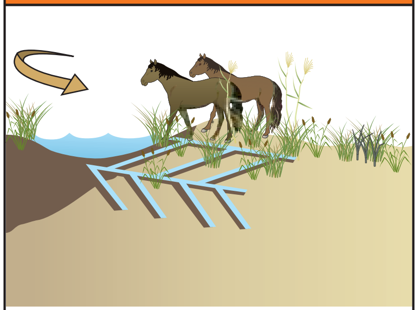
67% GOOD : CONFIDENCE HIGH



Assessed bay subtidal and mudflats habitat had abundant seagrasses, very degraded clam density, good water quality, a very low concentration of bacteria, low sediment contaminants, and a sustainable population of horseshoe crabs.

SALT MARSH

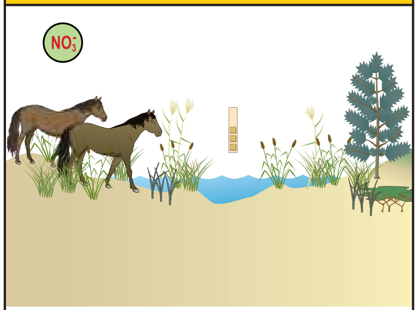
35% DEGRADED : CONFIDENCE FAIR



Assessed saltmarsh habitat had a low percentage of *Phragmites* cover, and a large horse population. The habitat experienced high shoreline erosion, and there is a high density of mosquito ditches.

INLAND WETLANDS

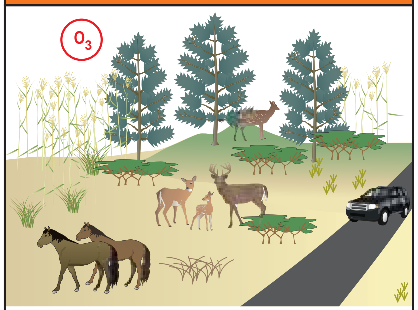
42% FAIR : CONFIDENCE LIMITED



Assessed inland wetlands habitat had a low percentage of *Phragmites* cover, a large horse population, fair water pH, and high deposition of wet nitrogen.

FOREST AND SHRUBLAND

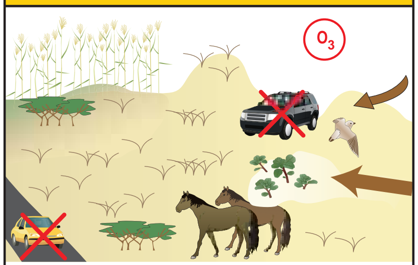
23% DEGRADED : CONFIDENCE FAIR



Assessed forest and shrubland habitat had a high % of *Phragmites* cover, a low % of impervious surfaces, a high abundance of horses and deer, and high levels of ozone.

DUNES AND GRASSLAND

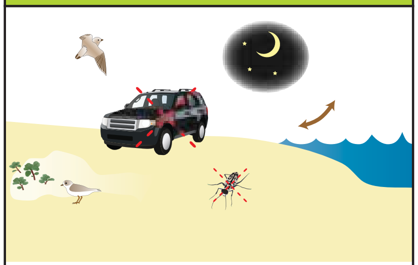
53% FAIR : CONFIDENCE HIGH



Assessed dunes and grassland habitat had a high percentage of *Phragmites* cover, and a large horse population. It was subject to natural coastal processes including overwash and upland accretion. Ozone levels were high, impervious surface was low, and over-sand vehicle trails were minimal.

BEACH AND INTERTIDAL

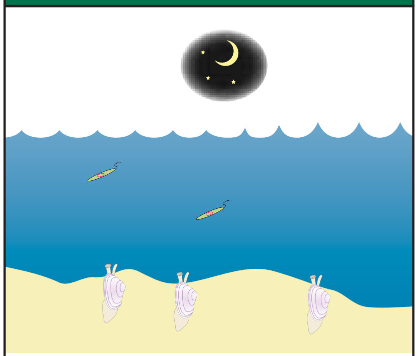
68% GOOD : CONFIDENCE HIGH



Assessed beach and intertidal habitat had a low abundance of tiger beetles, good piping plover fecundity, and good abundance of seabeach amaranth. The habitat was subject to a desirable rate of shoreline change, moderate OSV traffic, and low light pollution.

ATLANTIC SUBTIDAL

99% VERY GOOD : CONFIDENCE LIMITED



Assessed Atlantic subtidal habitat had low bacteria abundance, sustainable stocks of surfclams, and the night viewshed is unaffected by sources of artifical light.

Bay subtidal and mudflat habitat

Key findings	Recommendations
• Water quality good but degrading	• Continue to monitor conditions and work collaboratively with federal, state and local partners to identify and reduce sources. • Investigate septic sources from Town of Chincoteague and Captains Cove community.
• Seagrass has recent declines and low genetic diversity	• Focus on maintaining water quality. • Continue NPS Vital Signs monitoring to assist in understanding processes to maintain resource.
• Low but stable clam populations	• Support, and monitor effects of, dredging ban.
• Status of horseshoe crabs uncertain	• Standardize and expand population monitoring.
• Difficulty in assessing fin-fisheries status	• Encourage development of status and trends data.

Saltmarsh habitat

Key findings	Recommendations
• Storm overwash is critical to balance shoreline erosion	• Minimize artificial impediments to natural island overwash processes.
• Salt marsh is susceptible to the effects of accelerating sea level rise	• Continue SET monitoring of marsh sedimentation/subsidence processes
• Mosquito ditches are abundant	• Continue infilling ditches on experimental basis, monitoring ecosystem effects.
• Horses overgraze and trample the marsh	• Manage to minimum self-sustaining population size.
• Invasive *Phragmites* currently controlled in this habitat	• Continue *Phragmites* control efforts.
• Lack of knowledge on secretive marsh birds	• Monitor to inform management decision making.

Forest and shrubland habitat

Key findings	Recommendations
• Invasive *Phragmites* abundant	• Continue active *Phragmites* control, and monitor ecosystem impacts of treatment.
• Horses overgraze vegetation	• Manage to minimum self-sustaining population size.
• Deer overgraze vegetation	• Develop indices of deer herbivory on vegetation in conjunction with deer density index, to inform decision making.
• Invasive plant species influence native communities	• Continue to monitor, track, and eradicate invasive plant species.
• Limited knowledge of bird resource	• Inventory and monitor forest bird species.

Inland wetlands habitat

Key findings	Recommendations
• Poor air quality can impact these fragile habitats	• Initiate pond nutrient monitoring, and support regional air quality initiatives.
• Horses overgraze and trample limited freshwater pond resources	• Manage to minimum self-sustaining population size.
• Biotic resources inventoried, limited condition and trend information	• Develop indicators and techniques for assessing and monitoring biological integrity.
• Invasive plant species influence native communities	• Continue to monitor, track, and eradicate invasive plant species.
• These habitats are poorly characterized	• Study interrelationships with groundwater and storm overwash/flooding events, to inform management.

Dune and grassland habitat

Key findings	Recommendations
• Key biota impacted by poor air quality	• Support regional air quality initiatives, and monitor for specific impacts.
• Invasive *Phragmites* abundant	• Continue active *Phragmites* control, and monitor ecosystem impacts of treatment.
• Horses overgraze vegetation	• Manage to minimum self-sustaining population size.
• Dunes rely on natural shoreline processes	• Continue to minimize over-sand vehicle trails and minimize artificial impediments to natural island overwash processes.
• Invasive plant species influence native communities	• Continue to monitor, track, and eradicate invasive plant species.

Beach and intertidal habitat

Key findings	Recommendations
• Tiger beetle populations stable but low and limited in extent	• Minimize length of beach accessed by over-sand vehicles.
• Seabeach amaranth and piping plover require overwash habitat	• Minimize artificial impediments to natural island overwash processes.
• Shoreline rate of change is occurring at historical rates	• Maintain sand bypass to northern end of Assateague Island.
• Lack of current data on migratory shorebirds and intertidal biota	• Monitor to inform management decisions.

Atlantic subtidal habitat

Key findings	Recommendations
• Critical lack of knowledge	• Baseline surveys of benthic habitats.
	• Identify sensitive areas and key resources.
	• Collaborate with other agencies to initiate monitoring of water quality, fisheries and benthic habitats.
• Regional development threatens night sky conditions	• Collaborate with regional partners to reduce existing and prevent new impacts to night sky darkness.

Acknowledgements

We acknowledge input and comments from many people, and particularly, Jonathan Chase, Debbie Morlock, Tami Pearl, Arty Rodriguez, Eric Sherry, Helen Violi, and Neil Winn from Assateague Island National Seashore, Penelope Pooler, Dennis Skidds, and Sara Stevens from the Northeast Coastal Barrier Network, Inventory and Monitoring Program, John Karish, Peter Sharpe, and Charley Roman from the National Park Service North East Region, and Greg Radcliffe from the University of Maryland Center for Environmental Science.

Chapter 1: NRCA background information

1.1 NCRA BACKGROUND INFORMATION

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter “parks”. For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park’s resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, not replace, traditional issue and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope;[1]
- employ hierarchical indicator frameworks;[2]
- identify or develop logical reference conditions/values to compare current condition data against;[3,4]
- emphasize spatial evaluation of conditions and GIS (map) products;[5]
- summarize key findings by park areas;[6] and
- follow national NRCA guidelines and standards for study design and reporting products.

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park’s boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for some of a park’s “vital

***NRCAs strive to provide** credible condition reporting for a subset of important park natural resources and indicators*

Important NRCA success factors

Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline.

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures → indicators → broader resource topics and park areas).

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings.

1. However, the breadth of natural resources and number/type of indicators evaluated will vary by park.
2. Frameworks help guide a multi-disciplinary selection of indicators and subsequent 'roll up' and reporting of data for measures → conditions for indicators → condition summaries by broader topics and park areas.
3. NRCAs must consider ecologically based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions.
4. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management 'triggers').
5. As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products.
6. In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds and 2) for other park areas as requested.

signs" monitoring indicators. They can also bring in relevant non-NPS data to help evaluate current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change effects on park natural resources is outside the project scope. However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[7] and help parks report to government accountability measures.[8]

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in our present data and knowledge bases across these varied study components.

NRCAs can yield new insights about current park resource conditions but in many cases their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Additional NRCA Program information is posted at: *http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm*

NRCA reporting products *provide a credible snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:*

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations (near-term operational planning and management)*
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values*

7. NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy (RSS) but study scope can be tailored to also work well as a post-RSS project.
8. While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of 'resource condition status' reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

Chapter 2: Introduction and resource setting

2.1 INTRODUCTION

2.1.1 History and enabling legislation

Native Americans are considered to have reached the Coastal Bays watershed around 10,000 years ago, with permanent settlements first occurring around AD 900, along with the advent of maize agriculture (Rountree & Davidson, 1997). The first European contact was the crew of the French explorer Giovanni de Verrazzano, who came ashore near Ocean City in 1524 (Truitt, 1971). In 1649, Henry Norwood and a group of British passengers were marooned on Assateague Island and Norwood's extensive account of their survival with the help of the Assateague tribe has been an important source of information regarding life among the Assateagues (Patton, 2005). English settlers started to arrive 10 years later in the late 1650's.

The first recorded private land ownership on Assateague Island was in 1678, with Daniel Jennifer being granted a portion of the island in Virginia (Patton, 2005). Shipwrecks were common on the mid-Atlantic beaches of North America during the 18th and 19th centuries. As a result a small industry established on Assateague Island, illegally scavenging cargo from these vessels (Hall et al., 2009). From the 17th to early 19th centuries, the beaches and coastal bays of Assateague Island also provided hiding places for pirates, including the infamous Edward Teach (better known as Blackbeard) (Truitt, 1971). In the mid to late 19th century, the coastal bays behind Assateague Island, in particular Chincoteague Bay, also provided a lucrative harvest of the Eastern oyster (*Crassostrea virginica*), until the opening of the 1933 inlet when the harvest declined due to increased parasites and predators. (Tarnowski, 1997; Boynton, 1970). After the Civil War ended in 1865, the Atlantic coast of Maryland and Virginia became a popular vacation destination, with accommodations such as Scott's Ocean Beach House hotel in Green Run and railroad access across Sinepuxent Bay to Ocean City (Petrocci, 2005). During the Prohibition era (1919–1933), further illegal activity became common, with the empty beaches of Assateague Island proving ideal for boot-leggers to land their cargo (Patton, 2005).

The newly-formed inlet at Ocean City, 1933.

After the opening of Ocean City Inlet by a storm in 1933 and subsequent stabilization during 1934, increased recreational opportunities for fishing, hunting and bathing brought Assateague Island to national attention (Mackintosh, 1982). In an effort to establish the National Park Service on the east coast and protect remaining public shorelines from development, the Park Service surveyed lands along the Atlantic and Gulf coasts. The aim was to identify areas that could be acquired and administered as national seashore recreational areas, to create new recreational opportunities in close proximity to major metropolitan areas in the east. Although several legislative bills were introduced in Congress in the 1940s, no action was taken to establish a national park along the Virginia/Maryland/Delaware coast at that time (Mackintosh, 1982).

In 1950, a group of investors from Baltimore and Washington bought 24 km (15 mi) of ocean-side land along Assateague Island, north of the Virginia state line. Anticipating future residential development on Assateague Island, an engineering consultant surveyed, subdivided, and

Photo: Ocean City Life-Saving Station Museum

Damage to Ocean City from the 1962 nor'easter storm.

plotted out lateral streets (Congress, 1965). Several thousand private lots were sold for development, and infrastructure (roads, electricity) construction was initiated (ASIS, 2003). At that time a coastal railroad was the main method of transport to the area, so most visitors came from Philadelphia rather than Baltimore. However, in 1952, completion of the Chesapeake Bay Bridge linked the Atlantic coast to the western shores of Chesapeake Bay and, with the automobile, tourists, property-seekers, and investors flocked to the Coastal Bays (Mackintosh, 1982). The Verrazano Bridge crossing Sinepuxent Bay to Assateague Island, was completed in 1964 (to service the newly created Assateague State Park and development interests on the island), and along with the bridge to Chincoteague Island, which had been completed two years earlier, access to Assateague Island continued to improve.

A study in 1955 did not recommend establishment of a national seashore recreational area because of increased private development on Assateague Island (NPS, 1955). However, another storm in March 1962—a three-day nor'easter known as the "Ash Wednesday Storm"—was devastating to Ocean City and Assateague Island as well as the entire Mid-Atlantic coast. This storm destroyed all but 16 cottages, 17 gun clubs, and a few other buildings, and therefore called into question the wisdom of private development on such a dynamic and unprotected property (Udall, 1965a). This storm also destroyed the artificial protective dune along Assateague Island, although it was promptly rebuilt in the hope of pursuing development plans. The Secretary of the Interior and the Governor of Maryland then decided to push towards establishing a park for public use, agreeing to a joint study of the area. Major factors listed by the Department of the Interior as rationale for creating the national seashore included a growing demand for seashore recreation, the infeasibility of private development on the island, and economic benefits to the local economy (Udall, 1965b).

Assateague Island National Seashore was formally proposed in early 1965 to administer lands by the National Park Service adjacent to Chincoteague National Wildlife Refuge and Assateague State Park, both previously established on Assateague Island. Later that year, it was officially established in law by President Lyndon B. Johnson on 21st September, despite continued opposition from the Assateague private landowners and Worcester County officials (Macintosh, 1982). The enabling legislation for the Seashore, written in 1965, established the National Seashore "… for the purpose of protecting and developing Assateague Island in the States of Maryland and Virginia for public outdoor recreation use and enjoyment" (Public law 89-195). A master plan including a connecting road down the Island and moderate scale hotel accommodations was established, but met with fierce opposition and a continued long political process to determine the amount of protection or development that would ultimately occur on the island (Mackintosh, 1982). The final form of the amendment was signed into law on October 21st 1976, concluding eleven years of uncertainty regarding the future direction of the Seashore (Public law 94-578). This amendment also called for a comprehensive plan for Assateague Island National Seashore, including "measures for the full protection and management of the natural resources and natural ecosystems of the Seashore", which was completed in September, 1979, leading on to a full General Management Plan which was finalized in

June 1982 (Mackintosh, 1982). The Seashore is currently (as of 2010) in the process of fully revising and updating this General Management Plan.

The Wilderness Act of 1964 ensured that the Chincoteague National Wildlife Refuge would be evaluated as a potential wilderness area, largely due to its lack of roads and remoteness (Public Law 88-57). In 1973, not only the refuge, but also the adjacent Seashore lands were evaluated for designation as a Federal Wilderness Area and 2,630 ha (6,500 acres) were recommended for eventual designation, with an immediate recommended designation of 526 ha (1,300 acres) in the refuge and 178 ha (440 acres) of the Seashore, all between 11.3 km (7.0 mi) north and 8.0 km (5.0 mi) south of the state border on Assateague Island (Mackintosh, 1982). As summarized in the General Management Plan for the Seashore, “This alternative was not selected because of long–term retained rights of individuals within the proposed wilderness boundary and because it would preclude existing methods of access for recreational purposes. When this area is free of retained rights, wilderness designation will be reconsidered.” (ASIS, 1982). Now that these retained rights have lapsed, wilderness designation is once again a potential future management option.

2.1.2 Geographic setting

Assateague Island and the associated Coastal Bays are geologically dynamic, reflecting changes on weekly to millennial time scales. The last glacial period ended around 10,000 years ago, and the consequent rise in sea level flooded the then-exposed continental shelf. The sand islands that had existed on the edge of the shelf migrated landward, forming barrier islands close to their present location approximately 4,500 years ago (Biggs, 1970, Toscano et al., 1989, Krantz et al., 2009; Figure 2.1). Assateague Island has a humid subtropical climate characterized by hot, humid summers, with frequent thunderstorms, and cool winters. This region is microtidal (tidal range of less than 1.5 m or 4.9 ft) and wave-dominated, this wave action creating longshore drift that moves predominantly south along the beach in the swash zone (Krantz et al., 2009; Fisher, 1967; Figure 2.2). During the summer, winds are mostly from the SSW, predominantly from 5-10 ms^{-1} (10-19 knots), while in the winter the dominant wind direction is NW, with wind speeds frequently greater than 10 ms^{-1} (19 knots) (Figure 2.3). Water temperature on the Atlantic side of Assateague Island ranges from mean values of 5-23°C (39-74°F) and significant wave height is generally in the

Photo: Tim Carruthers, IAN Image Library

The shoreline on Assateague Island is constantly changing. This beach cutaway was observed in fall 2010 at the north end of the island.

Figure 2.1. Location of Assateague Island National Seashore and the Coastal Bays of Maryland, Delaware, and Virginia.

Data source: *http://www.nature.nps.gov/stats/*

order of 1.5 m (5 ft), however wave height can be greater than 7m (21 ft) during storms (Figure 2.4).

As a wave-dominated barrier island, the dynamic geomorphology of Assateague Island is greatly influenced by major storm events, resulting in island overwash and breaches - the formation of channels through the Island. In the mid-Atlantic USA, these major storm events occur in two main categories; extra-tropical storms in the fall (October-November) or winter (February-March) and hurricanes during summer and fall (July – November) (Krantz et al., 2009). Extra-tropical storms, which form outside the tropics are referred to as 'nor'easters' due to the most damaging wind direction during these storms, as they move north along the coast. The 1962 storm that caused immense property damage, raising serious doubts about the potential of Assateague for development, was such a nor'easter. The second form of major storm, hurricanes, rarely make landfall along the mid-Atlantic barrier islands, but can still result in large waves and storm surges, such as in the case of the hurricane of 1933, which opened the Ocean City Inlet (Dolan et al., 1980).

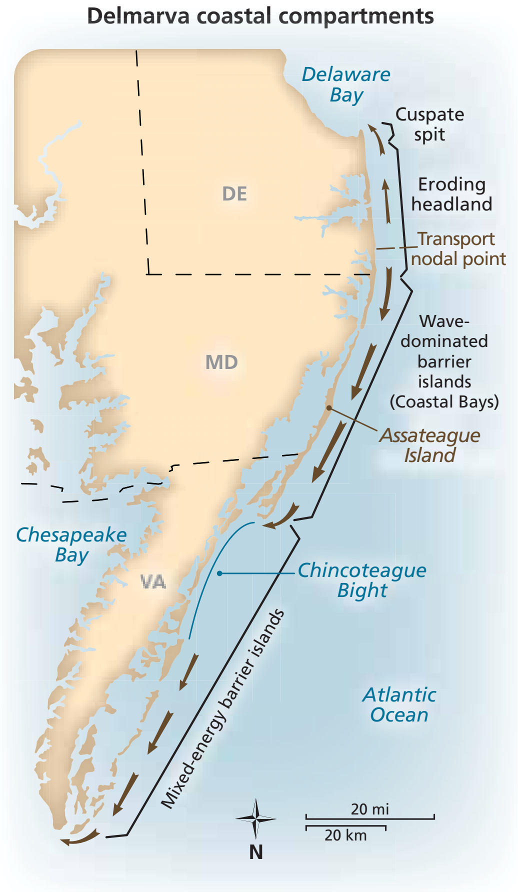


Figure 2.2. The Atlantic coast of Delmarva (Delaware-Maryland-Virginia) may be subdivided into four coastal compartments, each with a characteristic morphology related to sediment transport (brown arrows) and wave and tide energy.

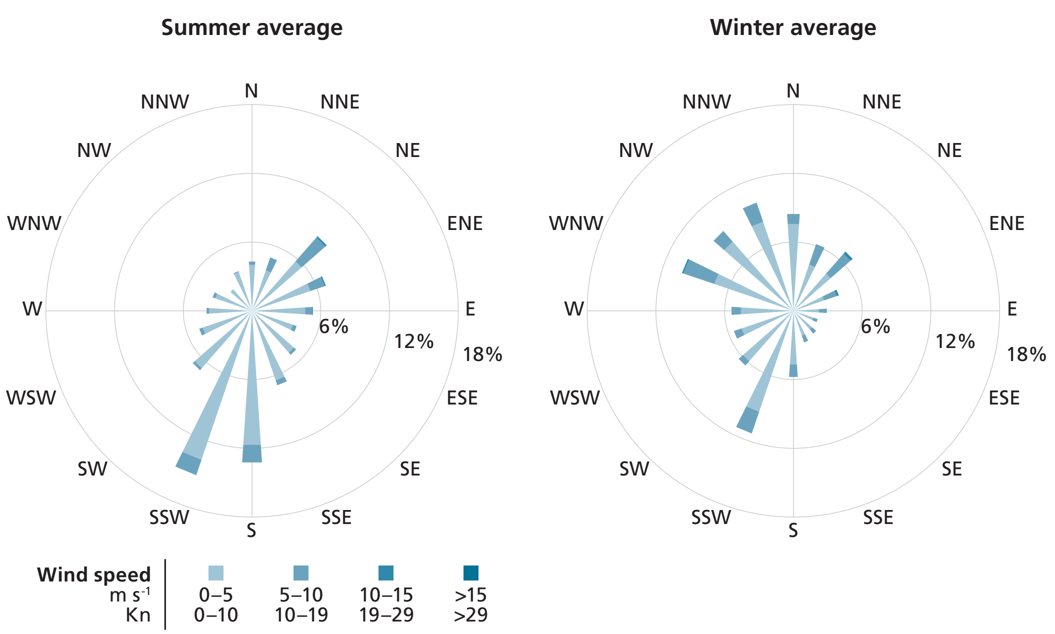


Figure 2.3. Seasonal wind speed & direction, 1995–2006. Wind conditions are primarily from the south during the summer and from the west in winter on Assateague Island. The summer average was taken from June 21-September 21. The winter average was taken from December 21-March 21.

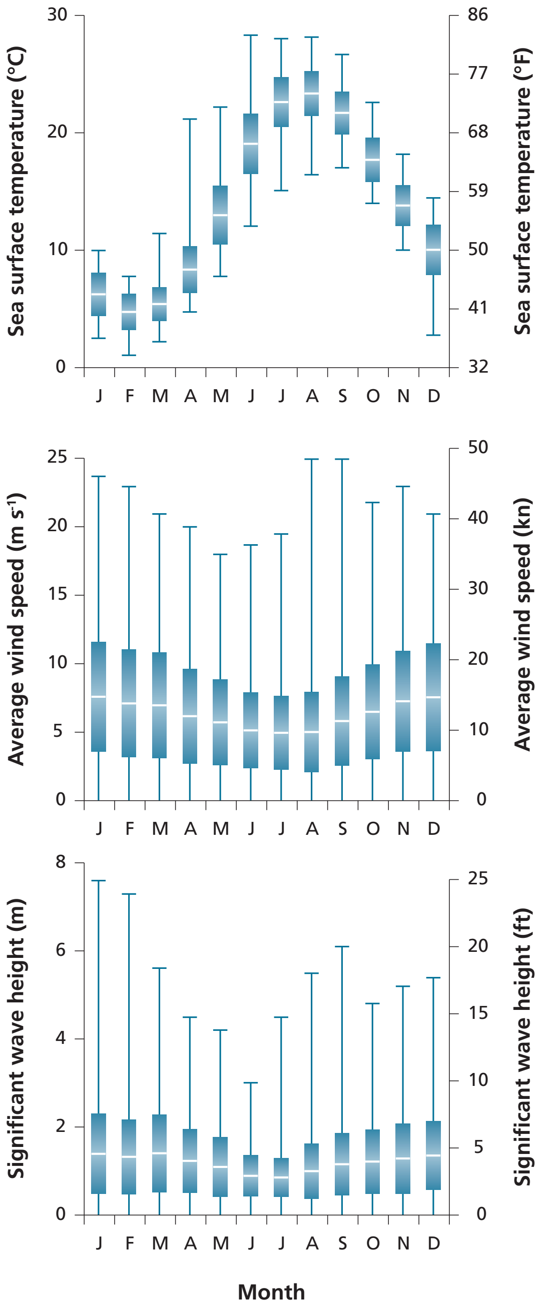


Figure 2.4. Marine climate, 1984–2005. Marine climate for the Atlantic Ocean off Assateague Island. Data show the median value, first and third quartiles, and lowest and highest values.

Assateague Island National Seashore (NPS managed lands and waters) encompasses the entire 59.5 km (37.0 mi) length of Assateague Island plus some adjacent small marsh islands. The seashore boundary also includes the water up to 0.8 km (0.5 mi) beyond the mean high water line on the Atlantic (east) side and a variable 0.18 km (0.12 mi) to 1.5 km (0.9 mi) on the bay-side (west), totaling an area of 16, 381 ha (40, 471 acres) (Public Law 89-195; Table 2.1; Figure 2.5). The Seashore is managed by the National Park Service (NPS), with the Maryland Park Service (MPS) responsible for Assateague State Park, and the U.S. Fish and Wildlife Service (USFWS) responsible for Chincoteague National Wildlife Refuge (Figure 2.5). The USFWS is responsible for 3,630 ha (8, 970 acres) of the island in Virginia and MPS is responsible for 210 ha (519 acres) of land and 90 ha (222 acres) of water on the Atlantic shore in Maryland (Table 2.1; Figure 2.5). The National Park Service is responsible for the remainder of the land, 3, 340 ha (8, 253 acres) almost all in Maryland, as well as the remainder of the water in Maryland (8, 231 ha; 20, 331 acres) and all of the water in Virginia (4, 803 ha; 11, 863 acres) (Table 2.1; Figure 2.5).

Table 2.1 Jurisdictions and areas of Assateague Island.

Island Designation	Land		Water		Total	
	ha	acres	ha	acres	ha	acres
Assateague Island (MD)	3,550	8,772	-	-	3,550	8,772
Assateague Island (VA)	3,640	8,994	-	-	3,640	8,994
Assateague Island (Total)	7,190	17,766	-	-	7,190	17,766
NPS managed lands & waters (MD)	3,340	8,253	8,231	20,331	11,571	28,584
NPS managed lands & waters (VA)	10	24	4,803	11,863	4,813	11,902
State Park (MD)	210	519	90	222	300	741
Chincoteague National Wildlife Refuge (VA)	3,630	8,970	0	0	3,630	8,970
Total protected area	7,190	17,766	13,124	32,416	20,314	50,197

Figure 2.5. Boundaries depicting the three management jurisdictions within Assateague Island National Seashore.

Photo: NPS ASIS

Approximately 95% of visitors to Assateague Island are day visitors. This photograph was taken during 4th July.

2.1.3 Visitation statistics

Recreational visitation to Assateague Island increased rapidly in the late 1960s after the establishment of the Seashore, reaching more than two million recreational visitors for the first time in 1973 (numbers include Maryland and Virginia, however, exclude Assateague State Park; ASIS, 2010a). While historical challenges in measuring visitor numbers don't allow detailed analysis of trends, a more accurate methodology initiated in recent years (2003-2009) has confirmed that total recreational visitors to the Seashore still number between 1.9 and 2.1 million per annum (ASIS, 2010a). A 2006 survey of visitors reported that 13% of respondents were local and 1.5% international, with most respondents (85%) travelling from the mid-Atlantic US states (ASIS, 2007). Visitors surveyed were mostly family groups (73%) who visited on more than one day (60%), and 80% planned to see horses and visit the beach during their visit (ASIS, 2007). With respect to natural resource condition, 80% of respondents expected clean beaches, wildlife, and fresh air to be present on the Seashore (ASIS, 2007).

Although most non-consumptive day visitors use the beach and trails in the developed zones of the Seashore, visitors who use over-sand vehicles (OSV's) are notable for accessing further areas of the park. There are two zones in the Seashore allowing beach access for over-sand vehicles - one in Maryland and one in Virginia. The number of vehicles accessing the beach annually has increased from 35,115 in 1993 to 79,196 in 2009 (ASIS, 2010a). Between 6,500 and 7000 permits are sold annually, but at any one time, the number of vehicles is limited to 145 vehicles from the Maryland access point and between 15 and 48 vehicles from the Virginia access point (depending on closure of areas for bird protection). A 2008 survey found that 74% of respondents stated their primary reason for using the OSV zones was surf fishing, and most of them visited multiple times per year, with 29% of respondents visiting the OSV zone between 21 and 100 times during the year (ASIS, 2008a).

Approximately 95% of visitors to Assateague Island (excluding Assateague State Park) are day visitors, however, the remaining 5% stay overnight either in tents or recreational vehicles (RV's) in the main campsites, or tents in the back country campsites (ASIS, 20010a). Between 2003 and 2008, the total number of recreational visitors staying overnight ranged from 79,000 to 116,000 per annum (ASIS, 20010a). The number of backcountry campers, entering the most remote areas of the island, either by foot or kayak, varied from 1,991 to 2,681 per year between 2003 and 2008 (ASIS, 2010a). In a 2008 survey, 58% of back country users stated kayak trips as their main motivation for visiting. Fifty percent of respondents thought more protection was needed, with 33% reporting concerns about OSV use in back country areas detracting from their experience (ASIS, 2008a). However, survey results of both OSV and back-country campers identified that both groups considered wildlife in the sea and on the land the most important natural feature of these areas (ASIS, 2008a).

Hunting of whitetail and Sika deer, upland game, and waterfowl are permitted within season in certain areas of the Seashore, which is the other major visitor use (ASIS, 2010b). The main region of the Seashore open to consumptive visitor use is the region south of the main visitor developed zone in Maryland down to the Maryland/Virginia border (ASIS, 2010b). The hunting program is recognized as an important component of management for both Whitetail deer and Sika deer populations. Two other minimal user groups are present within the Seashore, those who enter via commercial or private boat and those who bring their horses into the park to ride, either as day use or campers. However, even though these users are accessing some of the lower traffic areas of the Seashore the numbers are relatively small (hundreds per annum).

2.2 NATURAL RESOURCES

2.2.1 Watersheds

Assateague Island delineates a series of coastal bays within Maryland and Virginia. The six sub-watersheds that flow in to these coastal bays (directly or indirectly) stretch from Delaware in the north, through Maryland and south into Virginia, with a total area of 453 km^2 (175 mi^2) (Figure 2.6). These watersheds are characterized by low elevation, with approximately half of the watershed having an elevation less than 4.6m (15 ft), and the whole watershed (except for some human structures) being less than 15.2m (50ft) above mean sea level (Figure 2.7). Elevation throughout the watershed is closely related to the natural soil drainage characteristics, with approximately half of the watershed being fine soil or clay with slow or very slow water infiltration rates, resulting in poorly drained or excessively poorly drained soils (Figure 2.8). All six subwatersheds in the region share common land use characteristics, with forest (38.4%), agriculture (33.3%), and wetland (16.3%) accounting for the majority of the watershed (Figure 2.9, Table 2.2). Isle of Wight Bay and Assawoman Bay have the highest areas of residential and commercial or urban development, with combined land areas of 38.6% and 28.0% of the sub-watersheds respectively (Figure 2.10; Table 2.2). Chincoteague Bay, the largest sub-watershed

Table 2.2. Land use in the watersheds of the Coastal Bays delineated by Assateague Island.

Watershed	Land area (km^2)	Ratio watershed: surface area	% of Watershed: Agriculture	Beaches & bare ground	Commercial & urban	Residential	Forest	Wetlands
Assawoman Bay (MD)	24.7	1.2	23.7	1.6	8.8	19.2	25.3	21.4
St. Martin River	95.5	11.4	48.2	< 1	5.3	10.1	33.9	2.4
Isle of Wight Bay	51.8	2.5	18.5	< 1	12.6	26.0	37.0	5.2
Newport Bay	113.0	7.1	35.0	< 1	3.4	6.9	42.4	11.9
Sinepuxent Bay	26.7	1.1	11.5	11.8	12.8	9.3	31.4	23.2
Chincoteague Bay	315.5	0.8	33.2	2.1	< 1	1.5	40.2	22.9
Total Coastal Bays (MD & VA)	627.2	1.6	33.3	1.8	3.6	6.8	38.4	16.3

Figure 2.6. Coastal Bays watershed and subwatersheds, including Assateague Island, which lies in the Chincoteague and Sinepuxent subwatersheds.

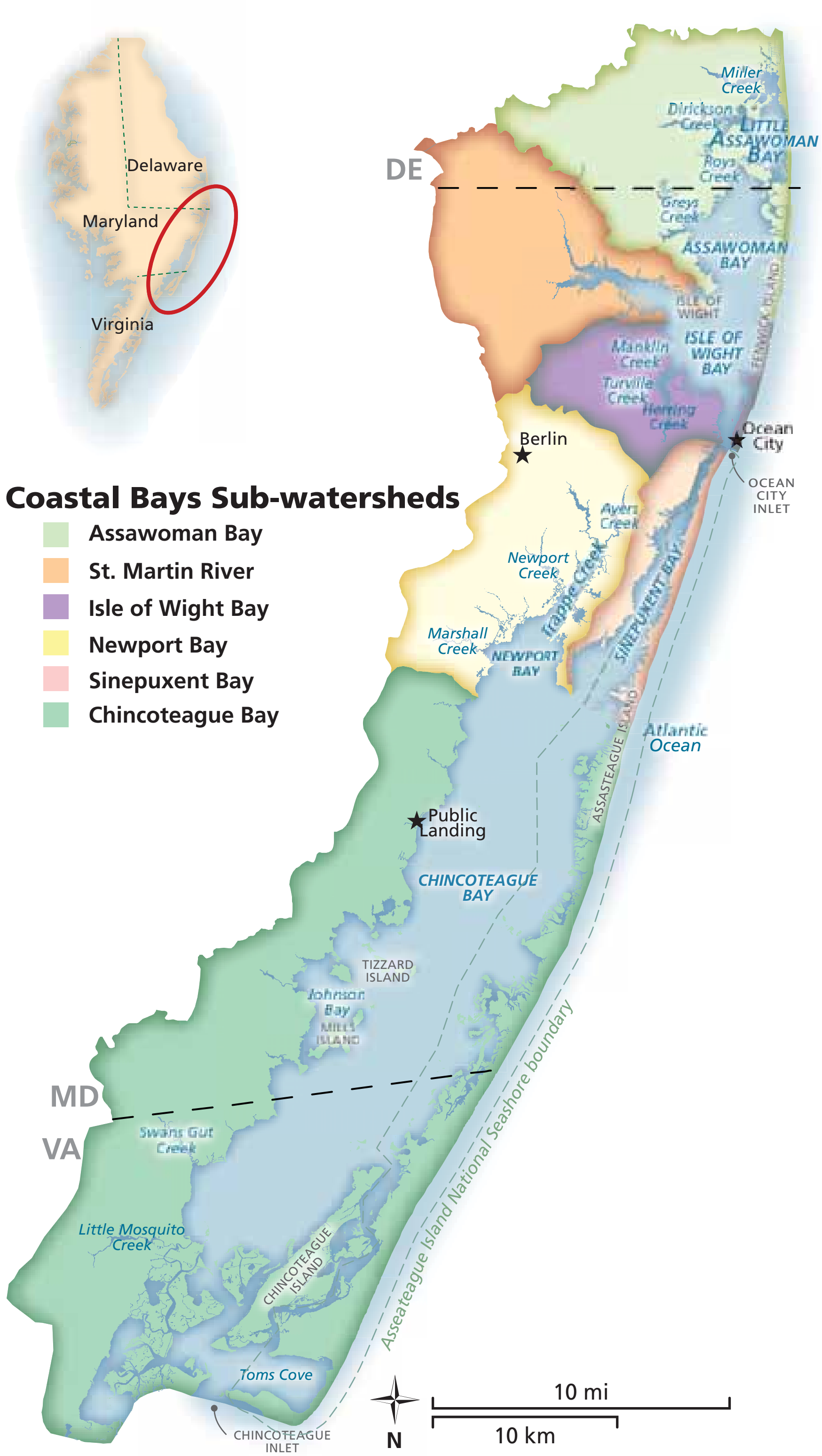
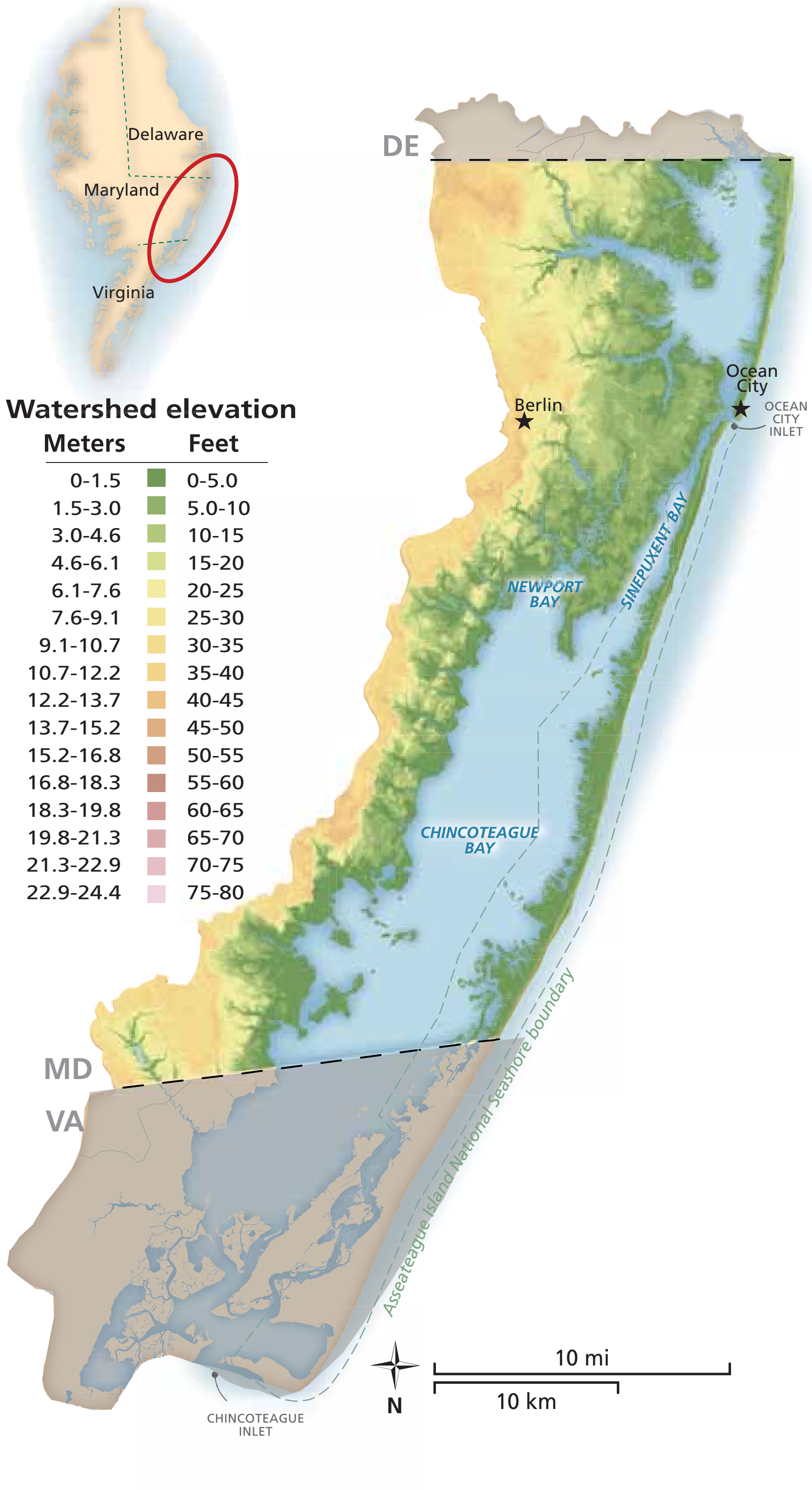
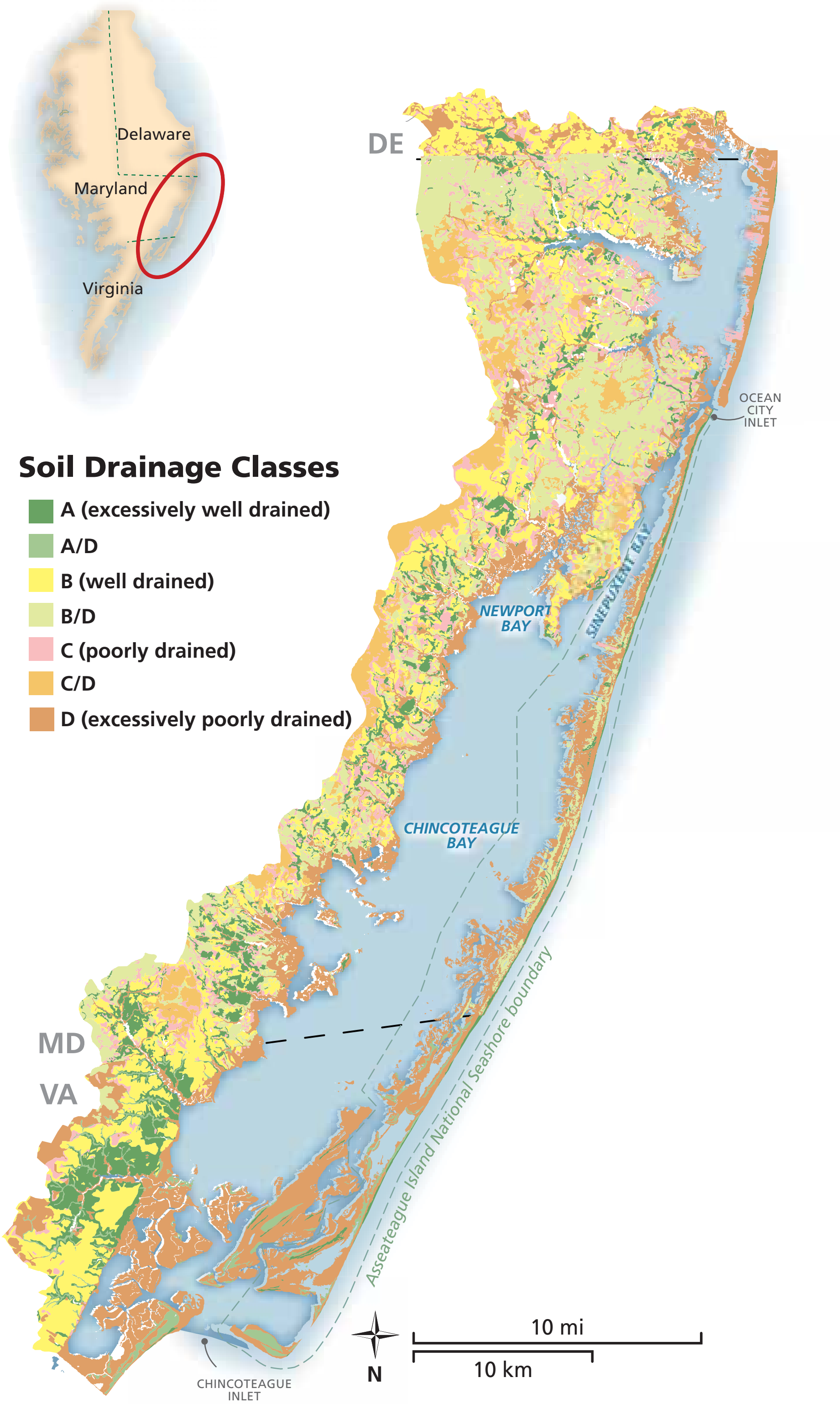


Figure 2.7. Watershed elevation within the Maryland section of the Coastal Bays.



Data source: SoilDataMart 2009

Figure 2.8. Soil drainage classes within the Coastal Bay watersheds. The first letter (A, B, C) explains the upper soil drainage properties (~1-2 m deep). Those drainage classes with /D have an impediment to drainage below the upper soil (e.g., a marine clay layer) which prevents the drainage of the upper soil.



Data source: SoilDataMart 2009

Figure 2.9. Land use within the Coastal Bays watersheds in 2004.

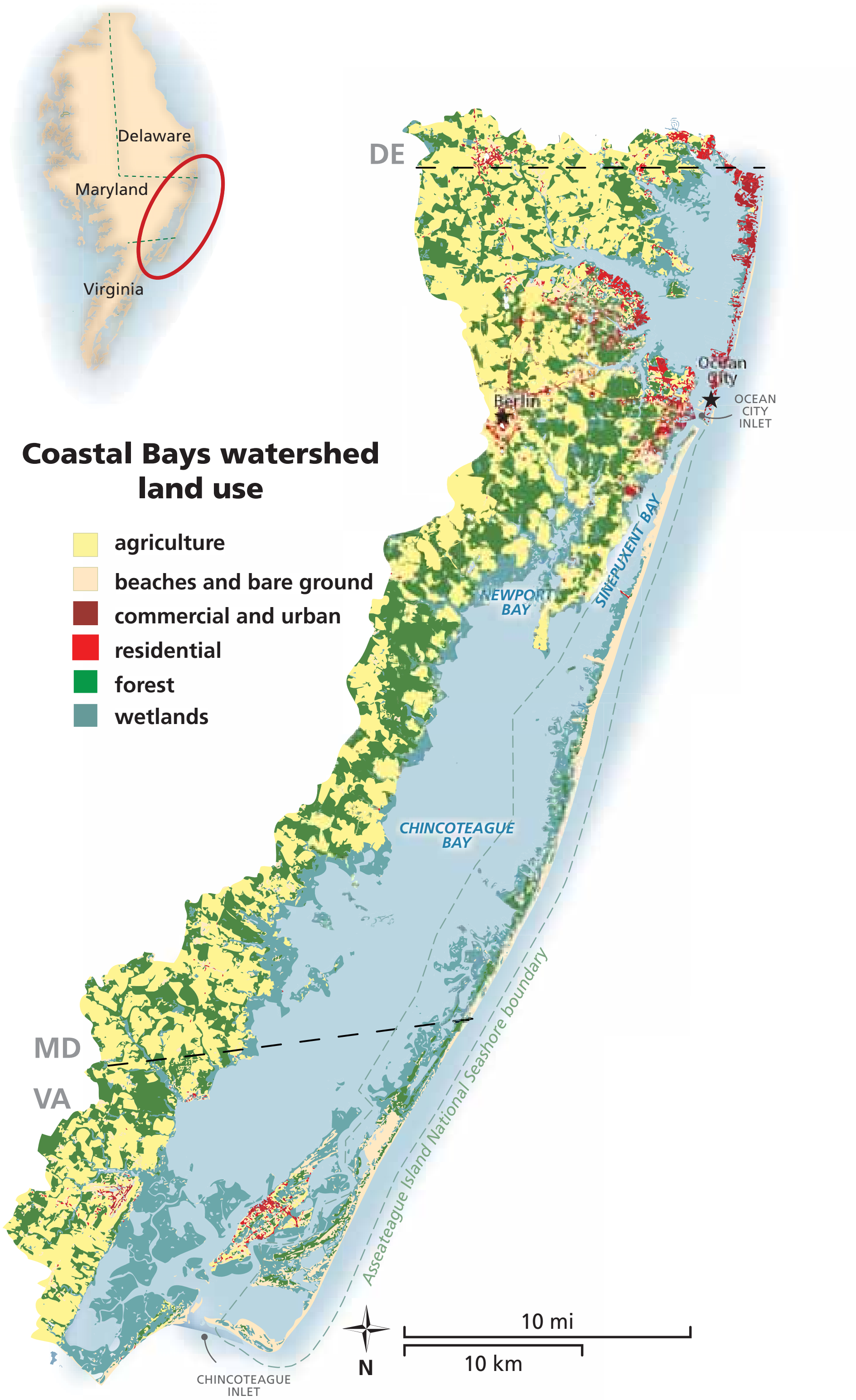
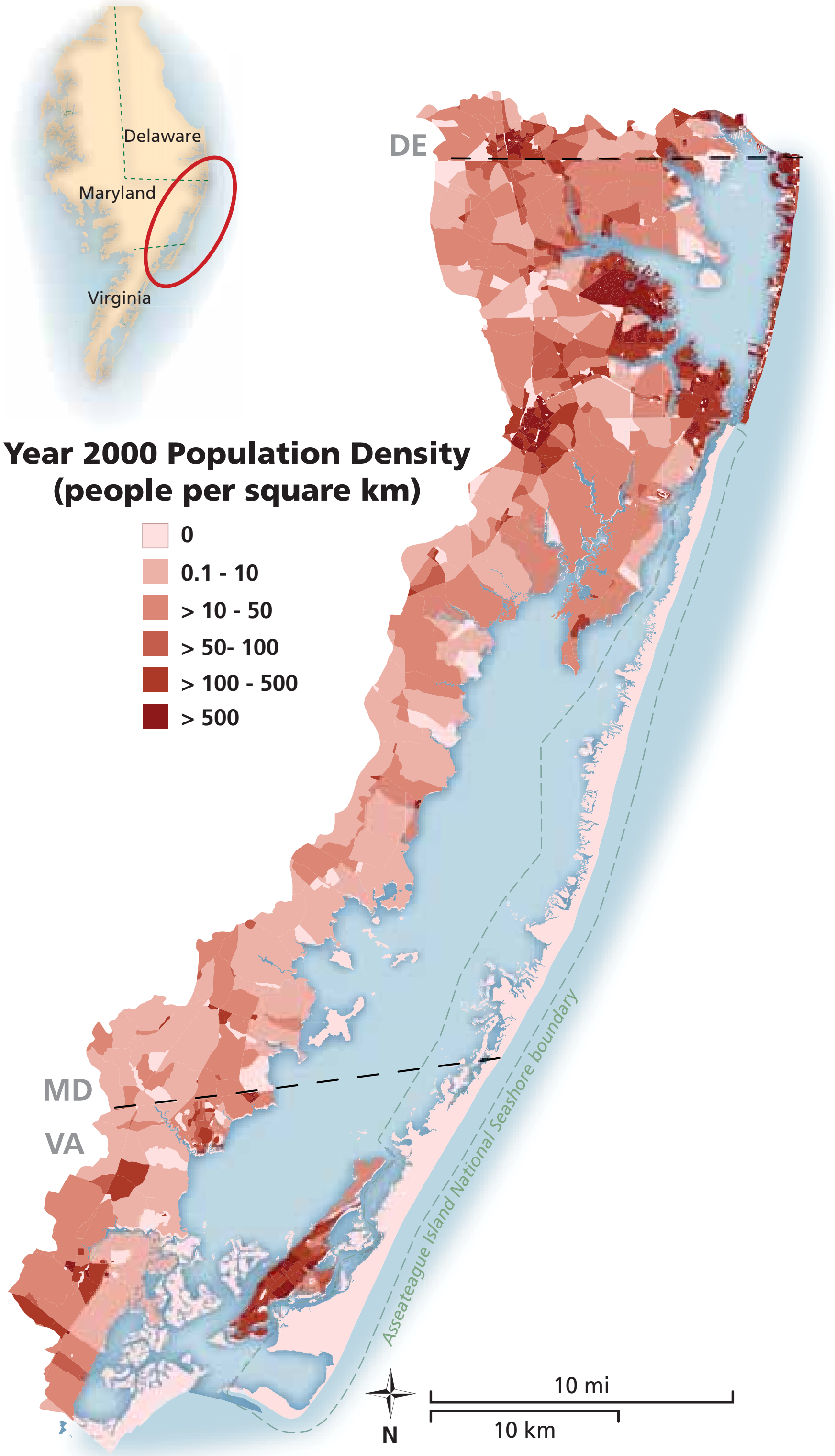


Figure 2.10. Block-level population density of the Coastal Bays in 2000.



Data source: NPScape Landscape Monitoring Project *http://science.nature.nps.gov/im/monitor/npscape/index.cfm.*

directly influencing Assateague Island National Seashore has 40.2% forest, 33.2% agricultural land, and 22.9% wetlands, while Sinepuxent and Newport Bay sub-watersheds have similarly high percentage areas of forest and wetland with small areal extend of residential and developed lands (Figure 2.9, Table 2.2).

2.2.2 Resource descriptions

Physical features

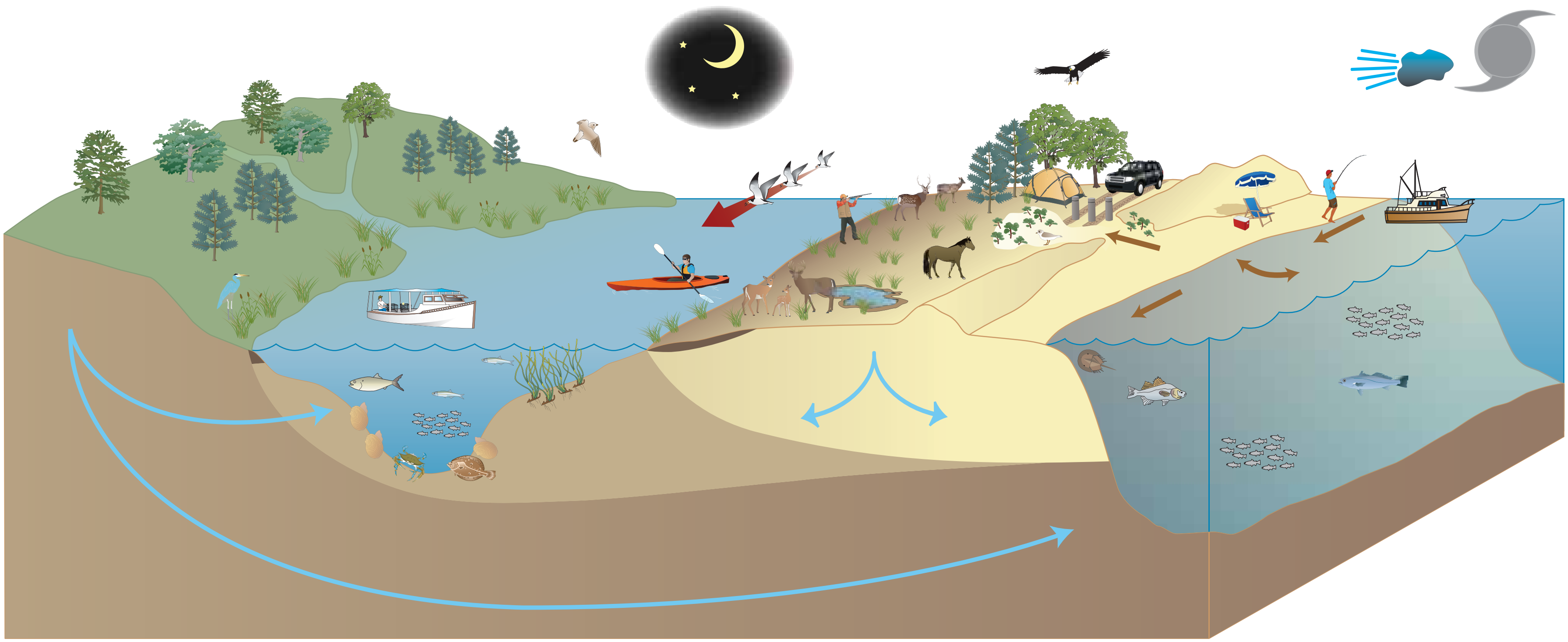
Assateague Island is a naturally dynamic coastal barrier island and many of these physical processes are key features in the maintenance of resource condition within the Seashore (Figure 2.11). The structure of mid-Atlantic barrier islands is a result of storm activity which causes island overwash by large waves, resulting in major sand erosion and accretion events including inlet formation and closure. These dynamic physical processes create unique habitats for flora and fauna (Krantz et al., 2009; Figure 2.12). Long shore drift of sediment in the swash zone has a net southerly flow, with annual movement of sand offshore by large storms during winter forming sand bars close to shore. These sandbars gradually migrate back on shore with continuous, but smaller, summer waves (Stauble et al., 1993; Krantz et al., 2009; Figure 2.2). In the narrow Sinepuxent Bay, current theory suggests that fresh groundwater discharges underneath Assateague Island directly to the ocean, while, in the broader reaches of Chincoteague Bay, groundwater becomes brackish or the fresh water discharges into Chincoteague Bay, within 1-2km (0.6-1.2mi) of the western shoreline (Dillow and Greene, 1999). This groundwater migrates slowly and is generally greater than 50 years old (Bratton et. al., 2009). Assateague Island has an independent groundwater system, with a fresh lens 6-7m (20-23 ft) deep in the center of the island and less than 1m (3ft) near both shores (Hall, 2005). Historical management actions to limit erosion and over-wash on Assateague Island, are currently being removed or modified to promote the naturally dynamic processes of over-wash and dune building (ASIS, 2008b).

Sand overwash provides nesting sites for the threatened Piping Plover (*Charadrius melodus*).

Ecosystem features

Abundant ecosystem features are supported by the diverse and unique habitats of Assateague Island (Figure 2.11). Globally rare sand over-wash habitat provides nesting sites for the shorebird, *Charadrus melodus* (piping plover), federally listed as threatened by the U.S Fish and Wildlife Service and near threatened on the International Union for the Conservation of Nature Red List (IUCN, 2010; USFWS, 1985). The dune annual, *Amaranthus pumilus* (sea-beach amaranth) is only found in these habitats between the high tide line and the base of the primary dune. Sea-beach amaranth was rediscovered in Assateague Island in 1998 after nearly 30 years without being observed, and is listed as federally threatened, state endangered, and globally rare (Tyndall et al., 2000; MNHP, 2010; USFWS, 1993). The Seashore is within the Atlantic migratory flyway, and is an important site for many migratory species, including abundant shorebirds (Dinsmore et. al., 1998). The long stretches of undeveloped shoreline, and managed use, promote habitats with low ambient noise (NPS, 2002). The Seashore also supports populations of the native white tail deer (*Odocoileus virginianus*) as well as the historically introduced sika deer (*Cervus nippon*) and horses (*Equus caballus*) (Keiper and Keenan, 1980; Keiper, 1985).

Figure 2.11. Conceptual diagram showing the key features of Assateague Island.



Physical features

Storms result in inlet formation, closure, and island overwash (Krantz et al. 2009).

Dynamic geomorphology includes longshore sand transport, island "rollover," and net westerly migration (Stauble et al. 1993; Krantz et al. 2009).

Mainland groundwater discharges to the coastal bays and the ocean (Dillow and Greene, 1999). Assateague groundwater is isolated (Hall, 2005).

Removal of artificial structures is restoring natural processes such as dune building and overwash (ASIS, 2008b).

Ecosystem features

Rare overwash habitat supports specialized and rare species such as piping plover and seabeach amaranth (IUCN, 2010; USFWS, 1985).

Birds use the island for overwintering and a stop along a major Atlantic migration corridor (Dinsmore et al. 1989).

The absence of ambient noise allows for sensitive species to be unimpacted by human activity (NPS 2002).

Native white-tail deer and historically introduced horses and sika deer (Keiper and Keenan, 1980; Keiper, 1985).

Human use features

The bays and ocean provide important habitat for commercial and recreational fisheries (Murphy and Secor 2006).

Aesthetic appeal and observation of unique fauna attracts millions of visitors every year (Hager 1996; ASIS, 2007).

Increasingly rare on the US Atlantic coast, night darkness characterizes the sky (Duriscoe et al. 2007) .

Hunting of native white-tail deer and introduced sika deer help control population size.

Human use features

Diverse, human use of Assateague Island National Seashore is predominantly non-extractive, but does include certain extractive activities (Figure 2.11). The Maryland coastal bays and offshore Atlantic fisheries support important commercial fisheries, and beach and bayside fishing is a key attraction for visitors accessing many areas of the Seashore (Murphy and Secor, 2006; ASIS, 2008a). The aesthetic appeal, beach, and unique fauna (including the feral horses) are key reasons for visiting the Seashore, and therefore important human use features (Hager, 1996; ASIS, 2007). The National Park Service is committed to monitoring and preserving natural night sky conditions (Duriscoe et al., 2007), and the Seashore is one of the longest sections of undeveloped coastline on the mid-Atlantic US coast, providing a rare dark sky experience. Hunting was recognized as an appropriate recreational activity in the enabling legislation of the Seashore and is additionally used in the population management of both species of deer present on the island (Public law 89-195).

Resource descriptions by habitat

Assateague Island National Seashore contains a diverse array of terrestrial and aquatic habitats, including bayside sub-tidal and mudflats, salt marsh, inland wetlands, forest and shrubland, dunes and grassland, beach and intertidal, and Atlantic sub-tidal habitats (Figure 2.13 and 2.14 combined; see chapter three for details of habitat classification). Sub-tidal habitat makes up approximately 64% of the total area within the Seashore boundary, with 6,402 ha (15,819 acres) on the Atlantic shore and 6,628 ha (16,378 acres) within Chincoteague and Sinepuxent Bays (Table 2.3). Of the 7,361 ha (18,190 acres) of terrestrial and

Figure 2.12. Inlets on Fenwick & Assateague Islands, 1690–2000.

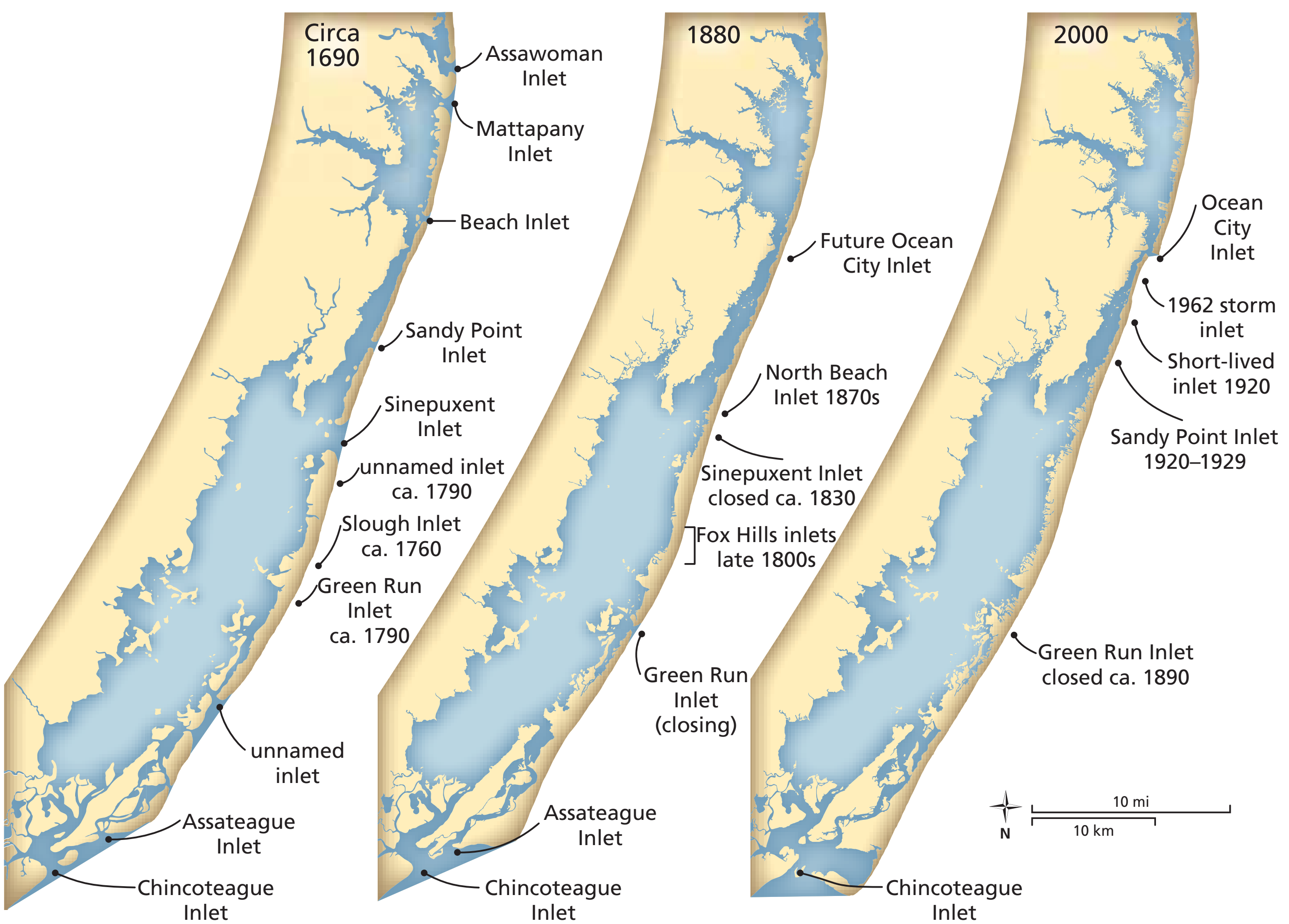
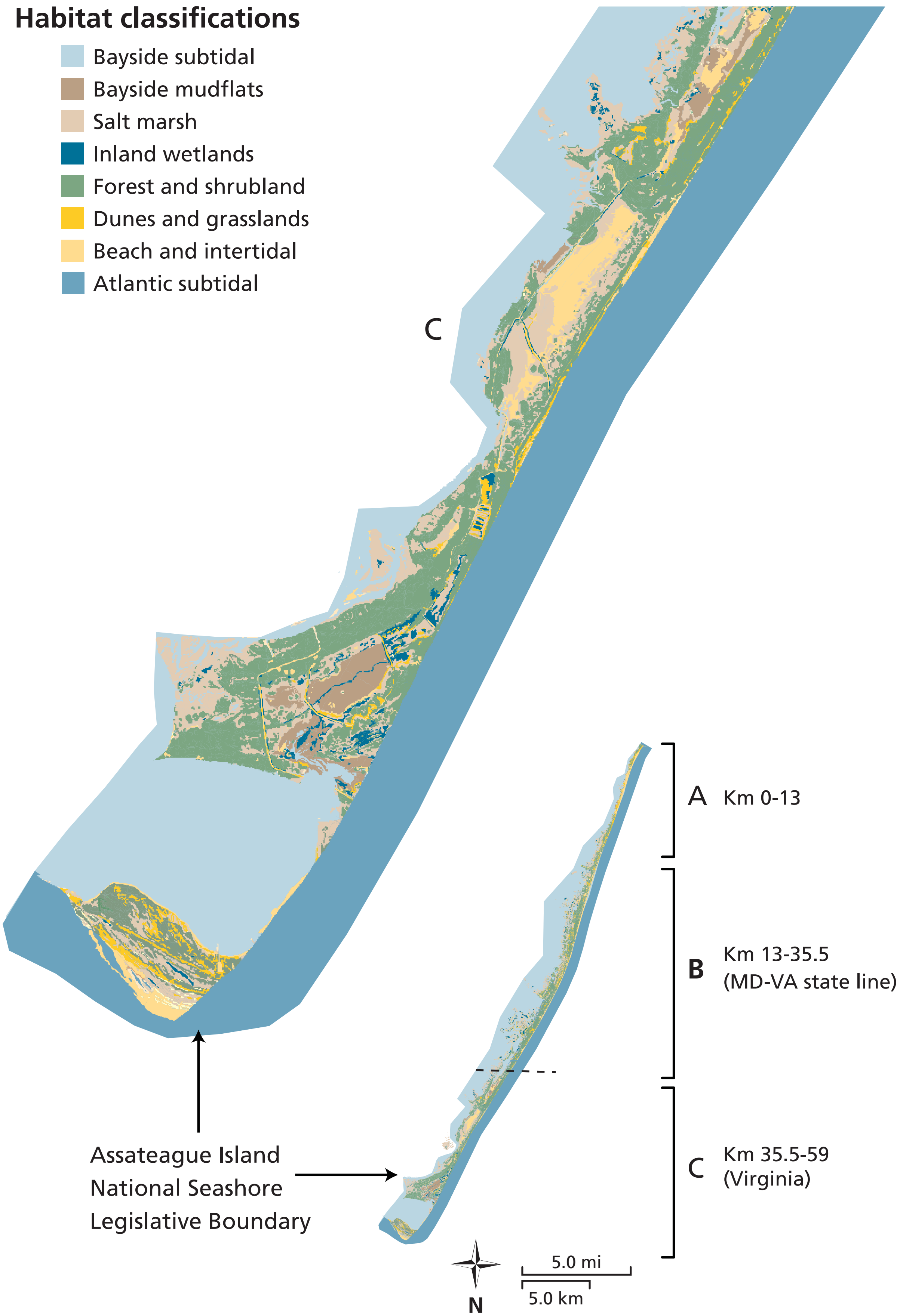


Figure 2.13. Habitat classifications on Assateague Island (see Chapter 3 for process of delineation)


Habitat classifications
Bayside subtidal
Bayside mudflats
Salt marsh
Inland wetlands
Forest and shrubland
Dunes and grasslands
Beach and intertidal
Atlantic subtidal
C
A Km 0-13
B Km 13-35.5 (MD-VA state line)
C Km 35.5-59 (Virginia)
Assateague Island National Seashore Legislative Boundary
N
5.0 mi
5.0 km

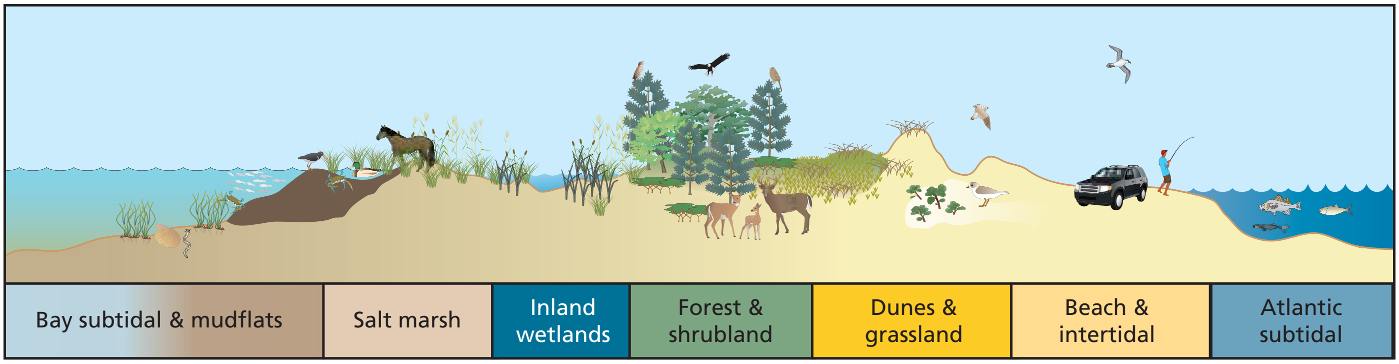


Figure 2.14. Assateague Island National Seashore Habitat Classifications

intertidal marsh habitats on Assateague Island, the most abundant habitats by area are forest and shrubland (39.8%), and salt marsh (28.8%), followed by beach and intertidal (13.1%) as well as dune and grassland (12.4%) habitats (Table 2.3).

Bayside subtidal and mudflats

Assateague Island National Seashore contains 6,628 ha (16,378 acres) of estuarine subtidal habitat in Chincoteague and Sinepuxent Bays, and a further 215 ha (532 acres) of intertidal mudflat. This combined habitat comprises 32% of the total area within the Seashore boundary (Table 2.3; Figure 2.13). These shallow bays, with a mean depth of just 1.0 – 1.2 m (3.3 – 3.9 ft), have a well mixed water column and slow water exchange time of up to two months in some areas of Chincoteague Bay results in large differences in salinity, wave energy, and turbidity throughout the Bays (Pritchard, 1960; Boynton et. al., 1996; Allen et. al., 2007). These estuarine habitats support a diverse range of ecosystem resources including extensive seagrass meadows (*Zostera marina* and *Ruppia maritima*), diverse migratory waterbirds including Atlantic brant (*Branta bernicla hrota*), and diverse finfish and invertebrate communities including summer founder (*Paralichthys dentatus*) and blue crabs (*Callinectes sapidus*) (Jesien et. al., 2009; Wilson et. al., 2009). These bays are highly connected to the Atlantic Ocean and therefore to other mid-Atlantic coastal bays, with many pelagic faunal species spawning outside the coastal bays (Murphy and Secor, 2006). Bayside beaches and mudflats are important foraging habitat, especially for young piping plover chicks (*Charadrius melodus*) (Loegering and Fraser, 1995). Good water quality in coastal systems is essential for supporting abundant resources and, based on a report of nutrient data from 1970 (Boynton et. al., 1996), Chincoteague Bay was considered one of the most pristine water bodies in the mid-Atlantic (Koch and Orth, 2003). However, these bays are considered to be highly susceptible to eutrophication and recent studies indicate that water quality has been declining since the late 1990's, with increasing nutrient concentrations, low dissolved oxygen, and blooms of the brown tide forming *Aureococcus anophagefferns*, (Bricker et al., 1999; Wazniak et al., 2007; Glibert et al., 2007).

Salt marsh

A total of 2,120 ha (5,238 acres), or 30% of the total area, of Assateague Island is salt marsh habitat (Table 2.3, Figure 2.13). These habitats are highly productive, providing habitat for fish, wildlife, and waterfowl as well as many ecosystem functions such as sediment stabilization and trapping, and nutrient cycling (Kennish, 2001). Prior to the mid 1980's, the low marsh areas of Assateague Island were dominated by cordgrass (*Spartina alterniflora*), however they now show mixed dominance of cordgrass and saltgrass (*Distichlis spicata*). Experimental studies suggested that selective grazing by the feral horses (*Equus caballus*) may have influenced species composition, however this was not confirmed by long term exclosure monitoring (Furbish and Albano, 1994). In the summer, wading birds like great egrets (*Casmerodius albus*) and clapper rails (*Rallus longirostris*) hunt along the edge of the marsh. Red-winged blackbirds (*Agelaius phoeniceus*) can be found among the taller reeds and rushes, and northern harriers (*Circus cyaneus*) hunt for small mammals and birds in this habitat during the winter months. River otters (*Lutra canadensis*), muskrat (*Ondatra zibethica*), and the diamond backed terrapin (*Malaclemys terrapin terrapin*) also live in Assateague's fresh and saltmarsh areas (Jessien et. al., 2009). The only native rat on Assateague Island, the rice rat (*Oryzomys palustris*), occurs in low densities but is widely distributed, especially within salt marsh areas (Dueser et al., 1978).

Inland wetlands

Inland wetlands make up just 3% of the total of Assateague Island, but provide an important and unique refuge and water source for many species (Table 2.3, Figure 2.13). During periods of rain, freshwater ponds often form inland, in the vicinity of forests and shrublands. These wetlands tend to be small and temporary, losing their water due to evaporation or drainage through the, sandy soil during the spring months. However some wetlands and ponds provide water for birds and wildlife all year long, due to input of fresh groundwater (Wilson et al., 2009). Wetlands also intercept and filter pollutants, sequester substantial quantities of carbon, process nutrients, and temporarily store runoff (Tiner et al., 2000). Herbaceous species of plants dominate these wetlands, due to a variety of factors including periodic overwash and the resultant exposure to salt water. In addition, the southern end of the island features a number of large, artificially created freshwater impoundments, where New Jersey chorus frogs (*Pseudacris triseriata kalmi*), bullfrogs (*Rana catesbeiana*), and green frogs (*Rana clamitans melanota*) breed. The meadow jumping mouse (*Zapus hudsonius*) and meadow vole (*Microtus pennsylvanicus*) live in grasses that border these wetlands, where they feed on seeds, plants, and insects.

Photo: Tim Carruthers, IAN Image Library

Saltmarsh and shrubland within the Seashore.

Forest and shrubland

Assateague Island has 2,930 ha (7,240 acres), or 41% by area, of forest and shrubland habitats (Table 2.3, Figure 2.13). Physical factors such as proximity to the water table, salt exposure, and disturbance from overwash promote distinct zonation patterns of vegetation, typical of coastal barrier islands (Dueser et. al., 1978). These communities include low and high shrub

Table 2.3. Habitat types within Assateague Island.

Habitat	% Total Land	Area of Island		% MD Land	MD Only	
		(ha)	(acres)		(ha)	(acres)
Atlantic Subtidal	--	6,402.0	15,819.3	--	3,600.0	8,895.6
Bayside Subtidal	--	6,628.0	16,377.8	--	4,630.0	11,440.7
Bayside Mudflats	3.0	215.1	531.6	0.4	13.0	32.2
Beach and Intertidal	13.5	962.1	2,377.4	12.7	455.7	1,126.0
Dune and Grassland	12.7	909.4	2,247.2	17.5	627.7	1,551.2
Inland Wetlands	3.1	224.6	555.0	3.0	106.5	263.1
Salt Marsh	29.7	2,120.0	5,238.5	27.4	984.9	2,433.6
Shrub and Forest	41.0	2,930.0	7,240.0	39.4	1,413.7	3,493.2
TOTAL AREA		20,391.2	50,386.8		11,831.5	29,235.6

Photo: NPS ASIS

Dunes or grasslands comprise 13% of the total land area on Assateague Island.

communities dominated by greater than 50% cover of wax myrtle (*Myrica cerifera*), pine forest dominated by loblolly pine (*Pinus taeda*), and a mixed hardwood forest (Dueser et. al., 1978). Many bird species use this habitat including tree swallows (*Tachycineta bicolor*) and myrtle warblers (*Dendroica coronate*); both of which depend upon the berries of wax-myrtle as a food resource. Both white-tailed and sika deer feed in the shrubland and find shelter in its thickets. Most forests are dominated by evergreen trees, including American holly (*Ilex opaca*), red cedar (*Juniperus virginiana*), and especially, the loblolly pine (*Pinus taeda*). Persimmon (*Diospyros virginiana*), sassafras (*Sassafras albidum*), red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), and oak (*Quercus sp.*) can be found among the pines. These trees provide shelter for ruby-crowned kinglets (*Regulus calendula*), downy woodpeckers (*Picoides pubescens*), and white-eyed vireos (*Vireo griseus*), which feed on insects. The great horned owl (*Bubo virginianus*) is a frequent nighttime predator, while the northern saw-whet owl (*Aegolius acadicus*) overwinters at Assateague (Brinker et al., 1997; Churchill et. al., 2000). Moist areas provide suitable conditions for rare wildflowers such as the crested fringed orchid (*Platanthera cristata*), which grows bright orange flowers in late summer, and rose pogonia (*Pogonia ophioglossoides*), which displays a single pink flower in late spring (Wilson et al., 2009).

Dune and Grassland

A total area of 909 ha (2,247 acres) of Assateague Island is dunes or grasslands, comprising 13% of the total land area (Table 2.3). The dunes have been classified into four main types, representing developmental stage; 'flats' are areas with no foredunes and some establishing vegetation; 'knolls' are rounded hummocks resulting from sand accumulation around vegetation; 'ridges' are older dunes with some dense vegetation and extensive root systems, and; 'buttes' are most likely the oldest dunes which are scarped with considerable erosion (Seliskar, 2003). This habitat is typical of mid-Atlantic barrier islands and the dominant vegetation includes American beach grass (*Ammophilia brevigulata*), panic grass (*Panicum spp*), and seaside goldenrod (*Solidago sempervirens*) (Dueser et al., 1978). American beach grass, particularly, is stimulated by sand burial and has an extensive root and rhizome system which promotes dune stabilization, however it is grazed heavily by the islands horse population (Seliskar, 2003).

Beach and intertidal

Along the length of Assateague Island, 14% of the land area is beach and intertidal habitat on the Atlantic coast (Table 2.3, Figure 2.13). One of the characteristic features of Assateague Island, are the abundant storm overwash flats (Kochel and Wampfler, 1989). These overwash areas and the sparsely vegetated upper beaches are some of the most significant areas on the Seashore for breeding birds, and provide habitat for several state listed plants as well as the globally rare, federally threatened, and state endangered, sea beach amaranth (*Amaranthus pumilus*) (Tyndall et al., 2000; Lea et al., 2000; MNHP, 2010; USFWS, 1993). Unique to barrier islands, these early successional habitats are used by a variety of rare ground-nesting shorebirds and colonial waterbirds. Shorebirds such as the piping plover (*Charadrius melodus*) and American oystercatcher (*Haematopus palliatus*), and colonial waterbirds such as the least tern (*Sterna antillarum*) breed on Assateague Island every summer. Common terns (*Sterna hirundo*) and black skimmers (*Rynchops niger*) historically nested on the beaches of Assateague, but have not successfully bred in recent years, largely due to predation pressure by red fox (*Vulpes vulpes*). Ground nesting species are also subject to disturbance by feral horses, and occasionally direct mortality of eggs and chicks.(NPS, 2008). In early spring, piping plovers (*Charadrius melodus*) arrive at Assateague and begin to perform their elaborate territorial and courtship displays. This federally threatened species is attracted to the island's sandy, storm washed beaches which they use to both nest and feed (USFWS, 1985). After spending the summer months hatching and fledging their chicks, the plovers depart in late summer for their wintering grounds in the southeastern United States and Caribbean (NPS, 2008).

Two species of state listed rare insects occur on Assateague Island, both are tiger beetles (*Cicendela*) and depend on ocean fronting beach and dune habitats. *Cicindela dorsalis media* is the rarer of the two species and is found only on the north end of the island and a small area just north of the Maryland-Virginia state line. This species forages along the ocean high tide line and lays its eggs in the upper beach and primary dunes. The population has ranged between 14 and 698 individuals during the period 1985 to 2006 (Knisley, 2007). *Cicindela lepida* occurs in interior dune habitats, seeming to prefer areas of dune blowouts and overwash channels and flats. This species is more widely distributed and abundant within the Seashore, with population estimates ranging between 84 and 892 from 1990 to 2006 (Knisley, 2007).

Atlantic subtidal

Of the entire area bounded within Assateague Island National Seashore, 31% or 6,402 ha (15,819 acres) are subtidal areas on the Atlantic Ocean side of the island (Table 2.3, Figure 2.13). Even though the nearshore region of this habitat supports the dynamic geomorphologic processes, such as long shore drift, that deliver sand to Assateague Island (Figure 2.2; Krantz, 2009), this is the least studied habitat within the Seashore. Consequently there is little knowledge of benthic habitats, flora, or fauna. Cetaceans are active in these waters year-round. Several species of dolphin are common; the bottlenose dolphin (*Tursiops truncates*) is the most common species during the summer, while harbor porpoises (*Phocoena phocoena*) occur more frequently during winter months. The area at the mouth of the Chesapeake Bay is a popular wintering location for immature right (*Eubalaena glacialis*) and humpbacked whales (*Megaptera novaeangliae*), and it is not uncommon to see them passing along the ocean side of Assateague Island (NPS, 2008).

Photo: Kevin T. Edwards, IAN Image Library

A female Least Tern accepts a fish and mates.

2.2.3 Resource issues overview

Past activities influencing resources

Coastal barrier islands are naturally dynamic systems, with storms opening and longshore drift closing literally dozens of inlets on what is now Assateague Island over the last three centuries (Figure 2.12). Management actions in response to storm impacts or potential impacts over the past eight decades have changed the naturally dynamic geological processes of Assateague Island, creating long term influences upon multiple aspects of the Seashore's natural resources. In early 1933, Assateague and Fenwick islands were joined, forming one continuous barrier island. The remnants of a hurricane in August 1933 caused a storm surge that swept across Assateague Island into the coastal bays, creating the present Ocean City inlet as this water cut a channel back to the ocean. The opening of this inlet destroyed many structures in and around Ocean City and also drastically changed the character of the coastal bays by increasing the salinity and oceanic flushing of the bay waters. The new inlet was stabilized in 1934, by the U.S. Army Corps of Engineers, with the construction of two rock jetties - one on either side of the inlet (Pendleton et al., 2004). This construction has had profound consequences for the sediment dynamics of the northern end of Assateague Island and the Coastal Bays, disrupting the southward longshore transport of sand along the island, resulting in sediment deprivation and therefore accelerated erosion at the northern end of Assateague Island (Krantz et al., 2009; Figure 2.2).

With the initiation of development and land subdivision in the 1950's on Assateague Island, an artificial dune was constructed along the length of the island, to protect private lands from future storm damage (ASIS, 2003). Although most of the artificial dune was destroyed by strong storms during the 1990s, its remnants continue to prevent the natural processes of sand overwash occurring in some areas of Assateague Island, particularly near the MD/VA state line. A two mile long artificial dune is still maintained within the Developed Zone of the park to protect infrastructure such as buildings and roads.

After the establishment of the National Seashore in 1965 (Public law 89-195), the stability of the island continued to be of major concern. The largest ongoing concern was sediment starvation resulting from the two rock jetties built by the U.S. Army Corps of Engineers to stabilize the Ocean City Inlet in 1934 (Krantz et al., 2009). By 2005, the north end of the island had retreated westward its entire width (about 500 m or 547 yards) because the inlet and jetties redirected the sand that would naturally have been deposited on the northern section of the island (Krantz et al., 2009; Figure 2.8). To address the erosion of northern Assateague Island, a joint planning study between the U.S. Army Corps of Engineers, National Park Service, Town of Ocean City, Worcester County, and Maryland Department of Natural Resources was initiated in the 1990s. The study produced a comprehensive plan for mitigating the impacts of the jetty-stabilized inlet on Assateague Island's sediment supply, and the resulting 'north end restoration project' was initiated in 2002 to address both historic and ongoing impacts from the inlet (Zimmerman, 2004).

In early 1998, two extra-tropical cyclones passed over Assateague Island, producing extremely large waves that threatened to breach the north end of the island (USGS, 1999). In an effort to prevent a breach from occurring, a 2.4 km (1.5 mi) emergency

Photo: Robert Blama, USACE

Stabilization of the Ocean City inlet in 1934 resulted in accelerated erosion at the northern end of Assateague Island. Photo taken September 2004.

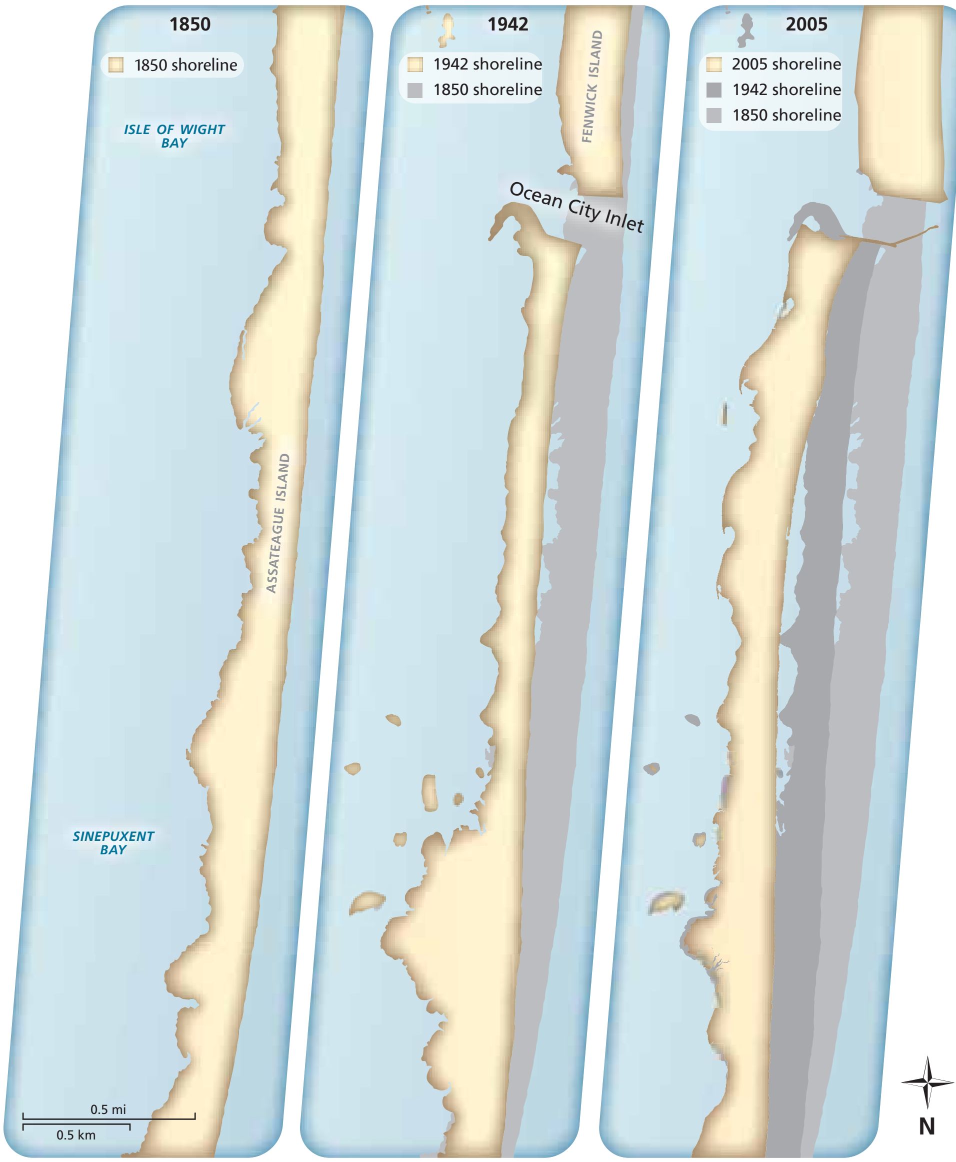


Figure 2.15. The evolution of Fenwick & Assateague Islands, 1850-2005

storm berm was constructed, starting 5.0 km (3.1 mi) south of the Ocean City Inlet. The berm persisted and was manipulated in the short term phase of the north end restoration project, aiming to reduce the potential for island breaching while allowing some natural overwash (Zimmerman, 2004). However, it prevented overwash entirely on the north end of Assateague Island and is still undergoing active modification to allow westerly overwash to occur at a rate similar to other areas in the north of the island (ASIS, 2008b).

The larger aim of the north end restoration plan was the replenishment of sand supply to the beaches south of Ocean City Inlet. As an additional part of the short-term component of the North End Restoration Project, in 2002, 1.4 million cubic meters (1.8 million cubic yards) of sand were placed on the beach face (moving the waterline further east) to replace a portion of the sediment lost due to the Ocean City Inlet since 1934 (Schupp et al., 2007). In 2004, the long-term component of the North End Restoration Project commenced, which continues to move 72,000 m^3 of sand twice a year (in spring and fall) from the ebb- and flood-tidal deltas around the inlet to the surf zone of Assateague Island, approximately 2.5-5.0 km (1.6-3.1 mi) south of the inlet (Zimmerman, 2004). Natural processes of waves and longshore transport then distribute this sand in the surf zone along the beach south from that point.

Photo: Jane Thomas, IAN Image Library

Poultry houses on the Chester River, west of Crumpton. Concentrated animal feeding operations are a significant source of nutrients from shared watersheds.

Resource condition threats and stressors

Internal park threats

As a result of historical and current human activities, there are stressors present within the Seashore that threaten natural resources (Figure 2.16).

Overgrazing and dune erosion have been observed as a result of the Seashore's feral horses (*Equus caballus*; Seliskar, 2003), as well as changes to marsh vegetation structure from selective grazing (Furbish and Albano, 1994). In addition to the horses, are populations of native white-tail deer (*Odocoileus virginianus*) and historically introduced sika deer (*Cervus nippon*) (Keiper, 1985). Combined, these ungulates impact vegetation structure in forest and shrub communities on the island (Sturm, 2007), and reduce populations of the threatened seabeach amaranth (*Amaranthus pumilus*; Sturm, 2008).

There are 105 recorded non-native plants in the Virginia region and 145 in the Maryland region of Assateague Island (Stalter and Lamont, 1990). While most of these species are relatively innocuous and have limited distribution, a few are highly invasive including *Phragmites australis*, which is known to have expanded regionally in tidal fresh, oligohaline, and mesohaline marsh areas (Rice et al., 2000).

Park visitors have the potential for direct impact such as disturbing habitat, for example with the use of over-sand vehicles, as well as indirect impacts such as the development of supportive infrastructure, including parking lots and bathrooms.

Ditching of salt marshes for the control of mosquito populations was prevalent in the mid-Atlantic region, including Assateague Island, prior to the 1950's (Kennish, 2001). Many of these ditches remain, and can reduce foraging area for wading and shorebirds (Clarke et al., 1984), as well as degrading estuarine water quality by increasing nutrient export from marshes (Koch and Gobler, 2009).

Watershed threats

The Seashore includes waters of Chincoteague and Sinepuxent Bays and the Atlantic ocean. These waters are all potentially impacted by increasing development throughout the watersheds adjoining the coastal bays (Figure 2.16). Within the Maryland portion of the watershed, 31.4% of the land area is used for agriculture (2002 data; Fertig et al., 2009). While small in area, concentrated animal feeding operations are a significant source of nutrients due to high loading rates (Figure 2.17, Beaulac and Reckhow, 1982; Mallin and Cahoon, 2003). Increasing nutrient loading to the coastal bays is evidenced by degrading water quality and impacts to seagrass meadows (Wazniak et al., 2007). Between 1973 and 2005, developed lands increased from 5.4% up to 27.6% of the Maryland portion of the coastal bays watershed, resulting in increased impervious surface and nutrient inputs (Figure 2.18; Boynton et al., 1996; Hall et al., 2009

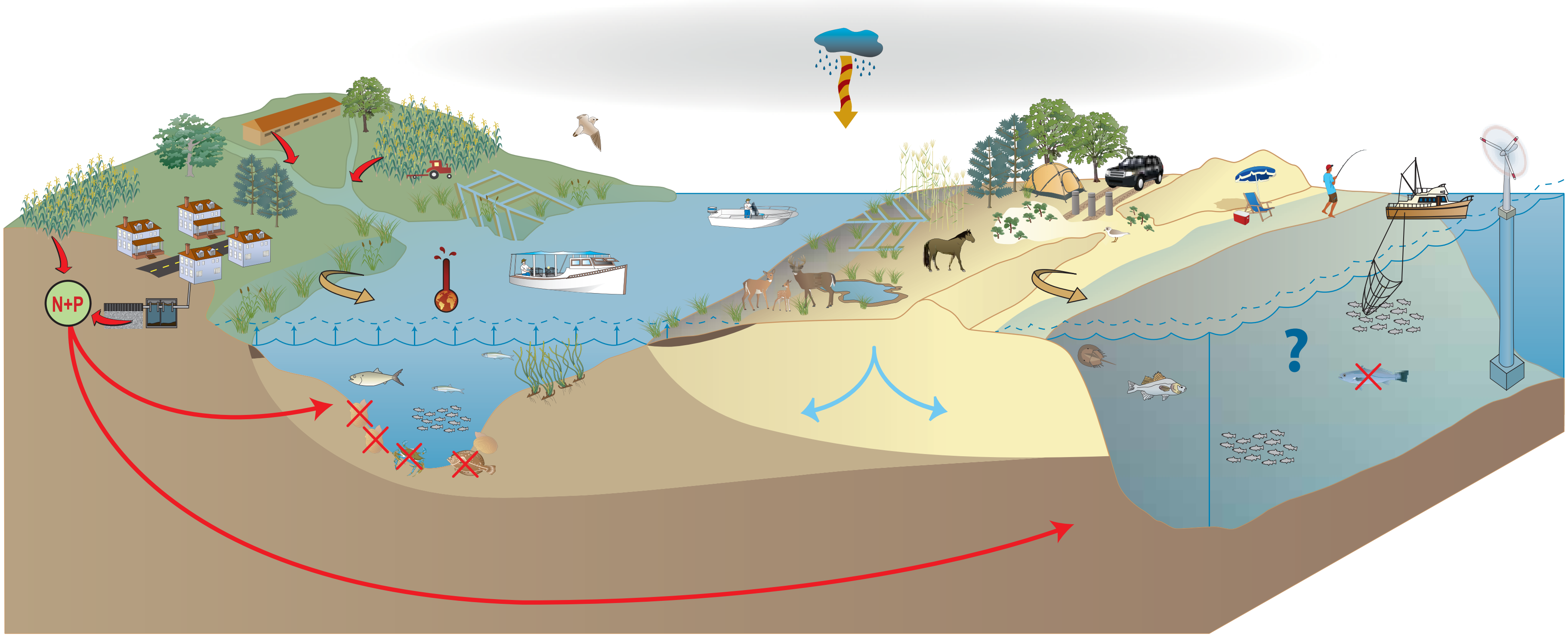
Regional and historical overfishing, as well as worsening water quality, are considered to be related to the observed decline in forage fish numbers since 1980 (Casey and Doctor, 2004).

Groundwater, even more than 50 years old, releases nutrients at locations throughout the coastal bays (Dillow et al., 2002; Bratton et al., 2009).

Regional threats

The mid-Atlantic region includes some of the highest population densities in north America, which is a component of some of

Figure 2.16. Conceptual diagram showing the key threats to Assateague Island.



Internal park threats

Overgrazing and trampling by deer and horses reduces biodiversity and disrupts dune formation and stabilization (Seliskar, 2003; Furbish & Albano, 1994).

Introduced invasive plant species such as *Phragmites* displace native vegetation (Stalter & Lamont, 1990; Rice et al. 2000).

Park visitors increase habitat disturbance.

Mosquito ditches have potentially adverse effects on salt marshes (Portnoy 1999).

Watershed threats

Agriculture and concentrated feeding operations in the Coastal Bays watershed increase nutrient inputs (Mallin & Cahoon, 2003; Beaulac & Reckhow, 1982).

Increasing human population results in greater impervious surfaces and more nutrient inputs (Hall et al. 2009).

Historical overfishing impacts the abundance of forage fish and clams (Casey and Doctor, 2004).

Nutrients are transported to the bay and ocean via groundwater (Dillow et al. 2002; Bratton et al. 2009).

Regional threats

Air quality degradation and deposition of nitrate is a significant source of nitrogen input (NPS, 2009; Boynton et al. 1996).

Climate change results in sea level rise, increased erosion, and species displacement (Najjar et al. 2000; Pendleton et al. 2004).

Potential offshore energy development could affect viewshed, night sky, benthic habitat, birds, fish, and marine mammals (Wahlberg & Westerberg, 2005; Madson et al. 2006; Burger et al. 2011).

A knowledge "gap" and lack of offshore data undermines management efforts and understanding of coastal processes

Figure 2.17. GIS data layer showing poultry house distribution within the watersheds of th Maryland Coastal Bays.

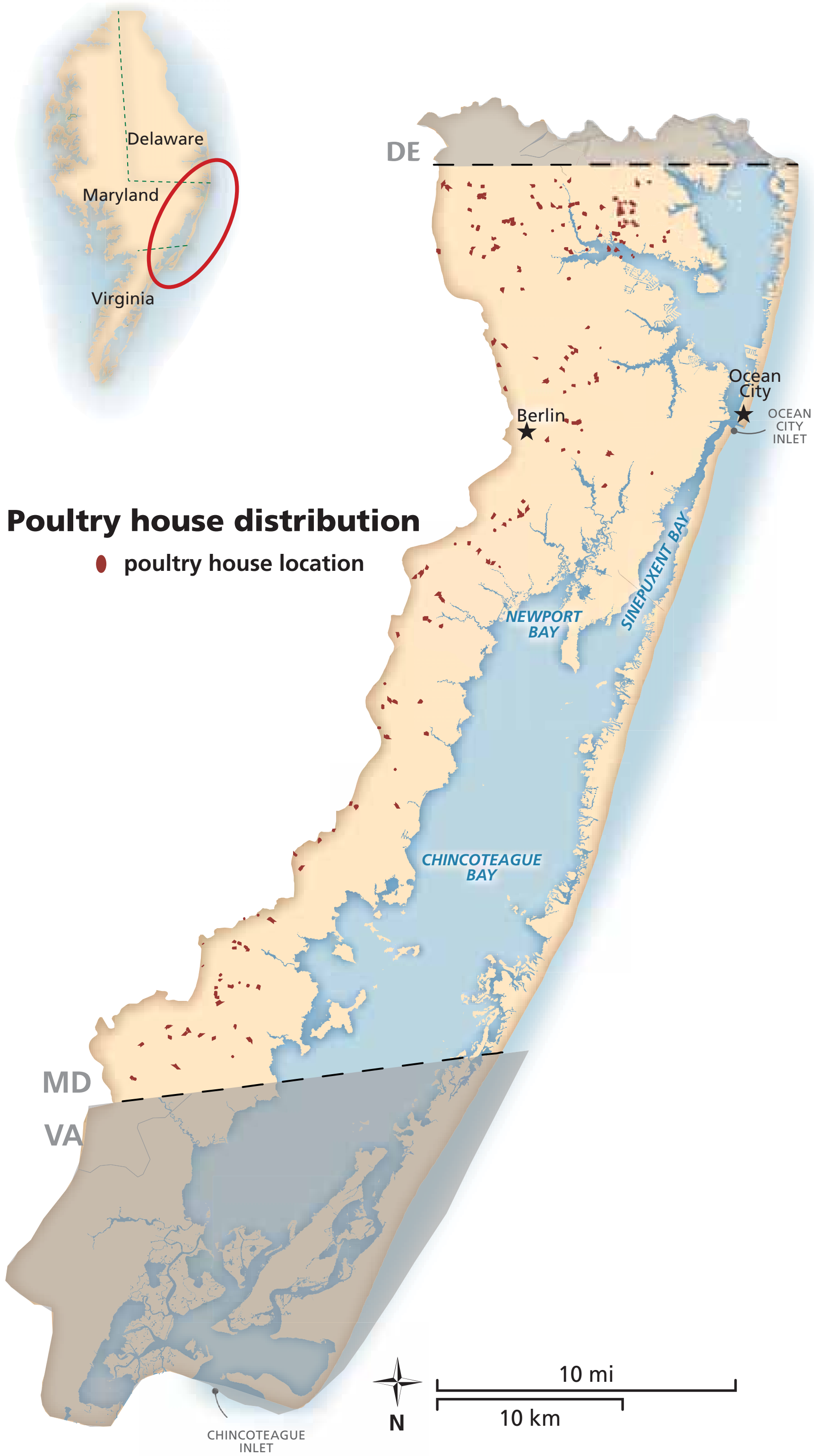


Figure 2.18. GIS data layer showing impervious surface cover within the Coastal Bays.

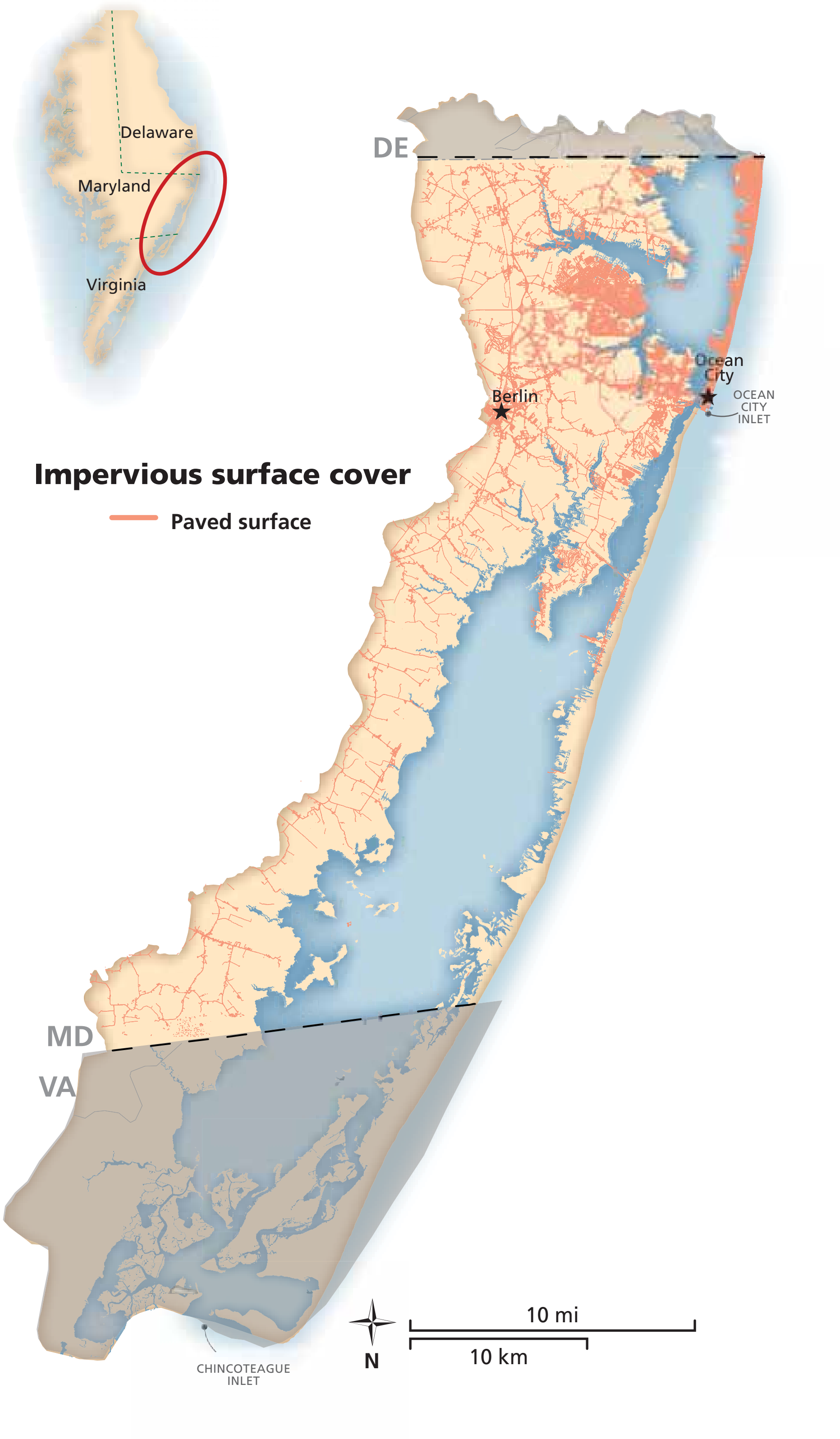


Photo: istockphoto.com

Proposed wind power development may disturb offshore habitat. Photo: istock.com

the regional scale stressors to the Seashore (Figure 2.16; 4.7). Throughout the central and eastern US, 19 out of 20 park monitoring sites have rates of nitrogen deposition that are of 'significant concern', suggesting a broad scale regional threat (NPS, 2009). The atmosphere is a major source of nitrogen to coastal waters. Modeling studies estimate at least one third of the total nitrogen loading to the Maryland region of the coastal bays comes from atmospheric sources (Boynton et al., 1996).

The mid-Atlantic region of the US has experienced almost twice the global mean rate of relative sea level rise over the past century (3-4 mm yr^{-1}), which is predicted to increase a further 19 cm by 2030, resulting in increased coastal flooding and changes to coastal geomorphological processes (Najjar et.al., 2000). Temperature is predicted to increase a further 1.3 °C by 2030, potentially causing species displacement, as well as exacerbating water quality degradation in the coastal bays by further decreasing summer oxygen concentrations (Najjar et.al., 2000). Along the length of Assateague Island, 60% of the shoreline has been assessed as high to very high vulnerability to climate change (Pendleton et. al., 2004).

Offshore energy development in the form of wind power has been proposed along the Maryland coastline and has the potential to disturb benthic marine habitats with towers and cables, interrupt natural night sky viewsheds by adding light pollution, impact cetacean behavior (especially during construction phases) (Madsen et. al., 2006), and affect fish due to noise and vibrations (Wahlberg and Westerberg, 2005) as well as migratory birds including the piping plover (*Charadrius melodus*) (Burger et. al., 2011). Lack of knowledge of benthic habitats along the inner continental shelf offshore from Assateague Island, poses a potential threat as shipping traffic and offshore developments increase with increasing population in the mid-Atlantic region.

2.3 RESOURCE STEWARDSHIP

2.3.1 Management directives and planning guidance

Fundamental Resources (ASIS, 2010d)

Fundamental resources and values are the features, systems, processes, experiences, scenes, sounds, or other resources that collectively capture the essence of the park and warrant primary consideration by managers because they are critical to achieving the park's purpose.

Barrier Island Habitats and Species

The unique environmental conditions found on barrier islands is reflected in the dynamic continuum of habitats stretching from ocean to bay, including beaches, dunes, grass and shrublands, freshwater wetlands, maritime forests, and salt marshes. The diverse landscape provides habitat for a multitude of specialized plant and animal species, many of which are rare, threatened, or endangered. Abundant and diverse populations of migratory birds - such as raptors, shorebirds, waterfowl, and neo-tropical migrants - use the Seashore seasonally for breeding, overwintering, and as stopover habitat while moving along the coastal route of the Atlantic Flyway.

High Quality Waters

High quality water resources within the Seashore's boundary define and sustain the coastal ecosystem and include fresh ground water and surface water systems, and extensive estuarine and marine waters.

Natural Coastal Processes

Natural processes including the action of tides, wind, waves, currents, storms, and sea level rise influence and shape the terrain of the barrier island and adjacent aquatic habitats.

Aquatic Habitats and Species

From open ocean to protected estuary, the Seashore includes a diverse array of aquatic habitats including abundant sea grass beds, expansive salt marshes, and a mosaic of sandy shallows and intertidal flats. These protected habitats support a rich marine life, ranging from small sedentary plants and invertebrates to large ocean-going marine mammals.

Natural Coastal Environment

The natural coastal environment of the Seashore exemplifies the meeting place of land and sea along the Mid-Atlantic coast, and includes miles of broad sandy beaches, an intricate mosaic of natural and scenic landscape features, and wilderness qualities.

Fundamental Values (ASIS, 2010d)

Visitor Experiences at the Seashore

The natural resources of the park provide visitors with a wide variety of active and passive recreational and educational opportunities. Expansive seascapes of ocean and bay, panoramic views, natural sounds, inviting waters, ocean breezes, and dark night skies provide a dramatic setting for an exceptional seashore experience. Visitors have the opportunity to experience the seashore in a variety of ways from driving on the beach to counting the stars by a camp fire, and from ranger guided educational activities to self guided explorations.

Other Important Resources (ASIS, 2010d)

Feral Horses

Horses have been present on Assateague Island for hundreds of years. The Seashore provides a unique opportunity to view wild horses in a natural setting, and a majority of visitors indicate that seeing horses is one of the primary reasons for visiting Assateague Island.

Cultural Resources

The National Seashore contains a variety of locally and nationally significant cultural resources, ranging from historic structures to archeological objects and sites. These structures and sites, as well as the associated documents and objects, are all that remain from the relatively brief periods when humans occupied Assateague Island. Combined, the Seashore's cultural resources tell the story of mankind's

A majority of visitors indicate that seeing horses is a primary reason for visiting Assateague Island.

Photo: NPS ASIS

inability to establish a permanent foothold on the constantly changing barrier island environment.

Related Resources (ASIS, 2010d)

Bay Watershed

The waters and mainland watershed of Chincoteague and Sinepuxent Bays extend far beyond park boundaries. The integrity of many fundamental park resources are affected by activities that occur outside of the park, but within the watershed.

Parkwide desired conditions (ASIS, 2010e)

Parkwide desired conditions are resource conditions that the National Park Service aspires to achieve and maintain over time, and the conditions necessary for visitors to understand, enjoy, and appreciate those resources.

Natural Coastal Processes

- Natural forces are the dominant factor shaping Assateague Island and coastal processes occur largely unaltered by human-induced impacts or activities.
- Sediment supply to the Island is largely unaltered by human-induced impacts or activities.

Aquatic Habitats and Species

- Aquatic habitats are largely unaffected by human activities and exhibit the full

Table 2.4 Natural resource management objectives for Assateague Island National Seashore (ASIS, 2010c).

Natural Resource Management Objectives	Detail / Explanation
Restore disturbed lands	Restoration of disturbed lands including old roads, former residential development, artificial impoundments, and mosquito ditches.
Control invasive non-native plants	Treatment and control of *Phragmites australis* and other invasive non-native plants.
Maintain natural coastal processes	Mitigation of impacts to natural sediment supply.
Protect natural landscape conditions	Restoration of natural landscape conditions to include: • absence of uncontrolled non-native invasive plants • populations of non-native ungulates appropriate to protect natural ecosystem conditions and values • OSV use managed for protection of ecosystem values • lands associated with former development restored • lands influenced by north end storm berm restored • salt marsh affected by mosquito ditching restored
Protect threatened & endangered species	Management and protection of federally listed T&E species including: • Piping plover (*Charadrius melodus*) • Seabeach amaranth (*Amaranthus pumilus*)
Protect species of management concern	Management and protection of 20 native plant and animal species of management concern.
Control invasive non-native animals	Management and control of invasive non-native animal species including: • Feral horses (*Equus ferus*) • Sika deer (*Cervus nippon*) • Nutria (*Myocastor coypus*) • Mute swan (*Cygnus olor*) • Domestic cat (*Felis catus*) • Gypsy moth (*Lymantria dispar*)
Monitor air quality	Monitoring of atmospheric ozone concentrations and nitrogen loading.
Protect & restore water quality	Monitoring, protection and restoration of water resources including marine and estuarine waters and fresh groundwater.
Protect & enhance wilderness character	Mitigation of impacts to wilderness character including non-native vegetation, former development, and incompatible visitor use.

Photo: NPS ASIS

Views within the park are substantially free of human development.

range of qualities and attributes created by the physical conditions and ecosystem processes inherent to the Mid-Atlantic region.

- Aquatic species reflect the natural biodiversity of the region and exhibit patterns of distribution and abundance largely unaffected by human activities.

Natural Coastal Environment

- Landscape features and conditions outside of the developed area (including lightscapes, soundscapes and atmospheric conditions) are a product of natural ecosystem processes and exhibit characteristics largely uninfluenced by human development or activities.
- Views of the Atlantic Ocean and Chincoteague Bay are substantially free of human development.

Barrier Island Habitats and Species

- Barrier island habitats are largely unaffected by human activities and exhibit the full range of qualities and attributes created by the physical conditions and ecosystem processes inherent to the Mid-Atlantic region.
- Plants and wildlife reflect the natural biodiversity and exhibit patterns of distribution and abundance largely unaffected by human activities.
- New high quality habitats created by natural forces and coastal processes are protected.
- Hunting supports resource management objectives.
- Non-native/invasive species introductions do not occur.

High Quality Waters (within the seashore)

- Physical, chemical, and hydrologic properties and dynamics of oceanic and estuarine waters are largely unaffected by human activities.
- Fresh surface and groundwater resources are largely unaffected by human activities.

Coastal Bays and Watershed

- Water quality and aquatic resources are largely unaffected by the conditions and activities occurring on adjacent waters and in the surrounding watershed.

Wild Horses

- Horses possess all characteristics of a wild free-roaming horse herd.
- Herd size is balanced to protect the long-term health of the horse population while

Photo: istockphoto.com

The habitats of Assateague Island support diverse visitor experiences.

minimizing horse impacts on the island ecosystem.

- Visitors to Assateague Island understand and respect the horses and act in a way that protects their wild nature.
- Human/horse conflicts are minimized.
- Interactions between feral horses and domestic horses are benign for both.

Visitor Experience at the Seashore

- Visitors enjoy the many high quality experiences the seashore has to offer while resources are protected.
- Visitors understand and appreciate the seashore's resources, including the potential effects of climate change on the seashore's resources.
- Appropriate recreational use continues to be welcomed in places where it does not impact resources or interpretive activities at the seashore; all public activities at the seashore are consistent with state laws and NPS policies and are determined to be appropriate.
- Conflicts among visitor user groups are minimized.

Global Climate Change

- Seashore facilities and transportation infrastructure are compatible with the anticipated effects of global climate change and accelerating rates of sea level rise.
- Human-caused stressors acting on Seashore resources are mitigated to enhance the resiliency of natural systems in the face of global climate change.
- The effects of global climate change and sea level rise on the coastal ecosystems of the seashore are monitored and understood.
- Climate-friendly practices are integrated into all park operations and activities to reduce the seashore's carbon footprint.
- Visitors understand the consequences of global climate change and their role in reducing greenhouse gas emissions and other stressors.
- Visitors support changes in Seashore access and recreational infrastructure needed to respond to global climate change and accelerating rates of sea level rise.
- Seashore resources are protected from the adverse effects of inappropriate local/regional climate change response actions.

2.3.2 Status of supporting science

Table 2.5 Monitoring data sets collected by Assateague Island National Seashore

Metric	Data Available	Reference/source
Non-native invasive animals		
Feral horse abundance	1994-2010	Annual data reports, ASIS
Deer density	2003-2006	Sturm, 2007
Gypsy moth abundance	1995-2010	Annual Surveillance Reports, USDA
Exotic plants		
Phragmites australis areal extent	2000-2009	Annual data reports; extent map
Exotic invasive area and treatment	2006-2010	Annual data reports, ASIS
Threatened & endangered animals		
Charadrius melodus (Piping plover) fledgling success, nests	1993-2010	Annual data reports, ASIS
Tiger Beetle Abundance	2001-2009	Knisely, 2009
Threatened & endangered plants		
Amaranthus pumilus (Seabeach amaranth) abundance	1998-2010	Annual data reports, ASIS
Aquatic flora		
Seagrass area	2000-2004, 2006-2010	VIMS, Orth et al., 2009
Geologic resources		
Shoreline position	1994-2010	ASIS, 2010a
Beach Shoreline Rate of Change	1849-2010	ASIS, 2010a
Topographic profiles	1995-2010	ASIS, 2010a
Lidar	1998-2010	ASIS, 2010a
Water quality		
Bayside nutrients, silica, TSS, pigments	1987-2010	ASIS, 2010a
Atmospheric		
Night viewshed	2009	NPS, Night Sky Program
Ozone	1995-2010	ASIS, 2010a
Wet sulfate and nitrogen deposition	2000-2010	NADP
Weather	1994-2010	ASIS, 2010a
Visitor use consumptive		
Hunting numbers and animals taken	1983-2010	ASIS, 2010a
Visitor use non-consumptive		
Over-sand vehicle permit numbers	2003-2010	ASIS, 2010a
Camping permits	2003-2010	ASIS, 2010a
Public health		
Bacteria counts	1992-2010	ASIS, 2010a

Table 2.6 Status of National Park Service Inventory reports for Assateague Island National Seashore.

Inventory Report	Status
Air quality	Complete
Air quality monitoring locations	Complete
Birds	In Development
Contaminant sources	Complete
Geology	In Development
Herps	In Progress
Invertebrates	Complete
Bats	Complete
Soil	Complete
Vascular plants	Complete
Vegetation mapping	In Progress
Water body locations	Complete
Water quality	Complete
Weather and cllimate	Complete

http://science.nature.nps.gov/im/units/ncbn/inv_reports.aspx - accessed Dec 2010

Table 2.7 Status of National Park Service Inventory and Monitoring Vital Signs monitoring for Assateague Island National Seashore.

Vital sign	Protocol status	Data
Coastal Geomorphology	In Review	Historic
Estuarine Nutrient Enrichment: Seagrass	Complete	2009
Estuarine Nutrient Enrichment: Water Quality	Complete	2003-2010
Estuarine Nutrient Loading	Complete	1990
Forest Health	Complete	
Landscape Change	Complete	
Marsh Birds	In Development	
Ocean Shoreline Position	Complete	1994-2010
Salt Marsh Elevation	Complete	2009-2010
Salt Marsh Nekton	Complete	2008
Salt Marsh Vegetation	Complete	2008
Visitor Use and Impact	Complete	

http://science.nature.nps.gov/im/units/ncbn/monitoring_products.aspx - accessed Dec 2010

Table 2.8. Summary of current and future National Coastal and Barrier Network vital signs monitoring data.

Measurements	Period	Data source
Coastal Topography		
Dune height	Planned for future	NCBN Monitoring Program
Dune width	Planned for future	NCBN Monitoring Program
Berm height	Planned for future	NCBN Monitoring Program
Berm width	Planned for future	NCBN Monitoring Program
Cliff height	Planned for future	NCBN Monitoring Program
Overwash fan locations	Planned for future	NCBN Monitoring Program
Vegetation edge	Planned for future	NCBN Monitoring Program
Foreshore slope	Planned for future	NCBN Monitoring Program
Cross-shore area change	Planned for future	NCBN Monitoring Program
Alongshore area change	Planned for future	NCBN Monitoring Program
Cross-shore volume change	Planned for future	NCBN Monitoring Program
Alongshore volume change	Planned for future	NCBN Monitoring Program
Shoreline position		
Shoreline position	Planned for future	NCBN Monitoring Program
Seagrass (SAV) Distribution		
Seagrass bed size	2000-2004, 2006-2010	VIMS Orth et al., 2009
Seagrass bed structure (cover class)	2000-2004, 2006-2010	NCBN Monitoring Program
Seagrass bed location	2000-2004, 2006-2010	NCBN Monitoring Program
Seagrass (SAV) Condition		
Seagrass density	Planned for future	NCBN Monitoring Program
Seagrass Biomass	Planned for future	NCBN Monitoring Program
Seagrass Canopy height	Planned for future	NCBN Monitoring Program
Seagrass Percent cover	Planned for future	NCBN Monitoring Program
Seagrass Seagrass depth limit	Planned for future	NCBN Monitoring Program
Epiphyte Cover	Planned for future	NCBN Monitoring Program
Grazing	Planned for future	NCBN Monitoring Program
Wasting Index	Planned for future	NCBN Monitoring Program
Water Temperature	Planned for future	NCBN Monitoring Program
Salinity	Planned for future	NCBN Monitoring Program
Light attenuation	Planned for future	NCBN Monitoring Program
Sediment Parameters	Planned for future	NCBN Monitoring Program
Estuarine Nitrogen Loading		
% Natural Vegetation-Nitrogen Inputs	1990	NCBN Monitoring Program
% Impervious Surface-Nitrogen Inputs	1990	NCBN Monitoring Program
% Agriculture-Nitrogen Inputs	1990	NCBN Monitoring Program
% Turf-Nitrogen Inputs	1990	NCBN Monitoring Program
% Wastewater-Nitrogen Inputs	1990	NCBN Monitoring Program
Total Nitrogen Inputs to Estuary	1990	NCBN Monitoring Program
Estuarine Sediment Organic Carbon		
% organic carbon in surficial sediments	TBD	NCBN Monitoring Program

Table 2.8. Summary of current and future National Coastal and Barrier Network vital signs monitoring data.

Measurements	Period	Data source
Estuarine Water Chemistry		
Dissolved oxygen	2005-2008	NCBN Monitoring Program
Water temperature	2005-2008	NCBN Monitoring Program
Salinity	2005-2008	NCBN Monitoring Program
Estuarine Water Quality		
Chlorophyll *a*	2005-2008	NCBN Monitoring Program
Estuarine Water Clarity		
Attenuation of Photosynthetically Available Radiation (PAR)	2005-2008	NCBN Monitoring Program
Turbidity	2005-2008	NCBN Monitoring Program
Salt Marsh Nekton Community Structure		
Nekton species abundance	2008	NCBN Monitoring Program
Nekton species size structure	2008	NCBN Monitoring Program
Invasive animals	2008	NCBN Monitoring Program
Pool/Creek Water salinity	2008	NCBN Monitoring Program
Pool/Creek Water depth	2008	NCBN Monitoring Program
Pool/Creek Water temperature	2008	NCBN Monitoring Program
Other Pool and creek metrics TBD	2008	NCBN Monitoring Program
Salt Marsh Vegetation Community Structure		
Vegetation percent cover	2008	NCBN Monitoring Program
Vegetion species composition	2008	NCBN Monitoring Program
Height of vegetation species of concern (example: *Phragmites*)	2008	NCBN Monitoring Program
Key invasive plant species	2008	NCBN Monitoring Program
Soil salinity	2008	NCBN Monitoring Program
Salt Marsh Sediment Elevation		
Relative elevation	2009	NCBN Monitoring Program
Sediment accretion	2009	NCBN Monitoring Program
Sediment erosion	2009	NCBN Monitoring Program
Shallow subsidence	2009	NCBN Monitoring Program
Salt Marsh Water Table		
Water table level	Planned for future	NCBN Monitoring Program
Visitor Use		
Distribution of visitors	Planned for future	NCBN Monitoring Program
Relative abundance of visitors	Planned for future	NCBN Monitoring Program
Distribution of visitor activity type	Planned for future	NCBN Monitoring Program
Abundance of visitor activity type	Planned for future	NCBN Monitoring Program
Landscape change		
Vegetation community abundance	Planned for future	NCBN Monitoring Program
Vegetation community distribution	Planned for future	NCBN Monitoring Program
Vegetation community patch size	Planned for future	NCBN Monitoring Program
Anderson Classification	Planned for future	NCBN Monitoring Program

Table 2.8. Summary of current and future National Coastal and Barrier Network vital signs monitoring data.

Measurements	Period	Data source
Anthropogenic modifications		
Type of anthropogenic shoreline structures	Planned for future	NCBN Monitoring Program
Location of anthropogenic shoreline structures	Planned for future	NCBN Monitoring Program
Number of anthropogenic shoreline structures	Planned for future	NCBN Monitoring Program
Offshore topography		
Topography metrics TBD	Planned for future	To be determined
Marine Hydrography		
Sea level position	Planned for future	To be determined
Tide range	Planned for future	To be determined
Wave characteristics	Planned for future	To be determined
Air Quality (Acid Deposition)		
Wet Deposition-SO_4^{3-}	2001-2003	NPS Air Resources Division
Wet Deposition-NO_3^-	2001-2003	NPS Air Resources Division
Dry Deposition-NO_3^-	1999-2003	NPS Air Resources Division
Dry Deposition-SO_4^{3-}	1999-2003	NPS Air Resources Division
Air Quality (Ozone)		
5 year average of annual 4th-highest 8-hour ozone concentration	1999-2003	NPS Air Resources Division
Air Quality (Visibility)		
Haze index on clearest days	1999-2003	NPS Air Resources Division
Haze index on haziest days	1999-2003	NPS Air Resources Division
Climate		
Climate Metrics TBD	Planned for future	NPClime

2.4 LITERATURE CITED (CHAPTER 2)

Allen, T.R., Tolvanen, H.T., Oertel, G.F., and MC-Cleod, G.M. 2007. Spatial characterization of environmental gradients in a coastal lagoon, Chincoteague Bay. *Estuaries and Coasts* 30(6): 959-977.

ASIS. 1982. Assateague Island National Seashore, General Management Plan. Assateague Island National Seashore. National Park Service.

ASIS. 2003. Historic Context Study, Waterfowl Hunting Camps for Hunting Lodges Retention Properties, Determination of Eligibility Study. Interview Log of interview of Dennard Conwell "Connie" Purnell by Pat Russell. ID no: NPS. DCP.7-31-03.02.

ASIS. 2007. Visitor Survey. Assateague Island National Seashore. National Park Service.

ASIS. 2008a. Visitor attitudes and experiences associated with the over sand vehicle zone and backcountry camping areas. Assateague Island National Seashore. National Park Service.

ASIS. 2008b. Proposal to create flow paths through the constructed berm at Assateague Island National Seashore. Assateague Island National Seashore. National Park Service.

ASIS. 2010a. Assateague Island National Seashore data repository. In: National Park Service Natural Resource Information Portal. **https://nrinfo.nps.gov/Home.mvc** Accessed December 2010.)

ASIS. 2010b. General hunting regulations. Assateague Island National Seashore. National Park Service. **http://www.nps.gov/asis/upload/09-10%20ASIS%20Hunt%20Plan.pdf** Accessed August 2010.

ASIS. 2010c. Division of Resource Management: FY2008 – FY2012 Strategic Plan, 2010 Work Plan. Assateague Island National Seashore. National Park Service.

ASIS. 2010d. Foundation Statement – Draft. Assateague Island National Seashore. National Park Service.

ASIS. 2010e. ASIS Desired Conditions – Draft. Assateague Island National Seashore. National Park Service.

Beaulac, M.N. and Reckhow, K.H. 1982. An examination of land use – nutrient export relationships. *Water Research Bulletin* 18: 1013-1024.

Biggs, R.B. 1970. The origin and geological history of Assateague Island, Maryland and Virginia. **In:** Natural Resources Institute, University of Maryland. *Assateague Ecological Studies, Part II: Environmental Threats.* Contribution #446, Chesapeake Biological Laboratory, Solomons, Maryland.

Boynton, W. 1970. The commercial fisheries of Chincoteague Bay – past, present and future. **In:** Natural Resources Institute, University of Maryland. *Assateague Ecological Studies, Part I: Environmental Information.* Contribution #446, Chesapeake Biological Laboratory, Solomons, Maryland.

Boynton, W.R., Murray, L., Hagy, J.P., Stokes, C. and Kemp, W.M. 1996. A comparative analysis of eutrophication patterns in a temperate coastal lagoon. *Estuaries* 19(2B): 408-421

Bratton, J.F., Böhlke, J.K., Krantz, D.E. and Tobias, C.R. 2009. Flow and geochemistry of groundwater beneath a back-barrier lagoon: the subterranean estuary at Chincoteague Bay, Maryland, USA. *Marine Chemistry* 113: 78-92.

Bricker, S.B., Clement, C.G., Pirhalla, D.E., Orlando, S.P. and Farrow, D.R.G. 1999. National estuarine eutrophication assessment: effect of nutrient enrichment in the nation's estuaries. National Oceanic and Atmospheric Administration, National Ocean Service, Special Projects Office and the National Ventres for Coastal Ocean Science, Silver Spring, Maryland, USA.

Brinker, D.F., K.E. Duffy, D.M. Whalen, B.D. Watts, and K.M. Dodge. 1997. Autumn migration of northern saw-whet owls (*Aegolius acadicus*) in the Middle Atlantic and Northeastern United States: What observations from 1995 suggest. **In:** Duncan, J.R., D.H. Johnson, and T.H. Nicholls (eds.). *Biology and Conservation of Owls of the Northern Hemisphere.* U.S. Department of Agriculture, Forest Service General Technical Report NC-190.

Burger, J., Gordon, C., Lawrence, J., Newman, J., Forcey, G. and Vlietstra, L. 2011. Risk evaluation for federally listed (roseate tern, piping plover) or candidate (red knot) bird species in offshore waters: a first step for managing the potential impacts of wind facility development on the Atlantic Outer Continental Shelf. *Renewable Energy* 36(1): 338-351

Casey, J. and Doctor, S. 2004. Status of finfish populations in the Maryland Coastal Bays. **In:** *Maryland's Coastal Bays ecosystem health assessment.* MD DNR-12-1202-0009. Chapter 8.2 pp 8/34 – 8/42.

Churchill, J.B., Wood, P.B. and Brinker, D.F. 2000. Diurnal roost characteristics of Northern Saw-whet Owls wintering at Assateague Island, Maryland. *Wilson Bulletin* 112(3): 332-336

Clarke, J.A., Harrington, B.A., Hruby, T. and Wasserman, F.E. 1984. The effect of ditching for mosquito control on salt marsh use by birds in Rowley, Massachusetts. *Journal of Field Ornithology* 55(2): 160-180.

Congress, Senate, Committee on Interior and Insular Affairs,Assateague Island National Seashore, Hearings on S. 20 and S. 1121, 89th Congress, 1st Session, Mar. 17, 18, 19, and 22, 1965, Part 2, pp. 309.

Dillow, J.J.A. and Greene, E.A. 1999. Ground water discharge and nitrate loadings to the coastal bays of Maryland. U.S. Geological Survey water Resources Investigations Report 99-4167, Maryland.

Dillow, J.J.A., W.S.L. Banks, and M.J. Smigaj. 2002. Ground-water quality and discharge to Chincoteague and Sinepuxent Bays adjacent to Assateague Island National Seashore, Maryland. United States Geological Survey. *Water-Resources Investigations Report* 02-4029

Dinsmore, S.J., Collazo, J.A. and Walters, J.R. 1998. Seasonal numbers and distribution of shorebirds on North Carolinas' Outer Banks. *Wilson Bulletin* 110(2): 171-181

Dolan, R., H. Lins, and J. Stewart. 1980. Geographical analysis of Fenwick Island, Maryland, a Middle Atlantic coast barrier island. U.S. Geological Survey, Washington D.C. Professional Paper 1177-A.

Duriscoe, D.M., Luginbuhl, C.B. and Moore, C.A. 2007. Measuring night-sky brightness with a wide-field CCD camera. *Publications of the Astronomical Society of the Pacific* 119 (852): 192-213.

Dueser, R.D., Porter, J.H. and Wieboldt, T.F. 1978. Species-habitat association and succession vectors for small mammal and land bird populations on Assateague Island National Seashore. Final report to National Park Service, Denver Service Center. Department of Environmental Sciences, University of Virginia.

Fertig, B., T.J.B. Carruthers, W.C. Dennison, A.B. Jones, F. Pantus, and B. Longstaff. 2009. Oyster and Macroalgae bioindicators detect elevated del-N15 in Maryland's Coastal Bays. *Estuaries and Coasts* 32: 773-786.

Fisher, J.J. 1967. Origin of barrier island shorelines: Middle Atlantic States. *Geological Society of America, Special Paper* 115: 66-67.

Furbish, C.E. and Albano, M. 1994. Selective herbivory and plant community structure in a mid-Atlantic salt marsh. *Ecology* 75(4): 1015-1022.

Glibert, P.M., Wazniak, C.E., Hall, M.R. and Sturgis, B. 2007. Seasonal and interannual trends in nitrogen and brown tide in Maryland's coastal bays. *Ecological Applications* 17(5): S79-S87.

Hager, P. 1996. Worcester County, MD. **In:** Beidler, K., P. Gant, M. Ramsay, and G. Schultz (eds.) *Proceedings—Delmarva's Coastal Bay watersheds: not yet up the creek.* U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division, Narragansett, Rhode Island, USA. EPA/600/R-95/052.

Hall, S.Z. 2005. Hydrodynamics of freshwater ponds on a siliciclastic barrier island, Assateague Island National Seashore, Maryland. Master of Science thesis, University of Maryland, Easton Shore, Maryland.

Hall, M.R., Cain, C.J., Casey, J.F., Tarnowski, M.L., Wazniak, C.E., Wells, D.W. and Wilson, D.E. 2009. Chapter 10: History and Future. **In:** Dennison, W.C., Thomas, J.E., Cain, C.J., Carruthers, T.J.B., Hall, M.R., Jesien, R.V., Wazniak, C.E. and Wilson, D.E. (eds). *Shifting Sands: environmental and cultural change in Maryland's Coastal Bays.* University of Maryland Center for Environmental Science. IAN Press.

IUCN. 2010. IUCN Red List of threatened species. Version 2010.3. **www.iucnredlist.org** Downloaded on 27 September 2010.

Jesien, R.V., A. Bolinger, D.F. Brinker, J.F. Casey, S.B. Doctor, C.P. Etgen, T.B. Eyler, M.R. Hall, M.L. Hoffman, J.V. Kilian, T.L. Kimmel, M.P. Luisi, R.F. Murphy, M.L. Tarnowski, G.D. Therres, J.E. Thomas, C.E. Wazniak, D.E. Wilson, and C.S. Zimmerman . 2009. Chapter 14: Diversity of Life in the Coastal Bays. **In:** Dennison, W.C., Thomas, J.E., Cain, C.J., Carruthers, T.J.B., Hall, M.R., Jesien, R.V., Wazniak, C.E. and Wilson, D.E. (eds). *Shifting Sands: environmental and cultural change in Maryland's Coastal Bays.* University of Maryland Center for Environmental Science. IAN Press.

Keiper, R.R. 1985. Are sika deer responsible for the decline of white-tailed deer on Assateague Island, Maryland? *Wildlife Society Bulletin* 13: 144-146.

Keiper, R.R. and Keenan, M.A. 1980. Nocturnal activity patterns of feral ponies. *Journal of Mammology* 61(1): 116-118.

Kennish, M.J. 2001. Coastal salt marsh systems in the U.S.: a review of anthropogenic impacts. *Journal of Coastal Research* 17(3): 731-748.

Knisley, C. B. 2007. Distribution and abundance of two rare tiger beetles, Cicindela dorsalis media and C. lepida, at Assateague Island National Seashore in 2006 – final report. National Park Service, Assateague Island National Seashore, Berlin, Maryland.

Knisely, C.B. 2009. Distribution and abundance of two rare tiger beetles, *Cicindela dorsalis media* and *C. lepida*, at Assateague Island National Seashore in 2008. Submitted to Assateague Island National Seashore March 7, 2009.

Koch, F., and C.J. Gobler. 2009. The effects of tidal export from salt marsh ditches on estuarine water quality and plankton communities. *Estuaries* *and Coasts* 32 (2): 261-275.

Koch, E.W. and Orth, R.J. 2003. The seagrasses of the mid-Atlantic coast of the United States. ***In:*** Greene, E.O. and Short, F.T. *World Atlas of Seagrasses.* University of California Press. Berkley, USA. Chapter 21. pp216 – 223

Kochel, R.C. and Wampfler, L.A. 1989. Relative role of overwash and Aeolian processes on washover fans, Assateague Island, Virginia-Maryland. *Journal of Coastal Research* 5(3): 453-475.

Krantz, D.E., C.A. Schupp, C.C. Spaur, J.E. Thomas, & D.V. Wells. 2009. Chapter 12: Dynamic systems at the land-sea interface. **In:** Dennison, W.C., Thomas, J.E., Cain, C.J., Carruthers, T.J.B., Hall, M.R., Jesien, R.V., Wazniak, C.E. and Wilson, D.E. (eds). *Shifting Sands: environmental and cultural change in Maryland's Coastal Bays.* University of Maryland Center for Environmental Science. IAN Press.

Lea, C., Hamilton, H., Hudson, F.K., Roeder, N. 2000. Additions to flora and rare plant surveys and status 1996-1999. Assateague Island National Seashore, Division of Resource Management Report.

Loegering, J.P. and Fraser, J.D. 1995. Affecting Piping Plover chick survival in different brood-rearing habitats. *The Journal of Wildlife Management* 59(4): 646-655.

Mackintosh, B. 1982. Assateague Island National Seashore: An Administrative History. History Division, National Park Service, Washington D.C.

Madsen, P.T., Wahlberg, M., Tougaard, J., Lucke, K. and Tyack., P. 2006. Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. *Marine Ecology Progress Series* 309: 279-295.

Mallin, M.A. and Cahoon, L.B. 2003. Industrialized animal production – a major source of nutrient and microbial pollution to aquatic ecosystems. *Population and Environment* 24(5): 369-385.

Maryland Natural Heritage Program. 2010. Rare, Threatened and Endangered Plants of Maryland. April 2010 edition. Maryland Department of Natural Resources, Wildlife and Heritage Service, Annapolis, Maryland.

Murphy, R.F., and Secor, D.H. 2006. Fish and blue crab assemblage structure in a U.S. mid Atlantic coastal lagoon complex. *Estuaries and Coasts* 29(6B):1121-1131.

Najjar, R.G., Walker, H.A., Anderson, P.J., Barron, E.J., Bord, R.J., Gibson, J.R., Kennedy, V.S., Knight, C.G., Megonigal, J.P., O'Connor, R.E., Polsky, C.D., Psuty, N.P., Richards, B.A., Sorenson, L.G., Steele, E.M. and Swanson, R.S. 2000. The Potential impacts of climate change on the mid-Atlantic coastal region. *Climate Research* 14(3): 219-233.

National Park Service. 1955. "A Report on a Seashore Recreation Area Survey of the Atlantic and Gulf Coasts," pp. 106—07.

National Park Service. 2002. "Assateague Island National Seashore, Personal Watercraft Use." 36 CFR Part 7, From the Federal Register Online via GPO Access [**wais.access.gpo.gov**]

National Park Service. 2008. Environmental Assessment of alternatives for managing the feral horses on Assateague Island National Seashore. Assateague Island National Seashore. U.S. Department of the Interior.

National Park Service. 2009. Air quality in national parks: annual performance and progress report. National Park Service, Department of the Interior. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266

Orth, R.J., Wilcox, D.J., Whitey, J.R., Nagey, L.S., Owens, A.L. and Kenne, A.K. 2010. 2009 Distribution of submerged aquatic vegetation in Chesapeake Bay and Coastal Bays. *Special Scientific Report* #152. Virginia Institute of Marine Science.

Patton, T. 2005. Listen to the Voices, Follow the Trails: Discovering Maryland's Seaside Heritage. Penned, Ink, LLC. Indianapolis, Indiana.

Pendleton, E.A., S.J. Williams, and E.R. Thieler. 2004. Coastal Vulnerability Assessment of Assateague Island National Seashore (ASIS) to Sea-Level Rise. U.S. Geological Survey Open-File Report 2004-1020.

Petrocci, C. 2005. Personal communication. Cultural heritage consultant, Chincoteague Island, Virginia, U.S.A.

Portnoy, J.W., 1999. Salt marsh diking and restoration: Biogeochemical implications of altered wetland hydrology. *Environmental Management* 24(1): 111-120.

PRITCHARD,D. W. 1960. Salt balance and exchange rate for Chincoteague Bay. *Chesapeake Science* 1 :48-57.

Public law 89-195. September 21, 1965. 79 Stat. 824.

Public law 94-578. September 3, 1976. 90 Stat. 2732.

Public law 88-57. September 3, 1964. 78 Stat. 890.

Rice, D., Rooth, J. and Stevenson, J.C. 2000. Colonization and expansion of Phragmites australis in upper Chesapeake Bay tidal marshes. *Wetlands* 20(2): 280-299.

Rountree, H.C. & T.E. Davidson. 1997. Eastern

Shore Indians of Virginia and Maryland. University of Virginia Press, Charlottesville, Virginia.

Schupp, C.A., Bass, G.P., and Grosskopf, W.G. 2007. Sand bypassing restores natural processes to Assateague Island National Seashore. **In:** Kraus, N.C. and Rosati, J.D. (Eds.). *Proceedings of Coastal Sediments '07.* Reston, VA: ASCE, pp. 1340-1353.

Seliskar, D.M. 2003. The response of *Ammophilab revigulata* and *Spartina patens* (Poaceae) to grazing by feral horses on a dynamic mid-Atlantic barrier island. *American Journal of Botany* 90(7): 1038-1044.

Stalter, R. and Lamont, E.E. 1990. The vascular flora of Assateague Island, Virginia. *Bulletin of the Torrey Botanical Club* 117 (1): 48-56.

Stauble, D.K., A.W. Garcia, N.C. Kraus, W.G. Grosskopf, and G.P. Bass. 1993. Beach Nourishment Project Response and Design Evaluation: Ocean City, Maryland, Report 1, 1988-1992. USAE Waterways Experiment Station, Vicksburg, Mississippi. Technical Report CERC-93-13.

Sturm, M. 2007. Assessment of the effects of feral horses, sika deer and white-tailed deer on Assateague Island's forest and shrub habitat. Assateague Island National Seashore, National Park Service.

Sturm, M. 2008. Saving the Seabeach Amaranth. *Park Science* 25(1).

Tarnowski, M.L. 1997. Oyster populations in Chincoteague Bay. In: Homer, M.L., Tarnowski, M.L., Bussell, R. and Rice, C. (eds). Coastal Bays Shellfish Inventory. Final report to Coastal Zone Management Division, Maryland Department of Natural Resources, Contract No. 14-96-134-CZM010, Grant No. NA570z0301. Annapolis, Maryland.

Thornberry-Ehrlich, T.L. 2005. Assateague Island National Seashore Geologic Resource Management Issues Scoping Summary. Colorado State University, Geologic Resource Evaluation. Summary of scoping meeting July 26-28, 2005.

Tiner, R.W., M. Starr, H. Berguist, and J. Swords. 2000. Watershed-based Wetland Characterization for Maryland's Nanticoke River and Coastal Bays Watersheds. National Wetland Inventory (NWI) Technical Report. U.S. Fish and Wildlife Service, NWI Program, Ecological Services, Region 5, Hadley, Massachusetts. Prepared for the Maryland Department of Natural Resources, Annapolis, Maryland.

Toscano, M.A. R.T. Kerhin, L.L. York, T.M. Cronin, & S.J. Williams. 1989. Quarternary Stratigraphy of the Inner Continental Shelf of Maryland. Maryland Geological Survey Report of Investigation 50, Baltimore, Maryland.

Truitt, R.V. 1971. Assateague, the Place Across: A Saga of Assateague Island. National Resources Institute, University of Maryland Educational Series no. 90, College Park, Maryland.

Tyndall, R.W., Tamsey, S. and Lea, C. 2000. The federally threatened *Amaranthus pumilus* Raf. (seabeach amaranth, Amaranthaceae) rediscovered on Assateague Island after 31 years. *Castanea* 65(2):165-167.

Udall, S. L. letter to Sen. Henry M. Jackson, Mar. 15, 1965a. in Senate Report 331, 89th Congress, 1st Session, June 15, 1965.

Udall, S.L. interview, 1965b. U.S., Congress, House, Committee on Interior and Insular Affairs, Assateague Island National Seashore, Hearings on H.R. 2701 et al., July 22, 23, and Aug. 16, 1965.

U.S. Fish and Wildlife Service. 1985. Endangered and threatened wildlife and plants; determination of endangered and threatened status for the piping plover: Final Rule. Federal Register 50(238) 50726-50734.

U.S. Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants; determination of seabeach amaranth (*Amaranthus pumilus*) to be a threatened species. Federal Register 58(65) 18035-18042.

USGS. 1999. 1998 Assateague Island Northeasters Impact Studies. 1999. USGS Center for Coastal Geology. Retrieved June 3, 2004 from **http://coastal.er.usgs.gov/hurricanes/assateague**

Wahlberg, M. and Westerberg, H. 2005. Hearing of fish and their reactions to sounds from offshore wind farms. *Marine Ecology Progress Series* 288:295-309.

Wazniak, C.E., Hall, M.R., Carruthers, T.J.B., Sturgis, B., Dennison, W.C. and Orth, R.J. 2007. Linking water quality to living resources in a mid-Atlantic lagoon system, USA. *Ecological Applications* 17(5S): 64-78.

Wilson, D.E., C.E. Wazniak, D.M. Boward, T.J.B. Carruthers, R.J. Chalmers, D.H. Clearwater, W.C. Dennison, A.B. Hairston-Strang, M.R. Hall, F.M. Irani, R.V. Jesien, W.M Knapp, E.W. Koch, K.L. Kyde, A.E. Luscher, M.D. Naylor, R.J. Orth, C.C. Spaur, M.L. Tarnowski, E.C. Wicks, and C.S. Zimmerman. 2009. Habitats of the Coastal Bays and Watershed. **In:** Dennison, W.C., J.E. Thomas, C.J. Cain, T.J.B. Carruthers, M.R. Hall, R.V. Jesien, C.E. Wazniak, & D.E. Wilson. *Shifting Sands: Environmental & Cultural Change in Maryland's Coastal Bays.* IAN Press, Cambridge, Maryland.

Zimmerman, Carl. 2004. "Executive Summary – North End Restoration". Assateague Island National Seashore, Resource Management Division.

Photo: Tim Carruthers, IAN Image Library

Chapter 3: Study approach

3.1 PRELIMINARY SCOPING

3.1.1 Park involvement

Preliminary scoping for the assessment of Assateague Island National Seashore began in December 2008. Archived data for park resources are organized into an electronic library, comprised of management reports, hard data files, and geospatial data (GIS), which provided the primary and main source of data resources (ASIS, 2010). Planning and exchange of data occurred through a series of meetings with park staff from Assateague Island National Seashore, the NPS Northeast and Coastal Barrier Network (NCBN) Inventory and Monitoring (I&M) Program, Regional NPS staff, and the University of Maryland Center for Environmental Science Integration and Application Network (UMCES-IAN) (Table A-1). Additional datasets were obtained from the Maryland Coastal Bays Program (MCBP), Virginia Institute of Marine Science (VIMS), EcoCheck (UMCES), the NPS GIS Division, the NPS Air Resources Division and Maryland Geological Survey.

Regular conference calls and meetings helped define seven key habitat types to include in the assessment, and Park staff helped identify key indicators to assess natural resource condition in each habitat. Oral history interviews at the park also helped provide the context of current conditions and background information not necessarily available in published form, or forthcoming in a formal meeting structure. Follow-up phone calls and emails developed metrics and interpretation of key findings and trends. In conjunction with ongoing monitoring and research, efforts were made to integrate metrics from the I&M Vital Signs monitoring program and the NPS Air Resources Division into this assessment.

Strong collaboration with park natural resource staff was essential to the success of this assessment, and key park staff invested significant time to assist in the development of reference conditions, calculation of novel metrics and interpretation of calculated results. This discourse resulted in several attempts to develop metrics based on limited or fragmented datasets that were ultimately not used, mostly because it was eventually decided that confidence in the data was just not high enough to warrant inclusion.


Photo: NPS ASIS

Ozone and weather station at Assateague Island National Seashore.

3.2 STUDY DESIGN

3.2.1 Indicator framework

Recognizing the large amount of data included in this assessment compiled from the Park's monitoring and stewardship activities, as well as other sources, the framework utilized for presenting assessment data in chapter 4 was the Vital Signs categorization developed by NPS I&M (Fancy et al., 2008). Metrics included in this assessment were sorted into their respective Vital Signs categories so that they could be utilized in future studies. Fancy et al., (2008) identified a key challenge of such large-scale monitoring programs to be the development of information products which integrate and translate large amounts of complex scientific data into highly aggregated metrics for communication to policy-makers and non-scientists. Aggregated indices were developed and presented within the current natural resource assessment for Assateague Island National Seashore.

3.2.2 Reporting areas

A habitat framework was used to assess the natural resource condition Assateague Island National Seashore. Recognizing that many ecological classification systems exist, many of which are based on vegetation communities (Anderson et al., 1998, Grossman et al., 1998) or land cover (Anderson et al., 1976). The International Union for Conservation of Nature (IUCN) habitat classification system was used to provide a foundation for the delineation of habitats in this assessment. In the initial workshop with the Park and other NPS staff, all were asked to identify habitats within the Park. This list provided the basis of discussions to ensure that essential ecological characteristics could be identified (resulting in a greater number of habitats) and that management and monitoring goals would be reflected (lesser number of habitats). Meeting participants came to a consensus of seven predominant ecological habitat types within Assateague Island National Seashore: bayside subtidal and mudflats, salt marsh, inland wetlands, forest and shrubland, dunes and grassland, beach and intertidal, and Atlantic subtidal. This classification system has a high-enough level of classification to permit comparisons to other systems (i.e., formation class or Anderson level one) while also being coarse enough to assess the condition of each habitat with data that is anticipated or already available. Vegetation types delineated by GIS data layers were used to classify regions into these habitats.

Habitats were delineated using the 1993 Vegetation Classification of the Maryland portion of Assateague Island National Seashore and the 1995 Vegetation Classification of the Virginia portion (Table 3.1). These GIS layers were derived from aerial photography and represented a single probable vegetation alliance within each polygon. Once a file was merged to comprise both states, the species-specific classifications were further summarized into more general land cover categories (i.e. mixed forest, grassland) and later further summarized into the seven final habitat groupings. Polygons that had been delineated as containing invasive herbaceous species were merged with the adjacent land cover category.

3.2.3 General approach and methods

The general approach taken to assess natural resource condition was to; determine indicators appropriate to inform current status within each habitat, establish a reference condition for each indicator, and then assess the percentage attainment of reference condition. Details of approach, background and justification are provided on a metric by metric basis in chapter 4. Once attainment was calculated for each indicator, an unweighted mean was calculated to determine the condition for each habitat and then similarly to combine habitats to calculate an overall park assessment. To present the current status in context, a conceptual framework of desired and degraded condition of each habitat was developed, based on the series of indicators identified as informing current condition within each habitat. These are presented in Chapter 5.

3.3 LITERATURE CITED (CHAPTER 3)

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. U.S. Geological Survey, Reston, VA ,Professional Paper 964.

Anderson, M., P. Bourgeron, M.T. Bryer, R. Crawford, L. Engelking, D. Faber-Langendoen, M. Gallyoun, K. Goodin, D.H. Grossman, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, L. Sneddon, and A.S. Weakley. 1998. International classification of ecological communities: Terrestrial vegetation of the United States. In: Volume II. The National Vegetation Classification System: List of types. The Nature Conservancy, Arlington, VA.

ASIS. 2010a. Assateague Island National Seashore data repository. In: National Park Service Natural Resource Information Portal. **https://nrinfo.nps.gov/Home.mvc** Accessed December 2010.)

Fancy, S.G., J.E. Gross, and S.L. Carter. 2008. Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment*: Electronically published May 29, 2008.

Grossman, D.H., D. Faber-Langendoen, A.S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International classification of ecological communities: Terrestrial vegetation of the United states. Volume I. The National Vegetation Classification System: development, status, and applications. The Nature Conservancy. Arlington, VA.

Table 3.1. Summary of major habitat classifications and data layers used in the classification of this assessment.

IUCN class	Habitat type	MD 1993 ASIS Vegetation Map Designation	MD 1993 ASIS Vegetation Map Designation
17 Other	Beach	Naturally occurring Unvegetated areas	Unvegetated / Build Up Area
1. Forest	Forest / Shrubland	*Prunus serotina / Myrica cerifera / Smilax rotundifolia* Forest	Cherry/Serviceberry / Oak
		Pinus taeda / Hudsonia tomentosa Woodland	Loblolly Pine Forest
		Pinus taeda / Myrica cerifera / Osmunda regalis Forest *Pinus taeda / Myrica cerifera / Vitis rotundifolia* Forest	Loblolly Pine Woodland Loblolly Pine / Oak Forest
			Standing Dead Trees
			Water Oak Forest
3. Shrubland	Forest / Shrubland	*Baccharis halimifolia - Iva frutescens / Spartina patens* Shrubland	Groundsel / Ivy Shrub
		Myrica (cerifera, pensylvanica) - Vaccinium corymbosum Shrubland	Myrtle/ Bayberry / Blueberry
		Myrica cerifera - Baccharis halimifolia / Spartina patens Shrubland	Wax Myrtle Shrub
		Myrica cerifera / Hydrocotyle spp. Shrubland	Bayberry Shrub
		Myrica pensylvanica / Schizachyrium scoparium ssp. littorale - Eupatorium hyssopifolium Sparse Shrubland	Wax Myrtle / Groundsel Shrub
		Smilax glauca - Toxicodendron radicans Shrubland	
4. Grassland	Grassland	*Ammophila breviligulata - Panicum (amarum, amarulum)* Herbaceous vegetation	Beach Heather
		Undifferentiated dry grasses	Dry Grass
		Spartina patens - Scirpus pungens - Solidago sempervirens (Upland) Herbaceous vegetation	Fimbristylis / Three-square
		Panicum virgatum / Spartina patens Herbaceous vegetation	Panicum
		Hudsonia tomentosa / Panicum (amarum, amarulum) Dwarf-shrubland	American Beachgrass
		Dead vegetation	
16. Other	Phragmites	*Phragmites australis* Herbaceous vegetation	Phragmites
5. Wetlands (Inland)	Inland Wetlands	*Typha angustifolia - Hibiscus moscheutos* Herbaceous vegetation	Wetland Plants
12. Marine Intertidal	Salt Marsh	*Juncus roemerianus* Herbaceous vegetation	Needle Rush
		Salicornia spp. - Sarcocornia perennis - Spartina alterniflora Herbaceous vegetation	Saltwort
		Scirpus pungens / Fimbristylis castanea Herbaceous vegetation	Saltmarsh Fleabane
		Spartina alterniflora / Ascophyllum nodosum Herbaceous vegetation	Saltmarsh Cordgrass
			BacopaDwarf Spikerush
			Saltmeadow Hay / Three-square
			Saltmeadow Hay / Saltgrass
12. Marine Intertidal	Bayside Intertidal / Mudflats	Algae - (Mixed Fines Alliance)	Mudflats
10. Marine Oceanic	Atlantic or Bayside Subtidal / Intertidal	Water	Water

Photo: NPS ASIS

4.1 AIR QUALITY

4.1.1 Wet nitrogen deposition

Relevance and context

During the 1940's and 1950's it was recognized in the United States and Britain that emissions from coal burning and large scale industry such as power plants and steel mills was causing severely degraded air quality in major cities. This resulted in severe human health impacts, and by the early 1970's the US EPA had established the National Ambient Air Quality Standards (NAAQS) (Porter and Johnson, 2007). Since 1970, in addition to human health effects, it was increasingly recognized that there were significant ecosystem impacts of atmospheric nitrogen deposition, including acidification and nutrient fertilization of waters and soils (NPS ARD, 2010). These impacts included such measurable effects as the disruption of nutrient cycling, changes to vegetation structure, loss of stream biodiversity, and the eutrophication of streams and coastal waters (Driscoll et al., 2001; Porter and Johnson, 2007).

Method

Data used for the assessment was interpolated between 2003 and 2007 for the central point within Assateague Island National Seashore, and supplied by NPS Air Resources Division (Table 4.19, 4.20; NPS ARD, 2010). There is currently only one assessment point for the Seashore so this value was assessed against the reference condition, either attaining or failing to attain this threshold value. To assess trends, data from National Atmospheric Deposition Program (NADP) was used for two sites, one on the seashore (MD 18) with data since 2000 and, to get a longer record, a second site at Wye Mills on the eastern shore of Maryland (MD 13) with data record from 1984 (Figure 4.1; http://nadp.sws.uiuc.edu/sites/ntnmap.asp).

Reference condition

The reference condition for total nitrogen wet deposition is ecological. Natural

Figure 4.1. Regional air quality monitoring sites for wet deposition of nitrogen, sulfate, and ozone. Data for 2003-2005 were interpolated by NPS I&M Network to estimate mean concentrations for Assateague Island National Seashore.

background total nitrogen deposition in the east of the US is 0.5 kg ha^{-1} yr^{-1} which equates to a wet deposition of approximately 0.25 kg ha^{-1} yr^{-1} (Porter and Morris, 2007; NPS ARD, 2010). Some sensitive ecosystems, such as coastal and estuarine waters, and upland areas, show responses to wet nitrogen deposition rates of 1.5 kg ha^{-1} y^{-1}, while there is no evidence of ecosystem harm at deposition rates less than 1 kg ha^{-1} y^{-1} (Fenn et al., 2003). NPS Air Resources Division has established wet nitrogen deposition guidelines as <1 kg ha^{-1} y^{-1} indicating good condition, 1-3 kg ha^{-1} y^{-1} indicating moderate, and >3 kg ha^{-1} y^{-1} indicating significant concern. For the current assessment the most conservative category of <1 kg ha^{-1} y^{-1} was used as the ecological threshold (NPS ARD, 2010).

Current condition

Interpolated wet nitrogen deposition for the Seashore between 2003-2007 was 4.5 kg ha^{-1} y^{-1} which fails the ecological threshold of no known effect (0% attainment) and indicates significant concern (Table 4.19, 4.21; NPS ARD, 2010).

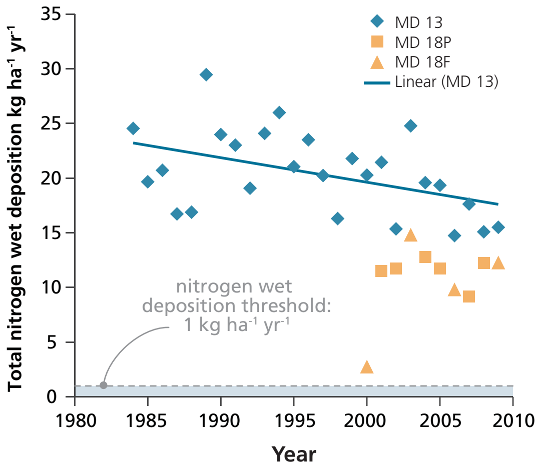


Figure 4.2. Wet deposition of total nitrogen within the Seashore (MD 18) and at Wye Mills on the eastern shore of Maryland (MD 13) (linear regression for MD 13 r2=0.2050, p=0.02, y=469.12-0.2247x). MD 18 P passed NADP sampling criteria, 18F did not pass NADP sampling criteria.

Trend

Wet nitrogen deposition within Assateague Island National Seashore over the past decade has shown no trend, however Wye Mills, on the eastern shore of Chesapeake Bay has a longer data record and has shown a significant downward trend since 1984 (Figure 4.2). This trend reflects US wide reductions in emissions over the past decades (Driscoll et al., 2001), and is consistent with reducing trends in most parks in the eastern US (NPS ARD, 2010), however clearly shows that large reductions in nitrogen wet deposition are still required to reduce negative impacts on natural resource condition and a clear set of ecosystem thresholds is required (Porter and Johnson, 2007).

Data gaps and confidence in assessment

Assateague Island National Seashore has only recently been included in the national assessment of park units by Air Resources Division and has not yet been included in the country wide trends analyses of park units. However, long term monitoring of wet total nitrogen deposition in the park was commenced in 2000, so with continued monitoring at MD 18 (within the Seashore) and incorporation of the Seashore into ARD reporting, future assessments will be able to provide a stronger assessment of trends. Confidence in the current assessment of condition was high and in the current assessment of trend was fair.

Sources of expertise

Air Resources Division, National Park Service; http://www.nature.nps.gov/air/

National Atmospheric Deposition Program; http://nadp.sws.uiuc.edu/

Ellen Porter, NPS biologist with the Air Resources Division, research and monitoring branch

Holly Salazer, NPS air resources coordinator for the Northeast Region

Literature cited

Driscoll, C.T., Lawrence, G.B., Bulger, A.J., Butler, T.J., Cronan, C.S., Eagar, C., Lambert, K.F., Likens, G.E., Stoddard, J.L. and Weathers, K.C. 2001. Acidic deposition in the northeastern United States: sources and inputs, ecosystem effects, and management strategies. *Bioscience* 51(3): 180-198.

Fenn, M.E., R. Haeuber, G.S. Tonnesen, J.S. Baron, S. Grossman-Clarke, D. Hope, D.A. Jaffe, S. Copeland, L. Geiser, H.M. Rueth, and J.O. Sickman. 2003. Nitrogen emissions, deposition, and monitoring in the Western United States. *BioScience* 53(4): 391-403.

National Park Service, Air Resources Division. 2010. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado.

Porter, E. and Johnson, S. 2007. Translating science into policy: using ecosystem thresholds to protect resources in Rocky Mountain National Park. *Environmental Pollution* 149: 268-280.

Porter, E., Morris, K. 2007. Wet Deposition Monitoring Protocol: Monitoring Atmospheric Pollutants in Wet Deposition. Natural Resource Technical Report NPS/NRPC/ARD/NRTR—2007/004. National Park Service, Fort Collins, Colorado.

4.1.2 Wet sulfate deposition

Relevance and context

Emissions of SO_2 in the US increased from nine million metric tons in 1900 up to 28.8 million metric tons by 1973, with some 60% of these emissions coming from electric utilities and 41% coming from the seven Midwest states centered on the Ohio Valley (Driscoll et al., 2001). Largely as a result of the clean air act, emissions of SO_2 had reduced to 17.8 million metric tons by 1996, and while large areas of the eastern US had annual sulfur wet deposition loads > 30 kg ha^{-1} yr^{-1} over the period 1983-1985, these areas were mostly < 25 kg ha^{-1} yr^{-1} by the period 1995-1997 (Driscoll et al., 2001). Once in the atmosphere, SO_2 is highly mobile and can be transported distances greater than 500 km (311 miles) (Driscoll et al., 2001).

Method

Data used for the assessment was interpolated between 2003 and 2007 for the central point within Assateague Island National Seashore, and supplied by NPS Air Resources Division (Table 4.19, 4.20; NPS ARD, 2010). There is currently only one assessment point for the Seashore so this value was assessed against the reference condition, either attaining or failing to attain this threshold value. To assess trends, data from National Atmospheric Deposition Program (NADP) was used for two sites, one on the seashore (MD 18) with data since 2000 and, to get a longer record, a second site at Wye Mills on the eastern shore of Maryland (MD 13) with data record from 1984 (Figure 4.1; http://nadp.sws.uiuc.edu/sites/ntnmap.asp).

Reference condition

The reference condition for wet sulfate deposition is ecological. Natural background sulfur deposition in the east of the US is 0.5 kg ha^{-1} yr^{-1} which equates to a wet deposition of approximately 0.25 kg ha^{-1} yr^{-1} (Porter and Morris, 2007; NPS ARD, 2010). NPS Air Resources Division has established wet sulfate deposition guidelines as <1 kg ha^{-1} y^{-1} indicating good condition, 1-3 kg ha^{-1} y^{-1} indicating moderate, and >3 kg ha^{-1} y^{-1} indicating significant concern.

Photo: Adrian Jones, IAN Image Library

Chalk Point power plant.

For the current assessment the most conservative category of <1 kg ha^{-1} y^{-1} was used as the ecological threshold (NPS ARD, 2010).

Current condition

Interpolated wet sulfate deposition for the Seashore between 2003-2007 was 5.41 kg ha^{-1} y^{-1} which fails the ecological threshold of no known effect (0% attainment) and indicates significant concern (Table 4.21; NPS ARD, 2010).

Trend

Wet sulfate deposition within Assateague Island National Seashore over the past decade has shown no trend, however Wye Mills, on the eastern shore of Chesapeake Bay has a longer data record and has shown a significant downward trend since 1984 (Figure 4.3). This trend reflects US wide reductions in emissions over the past decades (Driscoll et al., 2001), and is

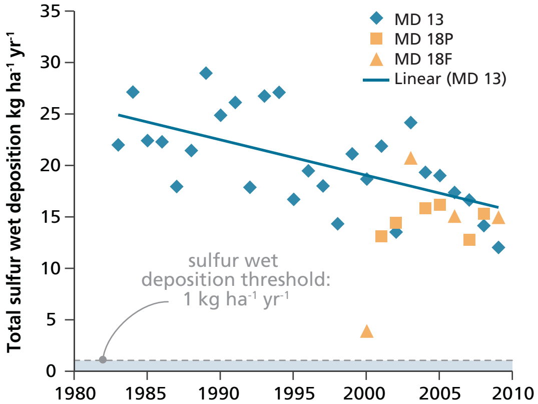


Figure 4.3. Sulfur wet deposition within the Seashore (MD 18) and at Wye Mills on the eastern shore of Maryland (MD 13) (linear regression for MD 13 r2=0.3626; p<0.01; y=714.23-0.3477x). MD 18 P passed NADP sampling criteria, 18F did not pass NADP sampling criteria.

consistent with reducing trends in most parks in the eastern US (NPS ARD, 2010), however clearly shows that large reductions in sulfur wet deposition are still required to reduce negative impacts on natural resource condition.

Data gaps and confidence in assessment

Assateague Island National Seashore has only recently been included in the national assessment of park units by Air Resources Division and has not yet been included in the country wide trends analyses of park units. However, long term monitoring of wet sulfate deposition in the park was commenced in 2000, so with continued monitoring at MD 18 (within the Seashore) and incorporation of the Seashore into ARD reporting, future assessments will be able to provide a stronger assessment of trends. Confidence in the current assessment of condition was high and in the current assessment of trend was fair.

Sources of expertise

Air Resources Division, National Park Service; http://www.nature.nps.gov/air/

National Atmospheric Deposition Program; http://nadp.sws.uiuc.edu/

Ellen Porter, NPS biologist with the Air Resources Division, research and monitoring branch

Holly Salazer, NPS air resources coordinator for the Northeast Region

Literature cited

Driscoll, C.T., Lawrence, G.B., Bulger, A.J., Butler, T.J., Cronan, C.S., Eagar, C., Lambert, K.F., Likens, G.E., Stoddard, J.L. and Weathers, K.C. 2001. Acidic deposition in the northeastern United States: sources and inputs, ecosystem effects, and management strategies. *Bioscience* 51(3): 180-198.

National Park Service, Air Resources Division. 2010. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado.

Porter, E., Morris, K. 2007. Wet Deposition Monitoring Protocol: Monitoring Atmospheric Pollutants in Wet Deposition. Natural Resource Technical Report NPS/NRPC/ARD/NRTR—2007/004. National Park Service, Fort Collins, Colorado.

4.1.3 Ozone

Relevance and context

Ozone is a secondary atmospheric pollutant, so is not directly emitted, but is formed by a sunlight driven chemical reaction on nitrous oxides and volatile organic compounds emitted largely from burning fossil fuels (Haagen-Smit and Fox, 1956). In humans, ozone can cause a number of health-related issues such as lung inflammation and reduced lung function, which can result in hospitalization. Concentrations of 0.12 ppm can be harmful with only short exposure during heavy exertion such as jogging, while similar symptoms can occur from prolonged exposure to concentrations of 0.08 ppm Ozone (McKee et al., 1996). One study on 28 plant species, in which plants were exposed for between three and six weeks, showed foliar impacts including premature defoliation in all species at ozone concentrations between 0.06 and 0.09 ppm (Kline et al., 2008). This suggests that a specific plant-based ecological threshold would likely be lower than the regulatory 0.075 ppm (Kline et al., 2008).

Method

Data used for the assessment was interpolated as the five-year average of the fourth-highest daily maximum eight-hour average ozone concentration measured at each monitoring station, between 2003 and 2007, for the central point within Assateague Island National Seashore, and supplied by NPS Air Resources Division (Table 4.19, 4.20; NPS ARD, 2010). There is currently only one assessment point for the Seashore so this value was assessed against the reference condition, either attaining or failing to attain this threshold value. For assessment of trends, regional data for the ten year trends in the fourth highest daily maximum eight hour ozone concentration was used (NPS ARD, 2010).

Reference condition

The reference condition and threshold for ozone is both regulatory and ecological. Ground-level ozone is regulated under the Clean Air Act and the U.S. EPA is required to set standard concentrations for ozone (U.S. EPA, 2004a). In 1997, the ozone threshold was set by the National Ambient

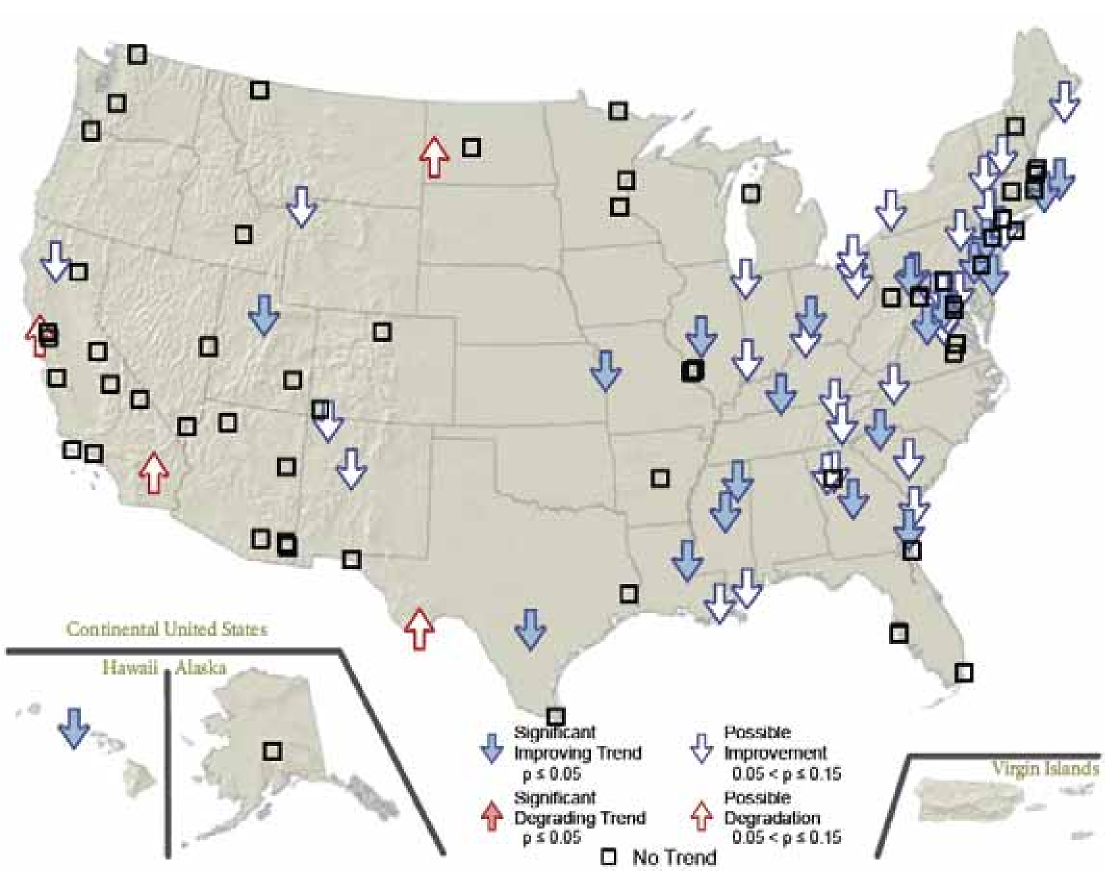


Figure 4.4. Trends in annual 4th-highest 8-hour ozone concentration, 1999–2008 (NPS ARD, 2010).

Air Quality Standards (NAAQS) as 0.08 ppm for the three year average annual 4th highest daily maximum 8-hour ozone concentrations (U.S. EPA, 2006a). This was lowered to 0.075 ppm (NAAQS, 2008), with a current proposal for further reduction to an acceptable range of 0.060-0.070 ppm (60-70 ppb) (Federal Register, 2010). Both are incorporated into the benchmarks to assess ozone condition within National Park units by the NPS Air Resources Division for interpolated five year average 4th highest daily maximum 8-hour ozone concentration (NPS ARD, 2010). Concentrations ≥76 ppb are considered as of significant concern, concentrations between 61-75 ppb as in moderate condition and concentrations ≤60 ppb (set as 80% of the standard concentration limit) as in good condition (NPS ARD, 2010). The 80% value (60 ppb) was used as the reference condition or threshold in this assessment.

Current condition

Interpolated 4th highest daily maximum 8-hour ozone concentration for the Seashore between 2003-2007 was 82.93 ppb which fails the ecological threshold (0% attainment) and indicates significant concern (Table 4.21; NPS ARD, 2010).

Trend

A country wide assessment of 10 year trends in ozone concentration within 159 National Park units found that in the eastern US no park units are showing a significant or possible declining trend, with many parks showing no trend but a majority showing significant or possible improvement in atmospheric ozone concentration (Figure 4.4; NPS ARD, 2010).

Key data gaps and confidence in assessment

Assateague Island National Seashore has only recently been included in the national assessment of park units by Air Resources Division and has not yet been included in the country wide trends analyses of park units for ozone. Confidence in the current assessment of condition was high and in the current assessment of trend was fair.

Sources of expertise

Air Resources Division, National Park Service; http://www.nature.nps.gov/air/

Ellen Porter, NPS biologist with the Air Resources Division, research and monitoring branch

Holly Salazer, NPS air resources coordinator for the Northeast Region

Literature cited

Federal Register Vol 75 No. 11, 40 CFR Parts 50 and 58, National Ambient Air Quality Standards for Ozone, Proposed Rules, January 19, 2010, p2938.

Haagen-Smit, A.J. and Fox, M.M. 1956. Ozone formation in photochemical oxidation of organic substances. Industrial and Engineering Chemistry 48(9): 1484-1487

Kline, L.J., Davis, D.D., Skelly, J.M., Savage. J.E. and Ferdinand, J. 2008. Ozone sensitivity of 28 plants selections exposed to ozone under controlled conditions. Northeastern Naturalist 15(1): 57-66.

McKee, D.J., V.V. Atwell, H.M. Richmond, W.P. Freas, and R.M. Rodriguez. 1996. Review of national ambient air quality standards for ozone, assessment of scientific and technical information. OAQPS Staff Paper. EPA-452/R-96-007.

NAAQS. 2008. National Ambient Air Quality Standards. **http://www.epa.gov/air/criteria.html#6**

National Park Service, Air Resources Division. 2010. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado.

U.S. EPA. 2004a. The Clean Air Act. Washington United States Environmental Protection Agency, Washington D.C. **http://epw.senate.gov/envlaws/cleanair.pdf**

U.S. EPA. 2006a. Air Quality Criteria for Ozone and Related Photochemical Oxidants. Volume I of III. EPA 600/R-05/004aF.

4.1.4 Visibility

Relevance and context

The presence of sulfates, organic matter, soot, nitrates, and soil dust all impair visibility, however the major cause of reduced visibility in the eastern US is sulfate particles formed from the SO2 of coal combustion (National Research Council 1993). The Clean Air Act includes visibility as one of its national goals as an indicator of emissions related to broader air quality degradation linked to human health impacts (U.S. EPA, 2004a).

Method

Data used for the assessment was an interpolation of 2003 through 2007 haze index, for the central point within Assateague Island National Seashore, and supplied by NPS Air Resources Division (Table 4.19, 4.20; NPS ARD, 2010). The haze index in deciviews (dv) indicates the difference between current group 50 (mean of the 40th – 60th percentile data) visibility and the natural group 50 visibility (estimated visibility in the absence of human caused visibility impairment) (U.S. EPA, 2003; NPS ARD, 2010). There is currently only one assessment point for the Seashore so this value was assessed against the reference condition, either attaining or failing to attain this threshold value. For assessment of trends, regional data for the ten year trends was used (NPS ARD, 2010).

Reference condition

The reference condition for visibility is regulatory as it estimates progress made towards preventing visibility impairment in the nation's largest parks and wilderness areas, known as the "Class I" areas (NPS, 2007a). A calculated haze index where the visibility is ≥8 dv above a natural visibility condition are considered of significant concern, concentrations between 2-8 dv above a natural visibility condition as in moderate condition and concentrations ≤ 2 dv above a natural visibility condition as in good condition (NPS ARD, 2010). The good condition, ≤ 2 dv, was used as the reference condition or threshold in this assessment.

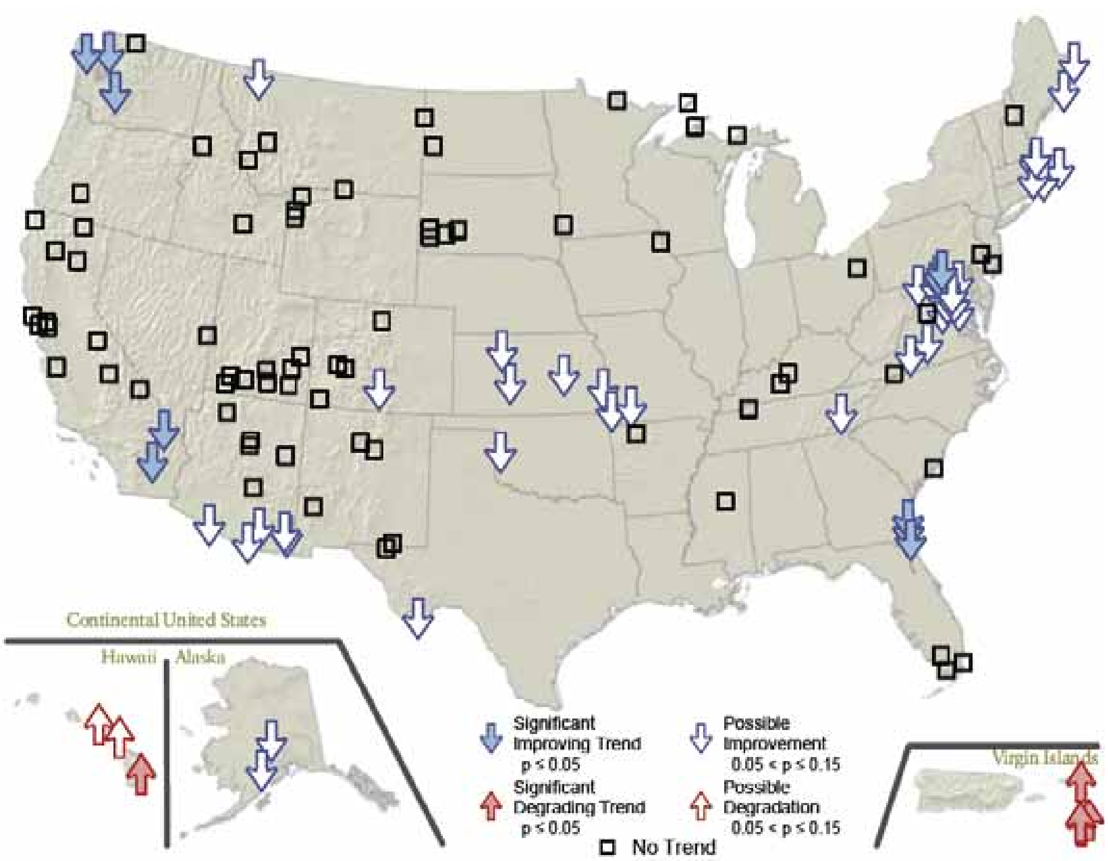


Figure 4.5. Trends in haze index (deciviews) on haziest days, 1999–2008 (NPS ARD, 2010).

Current condition

Interpolation of haze index scores between 2003-2007 resulted in a measurement for Assateague Island National Seashore of 12.86 dv which failed the regulatory threshold (0% attainment) and indicates significant concern (Table 4.21; NPS ARD, 2010).

Trend

A country wide assessment of 10 year trends in visibility within 163 National Park units found that, throughout the country, 12 park units showed significant improvement, five significant decline and the remaining 146 showed no trend (NPS ARD, 2010). Considering data from the haziest days in the eastern US, most park units showed possible improvement or no trend, but Catoctin Mountain Park in central Maryland was one of the units to show significant improvement (Figure 4.5; NPS ARD, 2010).

Key data gaps and confidence in assessment

Assateague Island National Seashore has only recently been included in the national assessment of park units by Air Resources Division and has not yet been included in the country wide trends analyses of park units for visibility. Confidence in the current assessment of condition was high and in the current assessment of trend was fair.

Sources of expertise

Air Resources Division, National Park Service; http://www.nature.nps.gov/air/

Ellen Porter, NPS biologist with the Air Resources Division, research and monitoring branch

Holly Salazer, NPS air resources coordinator for the Northeast Region

Literature cited

National Park Service. 2007a. 2006 Annual Performance and Progress Report: Air Quality in National Parks. **http://www.nature.nps.gov/air/Pubs/pdf/gpra/GPRA_AQ_ConditionsTrendReport2006.pdf**

National Park Service, Air Resources Division. 2010. Air quality in National Parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado.

National Research Council. 1993. Protecting Visibility in National Parks and Wilderness Areas. Committee on Haze in National Parks and Wilderness Areas, National Academies Press. **http://www.nap.edu/catalog/2097.html**

U.S. EPA. 2003. Guidance for Estimating Natural Visibility conditions Under the Regional Haze Program. EPA-454/B-03-005

U.S. EPA. 2004a. The Clean Air Act. Washington United States Environmental Protection Agency, Washington D.C. **http://epw.senate.gov/envlaws/cleanair.pdf**

4.1.5 Particulate matter (PM 2.5)

Relevance and context

Fine particles (PM 2.5) less than 2.5 µm diameter are emitted as smoke from power plants, gasoline and diesel engines, wood combustion, steel mills, forest fires, and chemical reactions such as the release of sulfur dioxide or nitrogen dioxide. These fine particles, airborne soot, have multiple human health impacts and can aggravate lung disease and cause non-fatal heart and asthma attacks, acute bronchitis, respiratory infection, coughing, wheezing, shortness of breath, and changes in lung function (U.S. EPA, 2006b). In recognition of these significant health impacts, ground level particulate matter is regulated under the Clean Air Act, and the U.S. EPA is required to set standard concentrations for airborne particulates (U.S. EPA, 2004a).

Method

Data was obtained from the US EPA Air Quality System (AQS) database (http://www.epa.gov/air/data/aqsdb.html) for the two sampling locations closest to the seashore; DE10 in Sussex County, Southern Delaware and MD24 in Cecil County on the Eastern Shore in Maryland (Table 4.19). Data was 24-hour densities, an annual mean was calculated by first taking a mean of daily values within each calendar quarter, then calculating an overall mean for each year. The three year mean was then calculated to compare to the threshold value, such that attainment indicated the number of sites and years meeting the primary standard (e-CFR, 2011).


Photo: istockphoto.com

Gasoline and diesel engines are a source of fine particles (PM 2.5).

Reference condition

The National Ambient Air Quality Standards (NAAQS) particulate matter regulatory threshold set in 1997 was 65 µg m^{-3} (U.S. EPA, 2004b) but has been lowered to a concentration of 35 µg m^{-3} (NAAQS, 2008). There are two primary standards for PM 2.5, the annual standard is met when the 3-year average of the annual mean concentration is ≤ 15.0 µg m^{-3}, the 24-hour or 'daily' standard is met when the 3 year average of the annual 98th percentile is ≤ 65.0 µg m^{-3} (NAAQS, 2008). The annual standard was used as the threshold value in the current assessment.

Table 4.1. Particulate matter (PM 2.5) for 2 sites (100051002 in southern Delaware and 24015003 on the Eastern Shore of Maryland). Concentrations are in µg m^{-3} , three year average of annual weighted mean values.

Year	Site 100051002 3-year mean	Site 240150003 3-year mean
2001	13.77	13.39
2002	13.17	12.90
2003	12.84	12.83
2004	13.35	13.21
2005	13.45	12.84
2006	13.38	12.58
2007	12.73	11.84
2008	11.69	11.14

Current condition

The two sites within the region of the Seashore between 1999 and 2003 had 100% attainment of the regulatory threshold of PM 2.5 ≤ 15.0 μg m^{-3} (Table 4.1).

Trend

Over the data range available no trend was present.

Data gaps and confidence in assessment

Data was temporally limited and not directly adjacent to the Seashore. Confidence in the current assessment of condition was fair and in the current assessment of trend was limited.

Sources of expertise

Interagency Monitoring of Protected Visual Environments (IMPROVE):

http://vista.cira.colostate.edu/improve/Data/IMPROVE/improve_data.htm

US EPA:
http://www.epa.gov/pm/standards.html

Literature cited

e-CFR. 2011. Electronic Code of Federal Regulations. Title 40. Protection of the environment. Subchapter C-Air Programs. Part 50 - National Primary and Secondary Ambient Air Quality Standards. **http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title40/40cfr50_main_02.tpl**

U.S. EPA. 2004a. The Clean Air Act. Washington United States Environmental Protection Agency, Washington D.C. **http://epw.senate.gov/envlaws/cleanair.pdf**

U.S. EPA. 2006b. Provisional Assessment of Recent Studies on Health Effects of Particulate Matter Exposure. EPA/600/R-06/063

U.S. EPA. 2004b. Air Quality Criteria for Particulate Matter Vol I of II. EPA/600/P-99/002aF **http://cfpub2.epa.gov/ncea/cfm/recordisplay.cfm?deid=87903**

NAAQS. 2008. National Ambient Air Quality Standards. **http://www.epa.gov/air/criteria.html#6**

4.1.6 Mercury deposition

Relevance and context

Atmospheric Mercury (Hg) comes from natural sources, including volcanic and geothermal activity as well as geological weathering, and anthropogenic sources such as burning of fossil fuels (43% of anthropogenic emissions), processing of mineral ores and incineration of certain waste products (UNEP, 2008). At a global scale, annual anthropogenic emissions of mercury approximately equal all natural marine and terrestrial emissions, with anthropogenic emissions in North America being 153 tonnes in 2005 (UNEP, 2008). Exposure of humans and other mammals to mercury in utero can result in mental retardation, cerebral palsy, deafness, blindness and dysarthria (speech disorder) and exposure as adults can lead to motor dysfunction and other neurological and mental impacts (U.S. EPA, 2001). Avian species' reproductive potential is negatively impacted by Hg, and measured trends in Hg deposition, from west to east across North America, can also be measured in the common loon (*Gavia immer*), and throughout North America in mosquitoes (Evers et al., 1998, Hammerschmidt and Fitzgerald, 2006). Mercury is also recorded to have a toxic effect on soil micro-flora, although no ecological depositional threshold is currently established (Meili et al., 2003).

Method

Data was obtained from the National Atmospheric Deposition Program, Mercury Deposition Network (http://nadp.sws.uiuc.edu/nadpdata/mdnsites.asp) for two sites; Harcum (VA98) in Gloucester County, Virginia and Smithsonian Environmental Research Center (MD00) in Edgewater, Maryland (Figure 4.1). Samples are collected weekly and within 24-hours of a precipitation event and analyzed for mercury concentration, measured in ng L^{-1}. Annual mean mercury concentrations were calculated for each sampling site and compared to the threshold.


Photo: istockphoto.com

Atmospheric mercury comes from natural sources including volcanic and geothermal activity.

Reference condition

The indirect regulatory threshold of 2 ng L^{-1} in rain water is a modeled estimate of mercury (Hg) in rainfall that may result in an Hg concentration of 0.5 mg kg^{-1} wet weight in inland fish (Meili et al., 2003). This was estimated under a condition of low organic soils, while highly humic soils are known to store large amounts of Hg that may potentially leach into inland waters, contributing much more than current atmospheric deposition (Meili et al., 2003). The U.S. EPA also has a lower recommended fish tissue regulatory maximum of 0.3 mg kg^{-1} wet weight, which would result in reducing the modeled atmospheric deposition threshold (U.S. EPA, 2001).

Table 4.2. Mercury concentration in precipitation from two sites in the region of Assateague Island National Seashore.

Site	Year	Hg (ng L^{-1})	SE
VA98	2005	8.21*	0.88
VA98	2006	10.15*	1.19
VA98	2007	12.39*	2.14
VA98	2008	9.77*	0.82
VA98	2009	8.45*	0.91
VA98	2010	6.23*	2.06
MD00	2007	11.87*	1.31
MD00	2008	10.74*	1.05
MD00	2009	9.10*	1.09
MD00	2010	8.78*	1.93

* Values outside of reference condition of 2ng L^{-1} mercury in rainwater.

Current condition

The two sites within the region of the Seashore failed to attain the indirect regulatory mean annual threshold of 2 ng L^{-1} in rain water between 2005 and 2010 (0% attainment) (Table 4.2).

Trend

Over the data range available no trend was present.

Data gaps and confidence in assessment

Data was temporally limited and not directly adjacent to the Seashore. Confidence in the current assessment of condition was limited and in the current assessment of trend was limited.

Sources of expertise

National Atmospheric Deposition Program, Mercury Deposition Network

http://nadp.sws.uiuc.edu/MDN/

Literature cited

Evers, D.C., J.D. Kaplan, M.W. Meyer, P.S. Reaman, W.E. Braselton, A. Major, N. Burgess, and A.M. Scheuhammer. 1998. Geographic trend in mercury measured in common loon feathers and blood. *Environmental Toxicology and Chemistry* 17(2): 173-183.

Hammerschmidt, C.R. and W.F. Fitzgerald. 2006. Bioaccumulation and trophic transfer of methylmercury in Long Island Sound. *Archives of Environmental Contamination and Toxicology* 51(3): 416–424.

Meili, M., K. Bishop, L. Bringmark, K. Johansson, J. Muthe, H. Sverdrup, and W. de Vries. 2003. Critical levels of atmospheric pollution: Criteria and concepts for operational modelling of mercury in forest and lake ecosystems. *The Science of the Total Environment* 304:83-106.

UNEP Chemicals Branch, 2008. The global atmospheric mercury assessment: sources, emissions and transport. UNEP – Chemicals, Geneva.

U.S. EPA. 2001. Water quality criterion for the protection of human health: methylmercury. U.S. Environmental Protection Agency, Washington D.C. EPA-823-R-01-001.

4.1.7 Night viewshed

Relevance and context

Natural lightscapes, including dark night skies, are an important component of visitors' park experiences, particularly since the lower 48 states of the US have some of the highest levels of artificial lighting in the world, with 60% of the population having insufficient night time darkness to fully transition over from cone to rod vision (NPS, 2007b; Longcore and Rich, 2004). Two aspects of light pollution are recognized, 'astronomical light pollution', reducing the ability to view stars and other celestial bodies and 'ecological light pollution', indicating effects on wildlife and wildlife behavior (Longcore and Rich, 2004. Ecological impacts on wildlife can include changes to biodiversity, migration patterns, and habitat quality for birds, trees, marine mammals, fish, and sea turtles, as well as changing animal interactions such as prey species losing the protective cover of darkness (Rich and Longcore, 2006). Regulations that limit the intensity of light and maintain longer wavelengths minimize the negative effects of artificial lighting, as already implemented in most counties in Florida for the protection of sea turtles (Salmon, 2003).

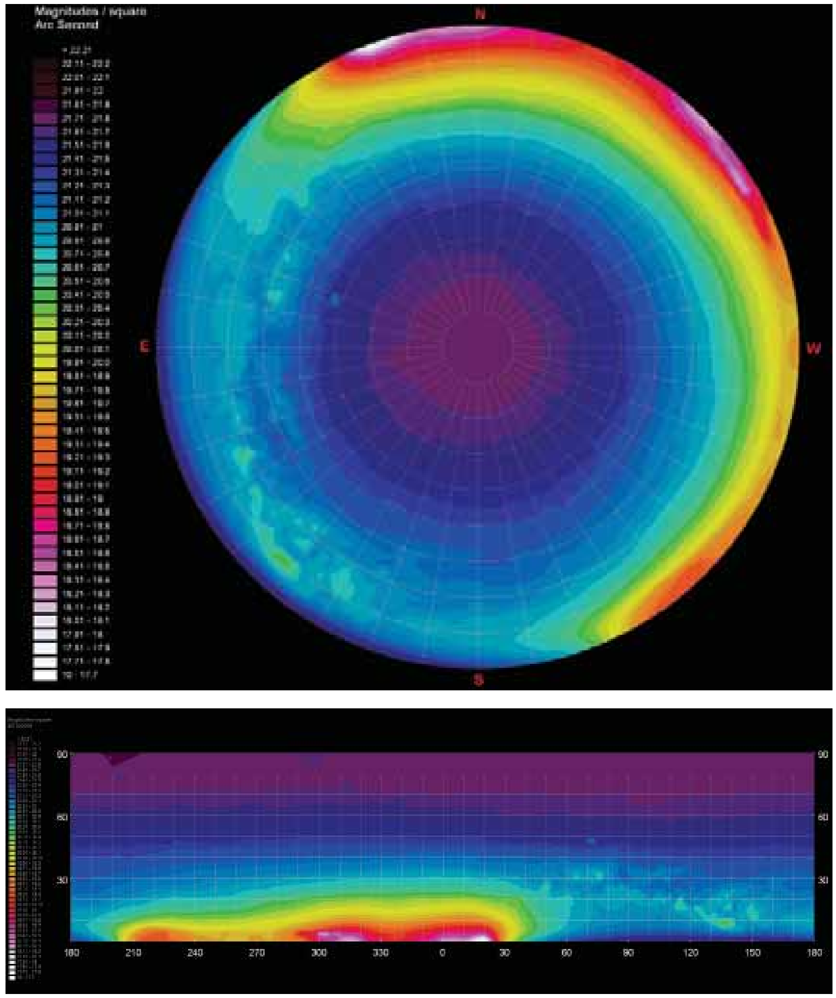


Figure 4.6. Night sky brightness (magnitudes arcsecond-2) at Green Run (kilometer 28) on Assateague Island, May 20 2009;; a) Polar projection, b) Panoramic projection; the bright spot between 0 and 30 degrees is light from Ocean City and between 300 and 330 is from the town of Berlin.

Method

Measurements were taken (six) with a CCD (charged coupled device) digital camera with a 'V' (green) filter and brightness measured in 'V magnitudes'. Reported data was collected from Green Run, at the 28 KM marker post on 19-20th May, 2009 (NPS, 2007b; Table 4.19, 4.20).

Reference condition

The reference condition of 21.5 magnitudes arcsecond^{-2} represents a value half a magnitude brighter than the observed and modeled value for natural sky brightness of 22.0 magnitudes arcsecond^{-2} at the zenith (Garstang, 1989a; Skiff, 2001; Table 4.20). During a full moon or in suburbs of a large city, V magnitudes of approximately 18.0 magnitudes arcsecond^{-2} have been previously measured, with one study recording a value of 18.7 magnitudes arcsecond^{-2} for urban centers from Rhode Island down to Connecticut, representing approximately 21 times natural background (Garstang, 1989a; Skiff, 2001).

Current condition

Mean night sky brightness, measured in May 2009 was 21.72± 0.02 magnitudes arcsecond^{-2} which passed the reference condition of 21.5 magnitudes arcsecond^{-2} (100% attainment) (Table 4.20, 4.21). Two main sources of light pollution were recorded, corresponding to Ocean City and the town of Berlin, however astronomical feature including the Milky Way and Beehive Clusters were readily observed. Natural vegetation on the west side of Assateague Island assists in maintaining darkness in the ocean beach habitats (NPS, 2007b).

Trend

Currently only the first year of sampling is reported, so no trend data is available. However, even with improvements in lighting technology, a very high correlation between increasing human population and light pollution throughout the US suggests that night sky brightness on the Seashore is also at risk of increasing (Garstung, 1989b).

Data gaps and confidence in assessment

Assateague Island National Seashore has only recently been included in the national assessment of park units by Air Resources Division for night sky brightness, and this monitoring will fill an important data need. Confidence in the current assessment of condition was high and in the current assessment of trend was limited.

Sources of expertise

National Park Service Air Resources Division, Night Sky Team

http://www.nature.nps.gov/air/lightscapes/monitorData/index.cfm

Literature cited

Garstang, R.H. 1989a. Night-sky brightness at observatories and sites. *Publications of the Astronomical Society of the Pacific* 101: 306-329.

Garstang, R.H. 1989b. The status and prospects for ground-based observatory sites. *Annual Review of Astronomy and Astrophysics* 27:19-40.

Longcore, T. and Rich, C. 2004. Ecological light pollution. *Frontiers in Ecology and the Environment* 2(4): 191-198.

National Park Service. 2007b. "Explore Air: Natural Nightscapes." NPS website, accessed 30.4.2010 Available **http://www.nature.nps.gov/air/lightscapes/**

Rich, C. and Longcore, T. (eds). 2006. Ecological consequences of artificial night lighting. Island Press, Washington, D.C.

Salmon, M. 2003. Artificial night lighting and sea turtles. *Biologist* 50(4): 163-168.

Skiff, B. 2001. "How dark can the night sky get?" Accessed February 6, 2011 from **http://www.astropix.com/HTML/L_STORY/SKYBRITE.HTM**

4.2 WATER QUALITY

4.2.1 Water quality index

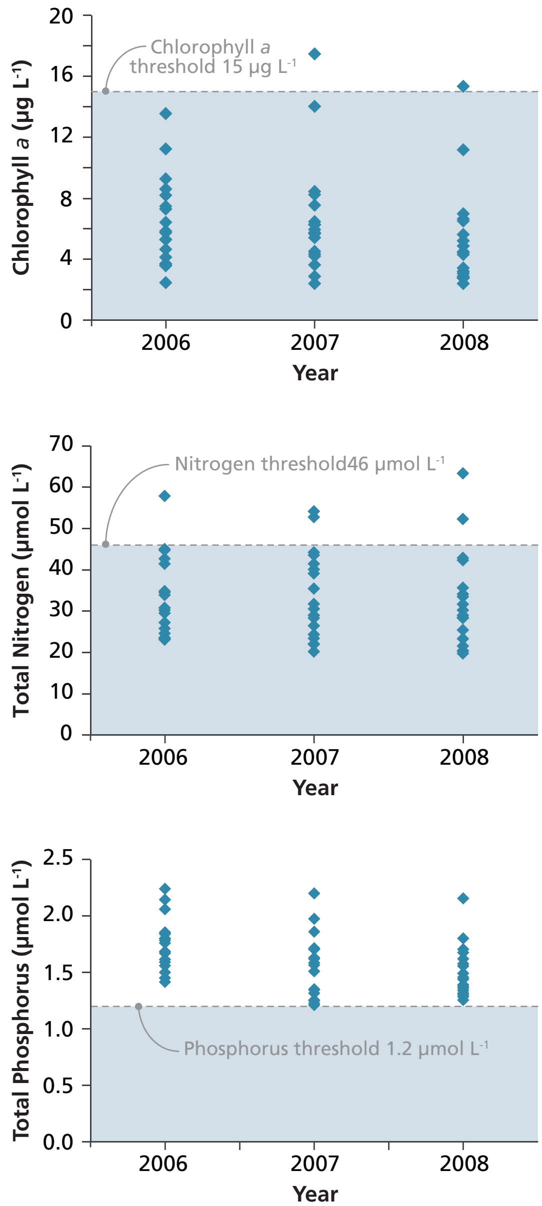


Figure 4.7. Water quality for 18 sites along the bay side of Assateague Island from 2005-2008, indicating attainment of reference condition a) Median Chlorophyll *a*; b) Median total nitrogen; c) Median total phosphorus

Relevance and context

Good estuarine water quality is needed to support many ecosystem resources, and Chincoteague Bay (the largest coastal bay adjacent to Assateague Island) was considered to have excellent water quality, based on a synthesis of data collected during the 1970's (Boynton et al., 1996; Koch and Orth, 2003). However, Chincoteague, and the adjoining coastal bays, have limited freshwater inflow from small watersheds and low tidal flushing, making them highly susceptible to eutrophication (Pritchard, 1960; Boynton et al., 1996; Bricker et al., 1999). Nutrients and phytoplankton are commonly used to evaluate estuarine ecosystems and biological impacts (Bricker et al., 1999). Specifically, patterns in water quality within these coastal bays have been linked to the abundance of the seagrass *Zostera marina* (Wazniak et al., 2007). Seagrass in general, and *Z. marina* specifically, provide food and habitat structure supporting a diversity of waterbirds, finfish, bivalves and crustaceans, including many commercially and recreationally important species (Orth et al., 2006b; Moore and Short, 2006).

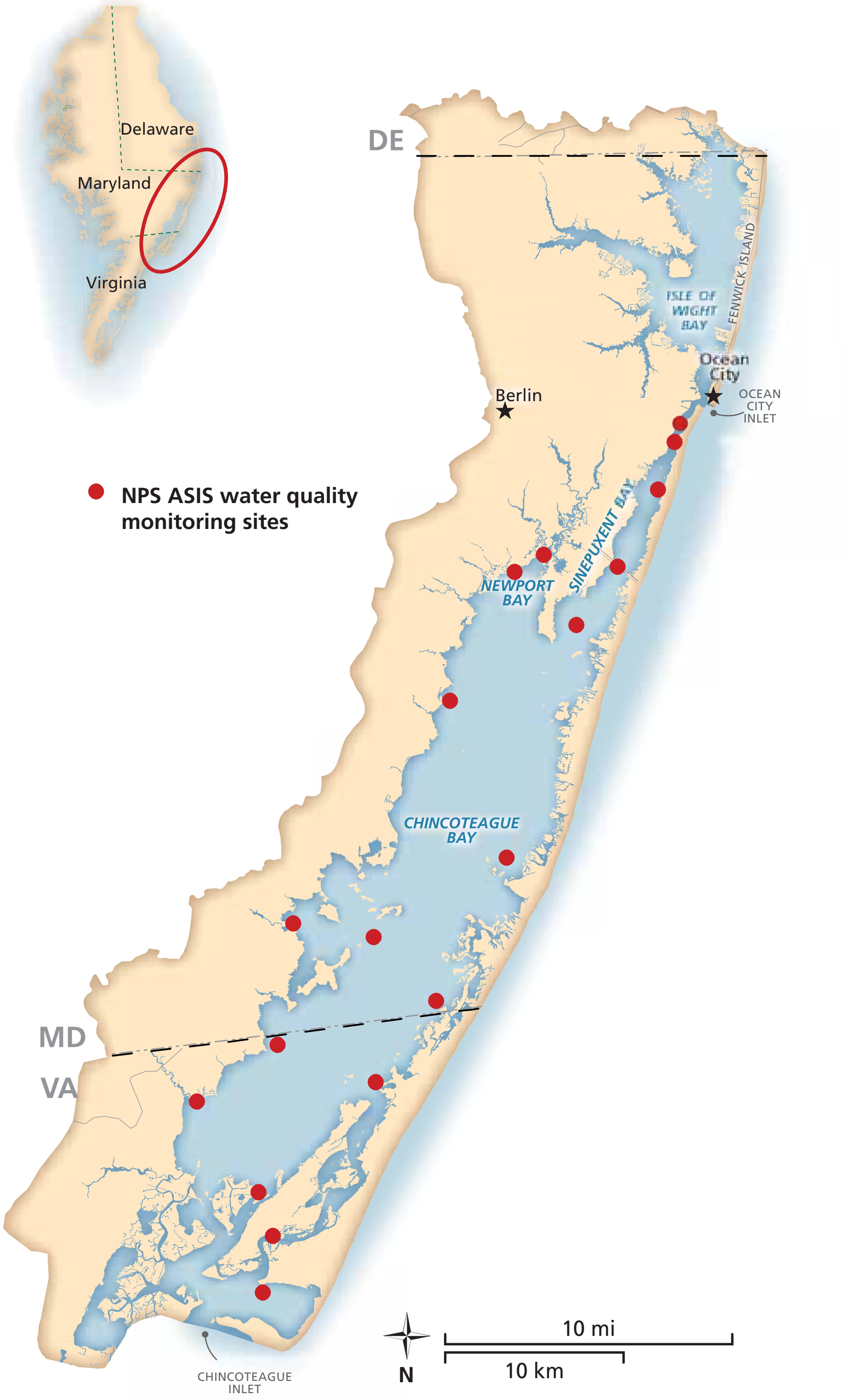
Method

Data collected from surface samples at 18 sites along the length of Assateague Island in Chincoteague, Sinepuxent and Newport Bays, collected by Assateague Island National Seashore monthly from 2006 through 2008 (total of 612 data points), were used to assess current condition (Figure 4.8; ASIS, 2010). Three water quality metrics, commonly used for assessing the condition of coastal and estuarine waters, were combined into an index of water quality; total nitrogen (TN), total phosphorus (TP) and chlorophyll *a* (Chl *a*) (Figure 4.7; Bricker et al., 1999, Kiddon et al., 2003, U.S. EPA, 2004). For all metrics, the annual median for each station was calculated, compared to the ecosystem reference condition and scored as meeting (one) or failing to meet (zero) each criterion, and then an unweighted mean was calculated for each site in each year (Carruthers and Wazniak, 2004, Wazniak et al., 2007). Overall assessment was the mean combined water quality index for all 18 sites for all three years. To assess long term trends, TN, TP and Chl *a* data from the same 18 sites were analyzed for linear and non-linear trends, seven sites had data from 1987-2006 and 11 sites had data from 1991-2006 (Wazniak et al., 2007; Wazniak et al., 2009).

Reference condition

Ecologically relevant reference conditions for these metrics were applied, specifically related to the maintenance of seagrass habitat (Stevenson et al., 1993, Kemp et al., 2004). Reference conditions were total nitrogen, <0.65 mg L^{-1} or <46 µmol L^{-1}; total

Figure 4.8. Sites sampled by the National Park Service used for measuring bayside water quality for Assateague Island National Seashore.



phosphorus, <0.037 mg L^{-1} or <1.2 µmol L^{-1}; Chlorophyll *a*, <15 µg L^{-1} (Dennison et. al., 1993; Stevenson et al., 1993; Ritter and Montagna, 1999).

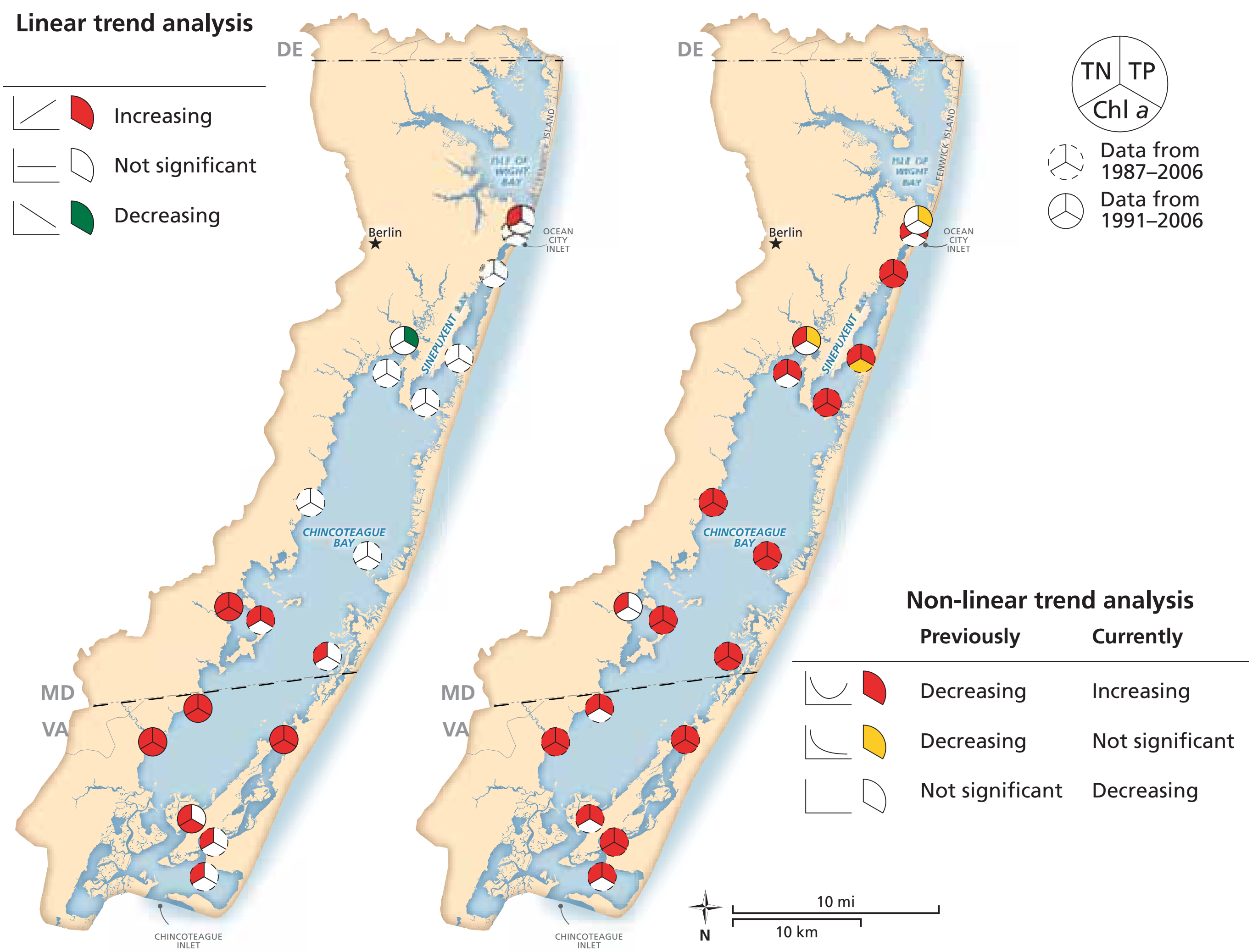
Current condition

Water quality in the coastal bays adjacent to Assateague Island was in good condition, with 63% attainment of reference values to sustain ecosystem resources (Table 4.21). Large differences occurred between metrics used within the index, however, with Chlorophyll *a* having a 96% attainment of reference condition and a global mean of 6.15 (±0.45) µg L^{-1}, total nitrogen a 91% attainment of reference condition and global mean of 33.1 (±1.4) µmol L^{-1}; while total phosphorus had a 4% attainment of reference condition and global mean of 1.61 (±0.04) µmol L^{-1}; (Figure 4.7). The current assessment is consistent with previous assessments of these coastal bays, indicating that phosphorus is consistently the largest water quality concern and that Sinepuxent and Chincoteague Bays have relatively good water quality compared to the adjacent and connected bays to the north (Carruthers and Wazniak, 2004; Wazniak et al., 2007; 2009).

Trend

Water quality within the coastal bays is declining, with Chlorophyll *a* (Chl *a*), total nitrogen (TN) and total phosphorus (TP) all showing significant increases (Figure 4.9; Wazniak et al., 2007; 2009). Comparison of linear trend analysis, which showed many water quality improvements through 2004 (Wazniak et al., 2007) or no trend with the addition of data through 2006 (Wazniak et al., 2009), to quadratic trend analysis,

Figure 4.9. Linear (left) and non linear (right) water quality trend analyses for total nitrogen (TN), total phosphorus (TP),and Chlorophyll *a* (chl *a*) in the coastal bays adjacent to Assateague Island.



Data source: after Wazniak et al, 2009)

indicates that there was an inflexion point in the late 1990's with a change from reducing to increasing concentrations of Chl *a*, TN and TP (Wazniak et al., 2007; 2009).

Data gaps and confidence in assessment

Monitoring data is sufficient for assessing condition and trend of water quality in Chincoteague and Sinepuxent Bays, however this does not allow assessment of source and specifically potential nutrient inputs from groundwater, a significant source of freshwater to these shallow coastal bays (Dillow and Green, 1999). Confidence in the current assessment of condition was high and in the current assessment of trend was high.

Sources of expertise

Brian Sturgis; Ecologist, Assateague Island National Seashore.

Tim Carruthers; Associate Research Scientist, University of Maryland Center for Environmental Science.

William Dennison; Vice President for Science Applications, University of Maryland Center for Environmental Science.

Michael Williams; Associate Research Scientist, Chesapeake Biological Laboratory.

Cathy Wazniak; Environmental Program Manager, Maryland Department of Natural Resources.

Literature cited

ASIS. 2010. Assateague Island National Seashore data repository. In: National Park Service Natural Resource Information Portal. **https://nrinfo.nps.gov/Home.mvc** Accessed December 2010.

Boynton, W.R., Murray, L., Hagy, J.D., Stokes, C. and Kemp, W.M. 1996. A comparative analysis of eutrophication patterns in a temperate coastal lagoon. *Estuaries* 19: 408-421.

Bricker, S.B., Clement, C.G., Pirhalla, D.E., Orlando, S.P. and Farrow, D.R.G. 1999. National Estuarine eutrophication assessment: effect of nutrient enrichment in the nation's estuaries. National Oceanic and Atmospheric Administration, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science, Silver Spring, Maryland, USA.

Carruthers, T.J.B. and Wazniak, C.E. 2004. Development of a water quality index for the Maryland Coastal Bays. In. Maryland's Coastal Bays – Ecosystem Health Assessment 2004, Chapter 4.4. Maryland Department of Natural Resources document DNR-12-1202-0009.

Dennison, W.C., Orth, R.J., Moore, K.A., Stevenson, J.C., Carter, V., Kollar, S., Bergstrom, P.W. and Batiuk, R.A. 1993. Assessing water quality with submerged aquatic vegetation. *Bioscience* 43:86-94.

Dillow, J.J.A. and Greene, E.A. 1999. Ground water discharge and nitrate loadings to the coastal bays of Maryland. U.S. Geological Survey water Resources Investigations Report 99-4167, Maryland.

Kemp, W. M., R. Batiuk, R. Bartleson, P. Bergstrom, V. Carter, C.L. Gallegos, W. Hunley, L. Karrh, E.W. Koch, J. M. Landwehr, K.A. Moore, L. Murray, M. Naylor, N.B. Rybicki, J. C. Stevenson, and D.J. Wilcox. 2004. Habitat requirements for submerged aquatic vegetation in Chesapeake Bay: water quality, light regime, and physical-chemical factors. *Estuaries* 27:363–377.

Kiddon, J.A., Paul, J.F., Buffam, H.W., Strobel, C.S., Hale, S.S., Cobb, D. and Brown, B.S. 2003. Ecological condition of US mid-Atlantic estuaries 1997-1998. *Marine Pollution Bulletin* 46:1224-1244.

Koch, E.W. and Orth, R.J. 2003. The seagrasses of the mid-Atlantic coast of the United States. **In:** Greene, E.O. and Short, F.T. *World Atlas of Seagrasses.* University of California Press. Berkley, USA. Chapter 21. pp216 – 223.

Moore, K.A. and Short, F.T. 2006. *Zostera*: biology, ecology and management. **In:** Larkum, A.W.D., Orth, R.J. and Duarte, C.M. (Eds). *Seagrasses: biology, ecology and conservation.* Springer, Dordrecht, The Netherlands. 691pp.

Orth, R.J., Carruthers, T.J.B., Dennison, W.C., Duarte, C.M., Fourqurean, J.W., Heck, K.L. Jr, Hughes, A.R., Kendrick, G.A., Kenworhy, W.J., Olyarnik, S., Short, F.T., Waycott, M. and Williams, S.L. 2006b. A global crisis for seagrass ecosystems. *Bioscience* 56(12):987-996.

Pritchard, D.W. 1960. Salt balance and exchange rate for Chincoteague Bay. *Chesapeake Sciences* 1:48-57.

Stevenson, J. C., L. W. Staver, and K. W. Staver. 1993. Water quality associated with survival of submersed aquatic vegetation along an estuarine gradient. *Estuaries* 16:346–361.

Ritter, M.C. and Montagna, P.A. 1999. Seasonal hypoxia and models of benthic response in a Texas bay. Estuaries 22:7-20.

U.S. EPA (Environmental Protection Agency). 2004. National Coastal Condition Report II. EPA-620/R-03/002. EPA, Washington, D.C., USA.

Wazniak, C.E., Hall, M.R., Carruthers, T.J.B., Sturgis, B., Dennison, W.C. and Orth, R.J. 2007. Linking water quality to living resources in a mid-Atlantic lagoon system, USA. *Ecological Applications* 17(5S): 64-78.

Wazniak, C.E., Hall, M.R., Bailey, E.M., Boward, D.M., Boynton, W.R., Bratton, J.F., Carruthers, T.J.B., Chalmers, R.J., Cole, L.W., Cornwell, J.C., Fertig, B., Glibert, P.M., Jones, A.B., Jordan, T.E., McCoy, J., McGinty, M., Shedlock, R.J., Sherwell, J., Sturgis, R.B., Thomas, J.E., Trice, T.M. and Wells, D.V. 2009. Water quality responses to nutrients. **In:** Dennison, W.C., J.E. Thomas, C.J. Cain, T.J.B. Carruthers, M.R. Hall, R.V. Jesien, C.E. Wazniak, & D.E. Wilson. *Shifting Sands: Environmental & Cultural Change in Maryland's Coastal Bays.* IAN Press, Cambridge, Maryland.

4.2.2 Water pH

Relevance and context

The fresh and brackish ponds on Assateague Island are important and unique habitat for plants, invertebrates, fish and amphibians as well as an important water source for the Island's mammals and birds. During periods of rain, particularly during the winter months, numerous ponds form throughout the interior if the island. While many tend to be small and temporary, some remain throughout the year due to groundwater input (Figure 4.10; Wilson et al, 2009). With deposition rates of wet sulfate and wet nitrogen being of significant concern regionally, these fresh water habitats have the potential to be impacted by acidification, although direct linkages between rainfall and ephemeral pond acidity are not well established (Sardinski and Dunson, 1992; NPS ARD, 2010). Salamanders and fish are susceptible to extreme pH values and can be limited by food availability even at less extreme acidification, for example by reduced zooplankton and periphyton communities (Sadinski and Dunson, 1992; Barr and Babbitt, 2002). Surveys in North Carolina found a decline in Anuran species richness with reduced pH, with some frog and newt species being totally absent in the more acidic ponds (Easton and Fauth, 2001).

Table 4.3. Mean pH from 21 monthly samples taken at 11 ponds on Assateague Island National Seashore during 2003-2004, reference condition is a range of 6.5-8.5 (Hall, 2005).

Pond	Mean pH
33F	5.7*
33E	5.4*
33D	4.8*
30B	6.1*
30A	5.9*
24A	7.0
23B	7.7
23A	7.9
18A	6.6
15A	7.0
11A	8.0

* Values outside of reference condition range of 6.5-8.5 mean pH.

Reduced pH can also result in reduced salamander hatching success, suppression of larval newt survival and impacts upon frog metamorphosis (Sadinski and Dunson, 1992).

Method

Data was collected monthly during a two year study of 11 of the ponds on Assateague Island, during 2003 and 2004 (Table 4.3; Hall, 2005). Mean pH for each sampled pond was compared to the reference condition and an overall attainment calculated.

Reference condition

A reference condition range of 6.5-8.5 was used for this assessment, which is the Maryland criteria for use I waters, for water contact recreation and protection of non-tidal, warm water aquatic life (COMAR, 2007a, Table 4.20). Although the fresh water resources on Assateague Island have not been specifically designated, this is consistent with other streams and fresh water habitats within Worcester County and the pH standard is the same for both (COMAR, 2007b).

Current condition

Current condition was fair with a mean pH range of 4.8 – 8.0 between ponds, with 54% of ponds attaining reference condition.

Trend

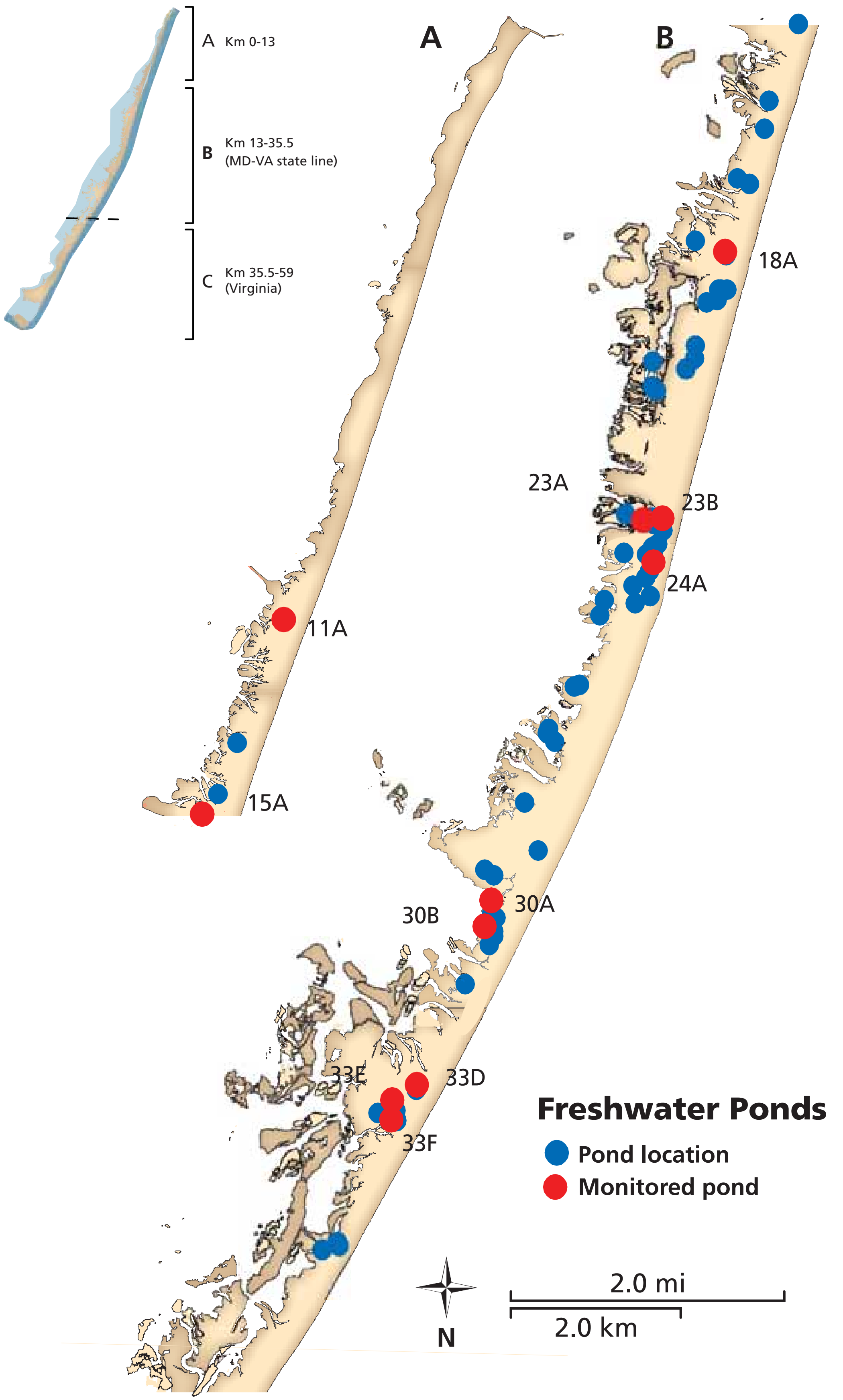
No assessment of trend is currently possible for this metric.

Data gaps and confidence in assessment

The only available data was from a one-time study in a subset of fresh water pools on Assateague. Regular monitoring of the pools and a broader survey is a key data gap. Confidence in the assessment of condition was limited and no assessment of trend was possible.

Sources of expertise

Brian Sturgis; Ecologist, Assateague Island National Seashore.



Data source: Hall, 2005

Figure 4.10. Freshwater pond locations on Assateague Island.

Literature cited

Barr , G.E. and Babbitt, K.J. 2002. Effects of biotic and abiotic factors on the distribution and abundance of larval two-lined salamanders (*Eurycea bislineata*) across spatial scales. *Oecologia* 133: 176-185.

COMAR (Code of Maryland Regulations). 2007a. 26.08.02.03-3: Water Quality Criteria Specific to Designated Uses. Title 26: Maryland Department of the Environment. Subtitle 08: *Water Pollution* Chapter 02: Water Quality.

COMAR (Code of Maryland Regulations). 2007b. 26.08.02.08: Water Quality Criteria Specific to Designated Uses. Title 26: Maryland Department of the Environment. Subtitle 08: Water Pollution. Chapter 02: Water Quality. **http://www.mde.state.md.us/programs/Water/TMDL/Water%20Quality%20Standards/Documents/www.mde.state.md.us/assets/document/Worcester_Cnty_DUs.pdf**

Easton, G.W. and Fauth, J.E. 2001. Ecological correlates of anuran species richness in temporary pools: a field study in South Carolina, USA. *Israel Journal of Zoology* 47(4): 347-365.

Hall, S.Z. 2005. Hydrodynamics of freshwater ponds on a siliclastic barrier island, Assateague Island National Seashore, Maryland. Masters Thesis. University of Maryland Eastern Shore.

National Park Service, Air Resources Division. 2010. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado.

Sadinski, W.J. and Dunson, W.A. 1992. A multi-level study of effects of low pH on amphibians of temporary ponds. *Journal of Herpetology* 26(4): 413-422.

Wilson, D.E., C.E. Wazniak, D.M. Boward, T.J.B. Carruthers, R.J. Chalmers, D.H. Clearwater, W.C. Dennison, A.B. Hairston-Strang, M.R. Hall, F.M. Irani, R.V. Jesien, W.M. Knapp, E.W. Koch, K.L. Kyde, A.E. Luscher, M.D. Naylor, R.J. Orth, C.C. Spaur, M.L. Tarnowski, E.C. Wicks, and C.S. Zimmerman. 2009. Chapter 15: Habitats of the Coastal Bays and Watershed. **In:** Dennison, W.C., J.E. Thomas, C.J. Cain, T.J.B. Carruthers, M.R. Hall, R.V. Jesien, C.E. Wazniak, & D.E. Wilson. *Shifting Sands: Environmental & Cultural Change in Maryland's Coastal Bays.* IAN Press, Cambridge, Maryland.

4.2.3 Bacterial abundance

Relevance and context

An increase in coastal development adjacent to Assateague Island increases the risk of public health hazards from contact with sanitary wastes. Exposure to marine recreational water with high bacterial densities from natural (e.g. birds, mammals) and human-induced (sewage, wastewater, runoff) sources has been linked to eye, ear, and skin infections, as well as gastroenteritis (Pruss, 1998, Haile et al., 1999). Of several bacterial measures that are often used for microbial risk assessment, the enterococcus density in seawater has been specified as the best single bacterial indicator of human health risk of infectious disease while swimming (Cabelli et al., 1983).

Method

Data was collected between 2000 and 2006 at eight sites on the Atlantic side and in 2006 at three sites on the Chincoteague Bay side of Assateague Island (Figure 4.12). A change in analytical methodology from membrane filtration to entero-alert between 2002 and 2003, and the consequent difference in reporting zero colony counts, resulted in a small shift between these years (Figure 4.11). Each sample was compared to the reference condition and the attainment over all sites and times calculated as a percentage attainment of reference condition.

Reference condition

Both Atlantic and Chincoteague Bay side shorelines of Assateague Island have been classified by Maryland Department of the Environment as designated use II; the support of estuarine and marine aquatic life and shellfish harvesting (COMAR, 2007b). For marine waters in this designated use, the single sample maximum allowable density of enterococcus bacteria for frequent full-body recreational contact is 104 MPN (Most Probable Number) /100 ml, which was used as the reference condition in this assessment (COMAR, 2007a).

Current condition

Current condition was very good with 99% attainment of reference condition over all samples. Atlantic coast samples were far below reference condition with a range of 0-83 and a mean of 7.8 MPN's. While one site on the Chincoteague shore, the Old Ferry Landing, had a range of 0-306 and a mean of 96.7 MPN's, reference condition was still only exceeded on six of 144 days sampled (Table A-2, A-3).

Trend

Long term data are only available for the Atlantic side sites, and bacteria concentrations remained far below reference condition and no clear direction trend was apparent.

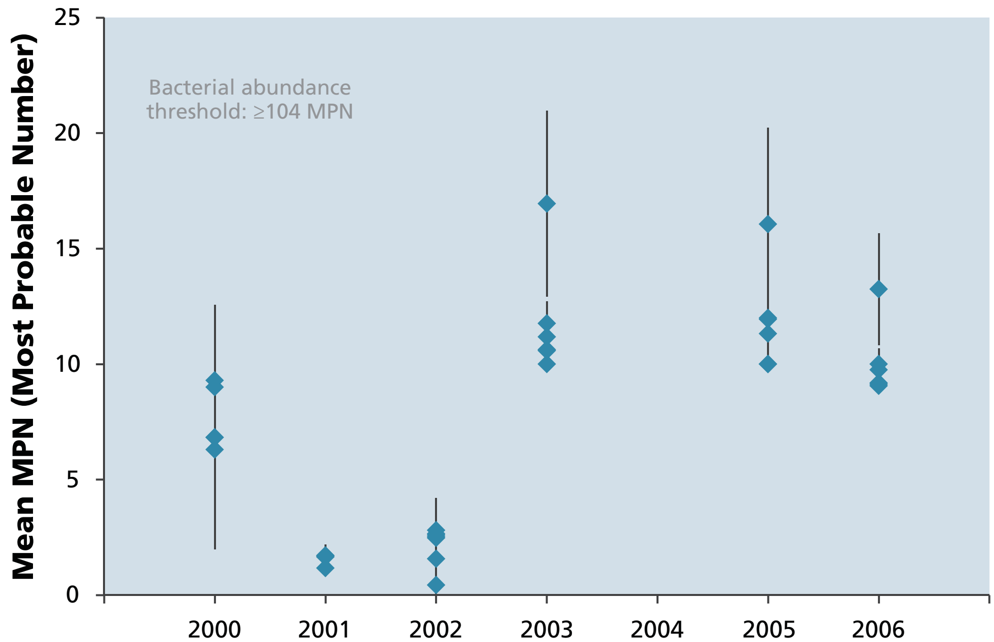
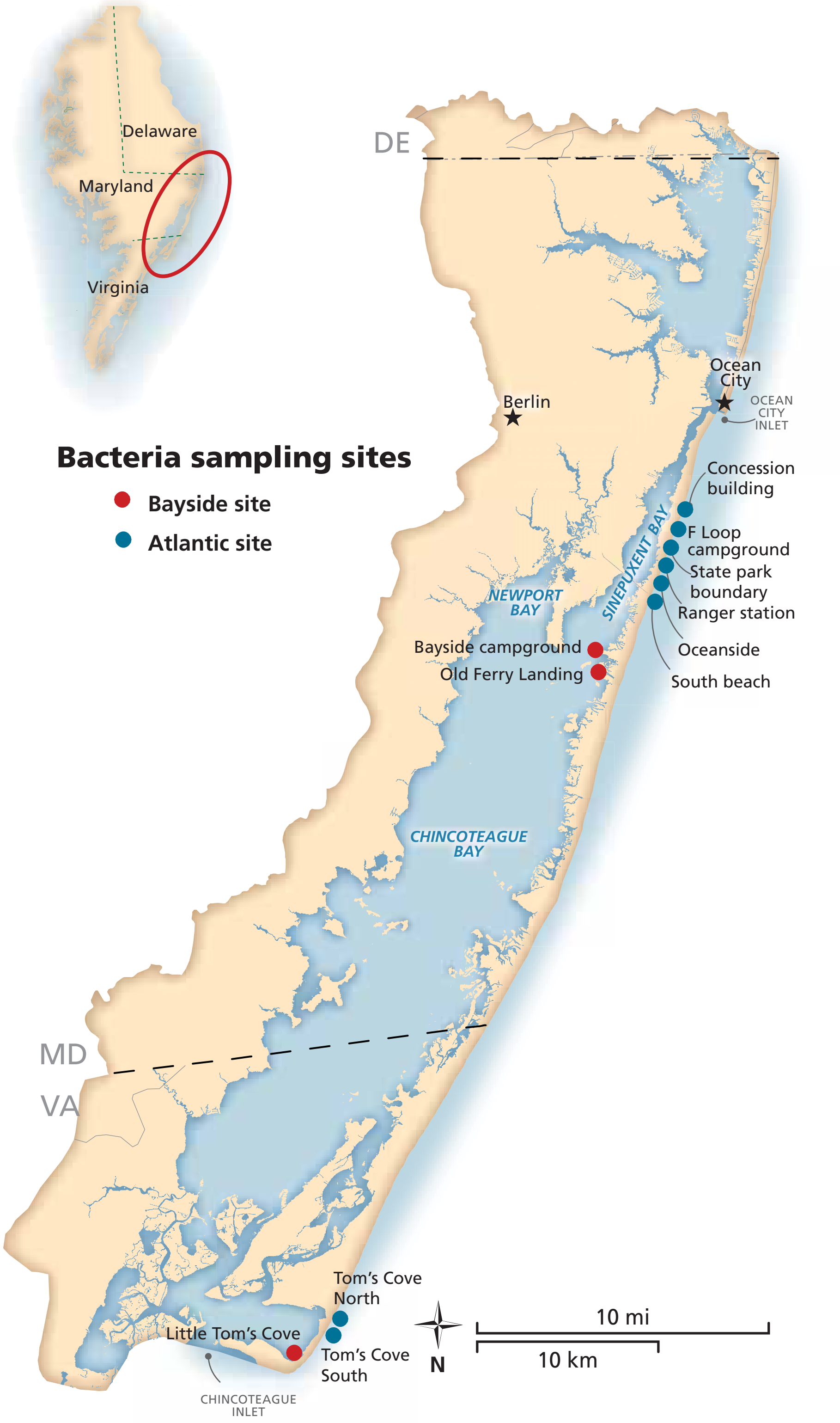


Figure 4.11. Long term trends in bacterial count data from eight sites on the Atlantic beach of Assateague Island National Seashore.

Figure 4.12.
Bayside and Atlantic sampling locations for monitoring bacteria at Assateague Island National Seashore.



Data source: Beach water quality reports and bayside water quality reports 2000-2006, NPS-ASIS

Data gaps and confidence in assessment

Only one year of data was available for Chincoteague Bay sites, continuation of this monitoring will allow for future assessment of trends. Confidence in the assessment of condition was high and assessment of trend was fair.

Sources of expertise

Brian Sturgis, Ecologist, Assateague Island National Seashore.

Carl Zimmerman; Resource Management Specialist, Assateague Island National Seashore.

Literature cited

Cabelli, V.J., A. Dufour, L. McCabe, and M. Levin. 1982. Swimming associated gastroenteritis and water quality. *American Journal of Epidemiology* 115(4):606–616.

COMAR (Code of Maryland Regulations). 2007a. 26.08.02.03-3: Water Quality Criteria Specific to Designated Uses. Title 26: Maryland Department of the Environment. Subtitle 08: *Water Pollution* Chapter 02: Water Quality.

COMAR (Code of Maryland Regulations). 2007b. 26.08.02.08: Water Quality Criteria Specific to Designated Uses. Title 26: Maryland Department of the Environment. Subtitle 08: Water Pollution. Chapter 02: Water Quality. **http://www.mde.state.md.us/programs/Water/TMDL/Water%20Quality%20Standards/Pages/programs/waterprograms/tmdl/wqstandards/wqs_designated_uses.aspx**

Haile R., J. Witte, M. Gold, R. Cressey, C. McGee, R. Millikan, A. Glasser, N. Harawa, C. Ervin, P. Harmon. 1999. The health effects of swimming in ocean water contaminated by storm drain runoff. *Epidemiology* 10(4):355–363.

Pruss, A. 1998. Review of epidemiological studies on health effects from exposure to recreational water. *International Journal of Epidemiology* 27: 1–9.

4.3 BIOLOGICAL INTEGRITY

4.3.1 *Phragmites*

Relevance and context

A major threat to the habitats and native communities of Assateague Island National Seashore are the non-native invasive plant species which have been introduced to the island. Non-native invasive plants found in and around the Seashore include the invasive strain of *Phragmites australis* (Common Reed), *Rosa multiflora* (Multiflora Rose), *Lonicera japonica* (Japanese Honeysuckle), *Miscanthus sinensis* (Chinese Silvergrass), and *Rosa wichuraiana* (Memorial Rose) (Chase et al, 2008). The most abundant invasive plant is *Phragmites australis*, a wetland plant that has invaded many sites on the Seashore in a variety of coastal habitats. *Phragmites* outcompetes native flora and threatens the native coastal communities that characterize Assateague Island, reducing habitat suitability for fauna, lowering plant diversity, and replacing native vegetation (Farnsworth and Meyerson, 1999, Mack et al., 2000, Teal and Peterson 2005).

Method

Active management of *Phragmites* by the National Park Service on the Seashore commenced in 2007 with a pilot one hectare aerial spraying project, followed by aerial and ground based mapping in 2008 into broad cover categories, and an initial aerial spraying of 185 acres (Chase and Sturm, 2008; Chase et al., 2008). A total of 534 acres of *Phragmites* were mapped in the Maryland portion of the Seashore. All cover categories with greater than 40% cover of *Phragmites* were used to calculate a 'total area of *Phragmites*' for the current assessment, and combined into one GIS layer (Figure 4.13, Chase et al., 2008). The current assessment was based on the initial 2008 mapping, prior to any spraying, and the calculated total area of *Phragmites* was compared to the total area of land in the Maryland portion of the Seashore to determine the percentage of land area that had >40% cover of *Phragmites*. Additionally, the areal extent of *Phragmites* was calculated by habitat type for Dune and Grassland, Salt Marsh, Forest and Shrubland, and Inland Wetlands for use in the combined habitat assessment (Table 4.4; Chapter 5).

Phragmites australis is a threat to several habitats within Assateague Island National Seashore.

Photo: NPS ASIS

Reference condition

The determined reference condition was that the total area of *Phragmites* should not exceed 2% of the land area in the Maryland portion of the Seashore (Table 4.20). Even small changes in cover of native flora can be indicators of significant decline in condition, so the reference condition of 2% or less cover of *Phragmites*, equates to a 'good' classification for condition of native flora as defined by Faber-Langendoen (2008). The Park management goal is to control *Phragmites* and maintain areal coverage at less than 2% of the Maryland portion of the Seashore. For inland wetland habitats, presence of *Phragmites* in a wetland is reported as a percentage of total wetland areas, however % cover of *Phragmites* is not reported. As these habitats are fragile, the reference condition was that no wetland ponds contain *Phragmites*. The reference condition was established in consideration of both the physical presence of this species and an abundance that would be sufficient to enable rapid re-establishment and spread (Ailstock, 2000).

Current condition

Currently 5.6% of the total area of the Seashore in Maryland has >40% cover of *Phragmites*, which is outside the reference condition (0% attainment). When areal

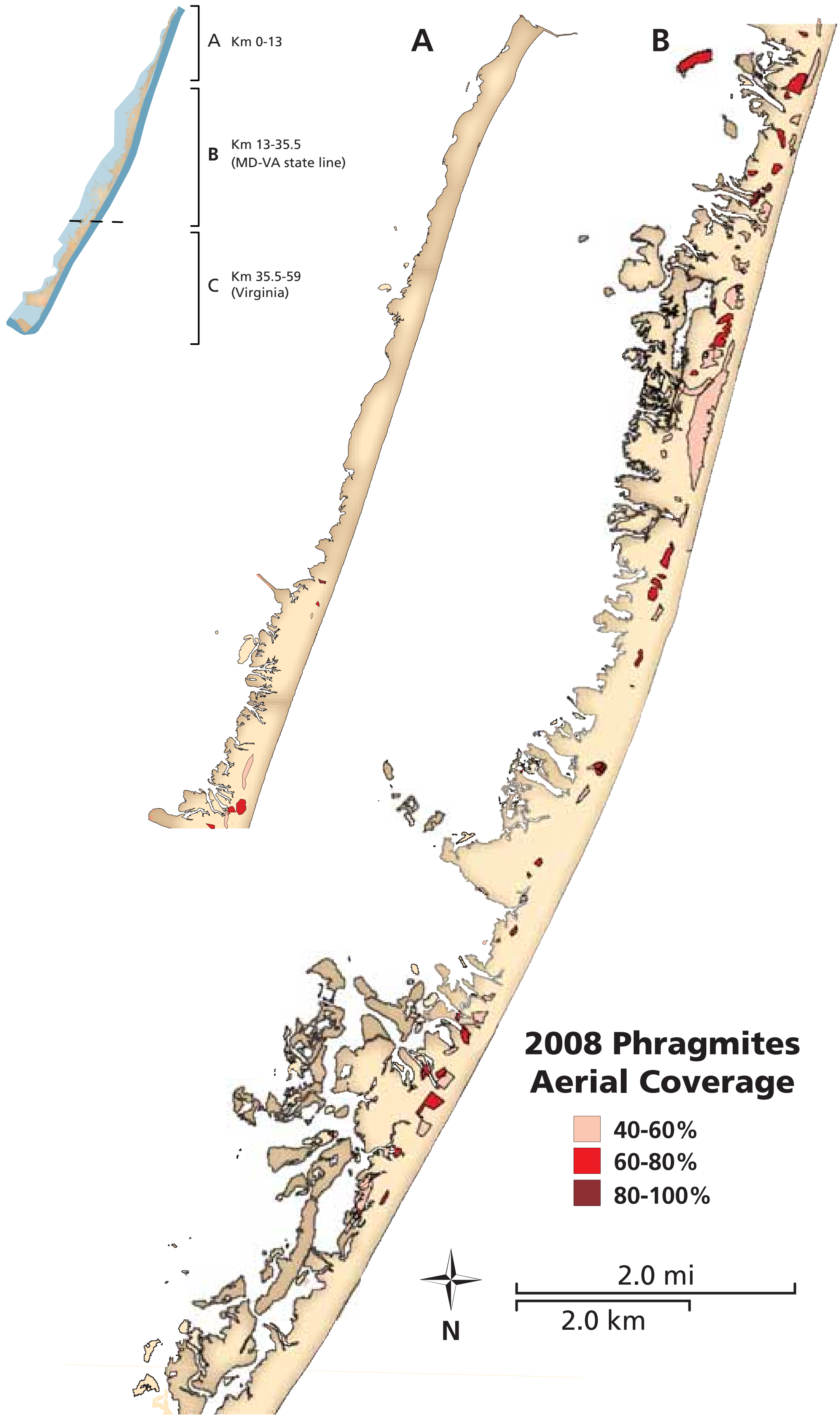


Figure 4.13. Aerial coverage of *Phragmites australis* in the Maryland section of Assateague Island National Seashore.

Data source: 2008 survey, ASIS, 2010

Table 4.4. Area of *Phragmites australis* in habitats of Assateague Island (MD area), as derived from 2008 ASIS-NPS aerial photography. Values that exceed the threshold (< 2% area) are in bold.

Habitat	Land area (m^2)	*Phragmites* area (m^2)	% Area
Dune and Grassland	6,277,472	177,307	2.82
Salt Marsh	9,848,657	143,642	1.46
Forest and Shrubland	14,136,885	838,468	5.93
Seashore land in Maryland	36,010,000	2,026,358	5.60
Inland Wetland	68 ponds	12 ponds with *Phragmites*	18% of ponds

extent of *Phragmites* was characterized by habitat, Dune and Grassland habitat contained 2.8% areal cover, Salt Marsh habitat meets the reference condition with 1.5% areal cover, and Shrub and Forest habitat is furthest from reference condition with 5.9% areal cover of *Phragmites* (Table 4.4).

Trend

Current management strategy is active removal of *Phragmites*, with an estimated 418 acres treated since 2008.

Data gaps and confidence in assessment

Data needs include continued surveys and mapping to determine trends and monitoring of *Phragmites* areas after treatment to assess effectiveness, as currently planned (Chase et al., 2008). Monitoring of non-target effects of treatment will also allow assessment of potential damage to the native plant communities and, if this is unacceptably high, may result in a re-assessment of the reference condition.

Confidence in assessment of condition was high and confidence in assessment of trend was fair.

Sources of expertise

Carl Zimmerman, Resource Management Specialist, Assateague Island National Seashore.

Helen Violi, Ecologist, Assateague Island National Seashore

Jonathan Chase, vegetation technician, Assateague Island National Seashore.

Neil Winn, Cartographic Technician, Assateague Island National Seashore

Literature cited

Ailstock, M.S. Adaptive Strategies of Common Reed *Phragmites australis*. *Phragmites* in Virginia: A Management Symposium, December 14, 2000, Library of Virginia, Richmond, Virginia.

Chase, J., M. Ryder, and M. Sturm. 2008. Assateague Island National Seashore Alien Plant Management Program 2008 Report. Division of Resource Management, Assateague Island National Seashore October 2008.

Chase, J. and Sturm, M. 2008. Assateague Island National Seashore Alien Plant Management Program Report 2006-2007. Division of Resource Management, Assateague Island National Seashore. March 2008.

Faber-Langendoen, D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, J. Christy. 2008. Ecological Performance Standards for Wetland Mitigation: An Approach Based on Ecological Integrity Assessments. NatureServe, Arlington, VA.

Farnsworth, E. J. and L. A. Meyerson. 1999. Species composition and interannual dynamics of a freshwater tidal plant community following removal of the invasive grass, *Phragmites australis*. *Biological Invasions* 1:115–127.

Mack, R.N., D. Simberloff, W.M. Lonsdale, H. Evans, M. Clout, and F.A. Bazzaz. 2000. Biotic invasions: Causes, epidemiology, global consequences, and control. *Ecological Applications* 10: 689–710.

Teal, J. M. and S. Peterson. 2005. The interaction between science and policy in the control of *Phragmites* in oligohaline marshes of Delaware Bay. *Restoration Ecology* 13:223–227.

4.3.2 Horse abundance

Relevance and context

Feral horses have been present on Assateague since the 1600's and are an integral part of the Island's cultural history and traditions. The current population of horses are managed as two distinct herds, divided by a trans-island fence along the state line (Zimmerman et al., 2006). The Virginia herd inhabits the Chincoteague National Wildlife Refuge and is owned by the Chincoteague Volunteer Fire Department, which manages the population size by holding an annual summer roundup to auction off most of the foals. The Maryland herd inhabits the Assateague Island National Seashore and Assateague State Park and is managed by the National Park Service (Zimmerman et al., 2006).

When Assateague Island National Seashore was established in 1965 (Public law 89-195), most of the horses had been removed from the Island's Maryland portion and confined to Chincoteague National Wildlife Refuge. However, a small, free-ranging herd belonging to a Maryland landowner continued to reside in the Maryland portion of the Island (ASIS, 2008). When the National Park Service acquired ownership of this herd in 1968, the population numbered approximately 28 and rapidly grew to 166 horses by 1994 (Zimmerman et al., 2006).

The horses have a strong social structure, currently forming 26 matriarchal bands each with one stallion, several mares and offspring that move collectively between grazing, resting and finding water (ASIS, 2008; Keiper, 1976). Approximately half of the bands remain in the same general location throughout the year, while the remainder move between different summer and winter locations (Powell et al., 2006). Eight of the bands permanently reside on the north end of the Island (northern 13 km, 8 mi, of the Island) or the developed area (Figure 2.5) and a further ten bands move into this area during the summer (ASIS, 2008).

During the initial period of NPS ownership the horse population grew by more than 10% annually. By the late 1970's the first evidence of resource damage caused by horses was reported (Zervanos and Keiper, 1979). The horses spend approximately two thirds of their grazing time in the salt marsh and one third in the dunes (Zervanos, 1978; Zervanos and Keiper, 1979). One of the ecological impacts occurs in the dunes where the horses graze heavily on American beachgrass (*Ammophilia brevigulata*), which has an extensive root and rhizome system that accumulates sand, making this grass an important species for initiating dune formation and maintaining dune stability (Seliskar, 1997). Under experimental conditions the horses were shown to

Photo: istockphoto.com

Feral horses grazing on saltmarsh cordgrass on Assateague Island.

selectively graze the low salt marsh cordgrass (*Spartina alterniflora*) over saltgrass (*Distichlis spicata*), therefore potentially influencing marsh plant community structure. Trampling by horses may also limit the ability of marshes to accumulate sediment to balance marsh erosion (Furbish and Albano, 1994; Zimmerman et al., 2006).

In addition, horses cause impacts in the beach overwash habitats where grazing (by both horses and deer) upon the globally rare, federally threatened and state endangered, sea beach amaranth (*Amaranthus pumilus*; MNHP, 2010; USFWS, 1993) has been shown to reduce plant survival by 27% and reduce mean plant size by 58% (Sturm, 2008), particularly significant because plant size is exponentially correlated to seed production (Lea et al., 2003). These habitats also contain a suite of state threatened and endangered plants, as well as the federally threatened shorebird the piping plover (*Charadrius melodus*), that have been impacted by horse grazing, trampling, and disturbance (Lea et al., 2000; Zimmerman et al., 2006; ASIS, 2001).

Large scale exclosure studies have reported that horse grazing also has impacts upon the Seashore's forest and shrub habitats, where the horse's generalist feeding habits can effect change in community composition, species abundance and overall vegetation cover (Sturm, 2007).

By 1994, when the horse population reached 166 individuals, the NPS began a concerted management effort to reduce the population size through the use of immunocontraceptives (Zimmerman et al., 2006; ASIS, 2008). The vaccine inhibits reproduction in mares and was found to be successful without interfering with active pregnancies or the social organization of the horse population (Kirkpatrick, 1995).

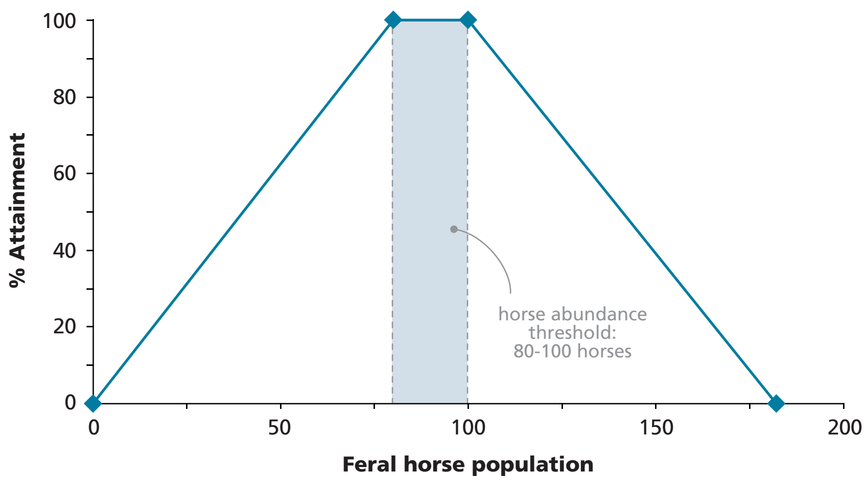


Figure 4.14. Application of management goal for feral horse population (80-100 individuals) to the calculation of % attainment of reference condition.

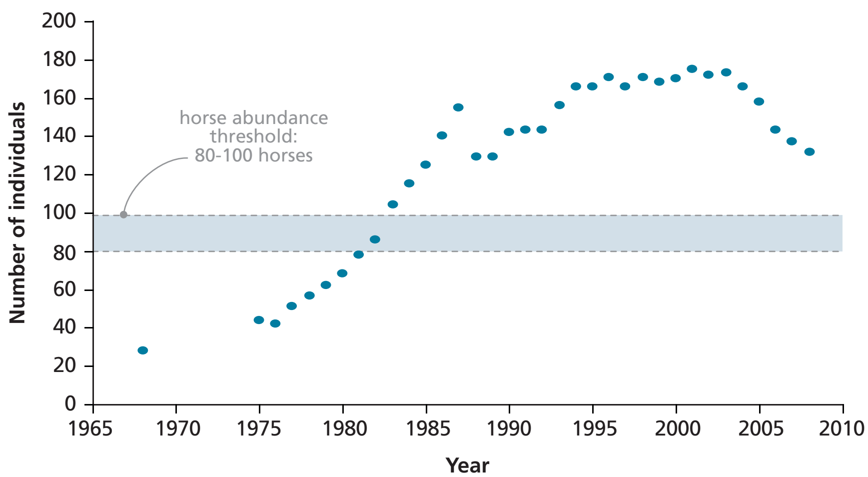


Figure 4.15. Feral horse abundance on the Maryland section of Assateague Island from 1968 until 2010 (Source: ASIS-NPS, annual horse monitoring reports 1968-2010; ASIS, 2010).

Two year old mares are treated with the immunocontraceptive for three years, after which treatment is ceased until such time as the mare has borne one foal when treatment recommences indefinitely (Kirkpatrick and Turner, 2002). With no natural predators on the island, foals and yearlings have a high survival rate of approximately 88% (Keiper and Houpt, 1984), and while life expectancy of both mares and stallions had been around 17 years, after the initiation of immunocontraception, the life expectancy of mares increased by 5-10 years (Turner and Kirkpatrick, 2002), which was significant in that it slowed the predicted rate of horse population reduction (Zimmerman et al., 2006).

Method

Annual counts of the feral horse population on Assateague Island have been carried out since 1975 (annual feral horse reports; ASIS, 2010) and these counts were directly used for the assessment of condition and trend, by comparing to the reference condition (Table 4.19, 4.20).

Reference condition

Although the feral horses are a non-native species with natural resource implications, they possess significant cultural value. Management goals therefore include both the maintenance of a viable herd as well as the maintenance of the ecosystem health of the habitats used by the horses (Zimmerman et al., 2006). The current management goal is to maintain a horse population on Assateague Island National Seashore between 80 and 100 individuals, as estimated by a simulation study to maintain genetic diversity, reproductive status, and health of the animals, while minimizing ecological impacts and disease (Ballou et al., 2008). This management goal was used as the desirable reference condition, that would achieve 100% attainment (Figure 4.14; Table 4.20). The extreme ranges of undesired condition were established as a population of 175 horses (the maximum population reached, in 2001) and zero, a simple linear calculation of % attainment of reference condition was calculated for horse populations between these end points (Figure 4.14).

Table 4.5. Abundance of horses on the Maryland section of Assateague Island during the assessment period (2000-2010), with calculations of attainment of reference condition. (Source: ASIS-NPS, annual horse monitoring reports 1968-2010; ASIS, 2010).

Year	Total horses	Attainment of Reference (%)
2000	170	6.65
2001	175	0
2002	172	4
2003	173	2.6
2004	166	12
2005	158	22.6
2006	143	42.6
2007	137	50.5
2008	132	57.2
2009	125	66.5
2010	115	79.8
Mean (2001-2010)	151	31.3
SE	4	6

Current condition

The current condition for the assessment period (2000-2010) was degraded, with the horse population ranging from 175 individuals in 2001 down to 115 in 2010.

Trend

The long-term trend of the feral horse population on the Seashore has been a significant increase since estimates began in 1968 ($r2=0.91$, $p<0.0001$; Figure 4.15). The total population of feral horses in 1968 was estimated at 28 individuals, which increased to 175 individuals by 2001 and, since the introduction of immunocontraception in 1994, has decreased back down to 115 in 2010, approaching the reference condition of 80-100 horses, attaining 79.8% of reference condition in 2010 (Figure 4.14, Table 4.5).

Data gaps and confidence in assessment

Currently collected monitoring data is appropriate for this assessment. A greater understanding of the direct impacts of horses, especially the effects of grazing and trampling on the regeneration and sedimentation of the marsh habitat would be beneficial.

Confidence in the assessment of condition was high and a confidence in assessment of trend was high.

Sources of expertise

Carl Zimmerman, Resource Management Specialist, Assateague Island National Seashore

Jack Kumer, Resource Management Specialist, Assateague Island National Seashore

Allison Turner, Biological Science Technician, Assateague Island National Seashore

Literature cited

ASIS. 2001. Piping plover (Charadrius melodus) management plan Assateague Island National Seashore. National Park Service. U.S. Department of the Interior.

ASIS. 2008. Environmental Assessment of Alternatives for Managing the Feral Horses of Assateague Island National Seashore.

ASIS. 2010. Assateague Island National Seashore data repository. In: National Park Service Natural Resource Information Portal. **https://nrinfo.nps.gov/Home.mvc** Accessed December 2010.

Ballou, J.D. et al., 2008. Simulation model for contraceptive management of the Assateague Island feral horse population using individual-based data. *Wildlife Research* 35(6): 502-512.

Furbish, C.E. and Albano, M. 1994. Selective herbivory and plant community structure in a mid-Atlantic salt marsh. *Ecology* 75(4):1015-1022.

Keiper, R.R. 1976. The Behavior, Ecology, and Social Organization of the Feral Ponies of Assateague Island. National Park Service.

Keiper, R.R. and Houpt, K. 1984. Reproduction in feral horses: an eight year study. *American Journal of Veterinary Research* 45: 991-995.

Kirkpatrick, J.F. 1995. Management of Wild Horses by Fertility Control: The Assateague Experience. National Park Service Scientific Monograph, National Park Service, Denver, CO 60 pp.

Kirkpatrick, J. F. and A. Turner. 2002. Reversibility of action and safety during pregnancy of immunizing against porcine zona pellucida in wild mares (Equus caballus). *Reproduction Supplement* 60:197-202.

Lea, C., M. Sturm, H. Hamilton, S. Weller, S. King, and B. McIntyre. 2003. Assateague Island National Seashore seabeach amaranth restoration final report—2002. National Park Service, Assateague Island National Seashore, Berlin, Maryland, USA.

Lea, C., Hamilton, H., Hudson, F.K., Roeder, N. 2000. Additions to flora and rare plant surveys and status 1996-1999. Assateague Island National Seashore, Division of Resource Management Report.

Maryland Natural Heritage Program. 2010. Rare, Threatened and Endangered Plants of Maryland. April 2010 edition. Maryland Department of Natural Resources, Wildlife and Heritage Service, Annapolis, Maryland.

Powell, D. M., D. E. Danze, and M.W. Gwinn. 2006. Predictors of biting fly harassment and its impact on habitat use by feral horses (*Equus caballus*) on a barrier island. *Journal of Ethology* 24: 147-154.

Public law 89-195. September 21, 1965. 79 Stat. 824.

Seliskar, D. 1997. The Effect of Grazing by Feral Horses on American Beachgrass at Assateague Island National Seashore. Final Report. University of Delaware.

Sturm, M. 2007. Assessment of the Effects of Feral Horses, Sika Deer and White-Tailed Deer on Assateague Island's Forest and Shrub Habitats. Assateague Island National Seashore.

Sturm, M. 2008. Saving the Seabeach Amaranth. *Park Science* 25(1).

U.S. Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants; determination of seabeach amaranth (*Amaranthus pumilus*) to be a threatened species. *Federal Register* 58(65) 18035-18042.

Zervanos, S. M. 1978. Summer determination of activity patterns of Assateague ponies by means of long range telemetry. National Park Service, Assateague Island National Seashore, Berlin, Maryland.

Zervanos, S. M. and R. R. Keiper. 1979. Winter activity patterns and carrying capacities of Assateague Island feral ponies. Final Report, Contract No. PX2000-8-D045. Assateague Island National Seashore, Berlin, MD. 12pp.

Zimmerman, C., M. Sturm, J. Ballou, and K. Traylor-Holzer (eds.). 2006. Horses of Assateague Island Population and Habitat Viability Assessment: Final Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN.

4.3.3 Deer density

Relevance and context

Two species of deer occur on Assateague Island, the native white tail deer (*Odocoileus virginianus*) and the introduced sika deer (*Cervus nippon*; actually a species of elk). Currently sika deer make up approximately 75% of the total deer population on the Seashore (Sturm, 2007). White tailed deer were largely unknown on Assateague Island until the late 1950's, with only very occasional sightings (Paradiso and Handley Jr., 1965). This reflected the low numbers of white tail deer throughout the mid Atlantic US states at that time, but concerted efforts by wildlife managers to regulate hunting during the early 20th century were effective in protecting and recovering white tail deer populations throughout the region (Waller and Alverson, 1997). The currently high population numbers for white-tailed deer regionally have been recognized since the 1980's as being of concern due to potentially large impacts upon regeneration of woody tree species as well as the occurrence and abundance of herbaceous species and consequent alterations to trophic interactions (Waller and Alverson, 1997). Sika deer, native to the orient, were introduced to James Island on Chesapeake Bay in 1916 and slowly began to spread into the Delmarva region (Flyger, 1960). Five animals were sold to a Berlin resident, resold and ultimately released onto Assateague Island where they moved to the south end of the island and multiplied to a herd in excess of 100 individuals by the late 1950's, (Flyger, 1960; Paradiso and Hendley Jr., 1965).

Public hunting was authorized as a recreational activity in the establishment of Assateague Island National Seashore (Public Law 89-195), and includes hunting of both sika and white tail deer with seasons for archery, muzzleloaders and shotguns (ASIS, 2010b). Public hunting is currently used as a mechanism for managing the deer populations on Assateague Island. From 2002-2006, an average of 141 deer were harvested annually during the hunting. However, despite regular hunting pressure since the 1970's in both the Seashore and Chincoteague National Wildlife Refuge, sika deer have become and remain the most abundant large mammal on Assateague Island.

Sika deer fawn on Assateague Island.

Method

Population size was estimated using distance sampling between 2003 and 2006. These population estimates were converted to densities using the total area of utilized habitat; shrub and forest, dune and grassland, inland wetlands and salt marsh (Table 4.19; Sturm, 2007), and then compared to the reference condition. The population estimates are highly conservative, as counts were carried out after the end of the hunting season but before the breeding season in each year, so the deer populations were at their annual minimum (Sturm, 2007).

Reference condition

A reference condition of forest habitats with less than 8.0 deer km^{-2} was deemed appropriate as the deer predominantly reside within the Seashore's forest and shrubland habitats (Diefenbach and Christensen, 2009; Table 3.8). A reference condition of <8.0 deer km^{-2} is a well-established forest threshold for the mid-Atlantic US mainland (Table 4.20, Horsley et al., 2003). Even densities as low as 3.7 deer km^{-2} have been shown to have detrimental effects on vegetation, reducing the species richness and abundance of herbs and shrubs, and an overwintering population density of <5.8 deer km^{-2} has been suggested as needed to

Table 4.6. Estimate of total deer density (combined total for white tail, Odocoileus virginianus and sika deer, Cervus nippon) on Assateague Island National Seashore between 2003 and 2006 (from Sturm, 2007).

Year	Sika deer	White tail deer	Total density (deer km^{-2})	95% CI
2003	343	122	14.86*	9.42-23.45
2004	368	113	15.37*	9.81-24.22
2005	401	104	16.13*	9.97-26.17
2006	342	116	14.63*	8.56-25.08
		Mean:	**15.25***	
		SE:	**0.33**	

* Values outside of reference condition range <8.0 deer km^{-2}.

maintain forest regeneration (Tilghman, 1989; Decalesta 1997). A large ecosystem manipulation study in central Massachusetts found that deer densities of 10-17 km^{-2} inhibited the regeneration of understory species, and densities of 3-6 km^{-2} supported a diverse and abundant forest understory (Healy, 1997). In addition, changes in undergrowth due to deer herbivory can account for a decrease in sensitive species of birds that depend on those areas for nesting, foraging, and protection (McShea and Rappole, 2000). Although songbird species vary in their sensitivity to increases in deer populations, changes can occur at deer densities greater than 7.9 km^{-2} (Decalesta, 1997). Recognizing that none of these studies were carried out on coastal barrier islands, reference densities should be applied with caution.

Current condition

Population estimates for the combined deer population for 2003-2006 (all available data) all exceed the reference condition of <8 deer km^{-2}, with a mean deer population of 15.2±0.3 deer km^{-2}, for all years. In all cases, the lower limit of the 95% confidence interval estimate was still higher than the reference condition, and these population estimates represent an annual minimum (Sturm, 2007; Table 4.6). As such, deer population density for 2003-2006 attains 0% of reference condition and indicates a very degraded condition. (Table 4.21).

Trend

Only four years of data for population estimates was available, during which time there were no major changes in overall deer population size (Table 4.6). Since the 1950's, however, white tail deer numbers have increased from close to zero to a population of over 100, and sika deer have increased from a population of approximately 160 to over 350, even with active hunting since the early 1970's (Paradiso and Handley Jr., 1965). The white tail population has been far from stable, however, the population collapsed in 1987 and only in 2006 was the population considered sufficiently stable to once again allow harvest of females.

Data gaps and confidence in assessment

Owing to the challenges associated with population estimation techniques, future assessments should emphasize the effects of deer herbivory on plant community health rather than absolute deer density. Site specific Indices of vegetation condition are currently being developed and, in conjunction with an index of deer density, should allow for a more accurate consideration of deer effects in future assessments. Confidence in assessment of current condition was fair and confidence in assessment of trend was limited.

Table 4.7. Summary of total deer harvest numbers 2002-2006 (Sturm, 2007).

Season	Sika deer	White tail deer
2002-2003	135	Closed
2003-2004	148	Closed
2004-2005	140	15
2005-2006	144	24

Sources of expertise

Carl Zimmerman, Resource Management Specialist, Assateague Island National Seashore

Jack Kumer, Resource Management Specialist, Assateague Island National Seashore

Literature cited

ASIS. 2010b. Assateague Island National Seashore General Hunting Regulations 2010-2011. **http:www.nps.gov/asis**

Decalesta, D.S. 1997. Deer Ecosystem Management. **In:** McShea, W.J., H.B. Underwood, and J.H. Rappole (eds). *The science of overabundance: Deer ecology and population management.* pp. 267-279. Springer, Netherlands.

Diefenbach, D. R., and S. A. Christensen. 2009. Movement and habitat use of sika and white-tailed deer on Assateague Island National Seashore, Maryland. Natural Resource Technical Report NPS/NER/NRTR—2009/140. National Park Service, Philadelphia,

Flyger, V. 1960. Sika Deer on Island in Maryland and Virginia. *Journal of Mammalogy* 41(1): 140.

Healy, W.M. 1997. Influence of deer on the structure and composition of oak forests in central Massachusetts. **In:** McShea, W.J., H.B. Underwood, and J.H. Rappole (eds). *The science of overabundance: Deer ecology and population management.* Springer, Netherlands. Pp. 249-266.

Horsley, S.B., S.L. Stout, and D.S. deCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. *Ecological Applications* 31(1):98-118.

McShea, W.J. and J.H. Rappole, 2000, Managing the abundance and diversity of breeding bird populations through manipulation of deer populations. *Conservation Biology* 14: 1161-1170.

Paradiso, J.T. and Handley Jr., C.O. 1965. Checklist of mammals on Assateague Island. *Chesapeake Science* 6(3): 167-171.

Public law 89-195. September 21, 1965. 79 Stat. 824.

Sturm, M. 2007. Assessment of the effects of feral horses, sika deer and white-tailed deer on Assateague Island's forest and shrub habitat. Assateague Island National Seashore, National Park Service.

Tilghman, N.G. 1989, Impacts of White-tailed deer on forest regeneration in NW Pennsylvania. *Journal of Wildlife Management* Vol 53, pp 524-532.

Waller, D.M. and Alverson, W.S. 1997. The white-tailed deer: a keystone herbivore. *Wildlife Society Bulletin* 25(2): 217-226.

4.3.4 Piping Plover fecundity

Relevance and context

North America is the only breeding grounds for the piping plover (*Charadrius melodus*) and while it was historically common, piping plovers were in threat of extinction in the early 20th Century due to hunting (Haig and Oring, 1985; USFWS, 1996). Protective legislation in 1925 resulted in some recovery of breeding populations, however numbers reached a maximum in the 1930's after which they once again continued to decline (Haig and Oring, 1985). The Atlantic population, which has four units (Atlantic Canada, New England, New York-New Jersey and Southern, including Assateague Island) and does not interbreed with the inland populations, had a documented decline of some 30% of breeding pairs between 1980 and 1984 (Haig and Oring, 1985; USFWS, 1996). In 1986, the Atlantic Coast population of the piping plover was added to the United States List of Endangered and Threatened Wildlife and Plants as a threatened species, and has also been listed as near threatened on the International Union for the Conservation of Nature Red List (USFWS, 1985; IUCN, 2010). Since being listed as threatened, and the subsequent implementation of the piping plover Atlantic coast recovery plan (USFWS, 1996), the number of breeding pairs in the Atlantic coast population has increased from 790 pairs in 1986 to 1,749 pairs in 2006, which is approaching the target population of 2000 breeding pairs (USFWS, 1996; Hecht and Melvin, 2009). This increase was not, however, uniform amongst the four recovery units on the Atlantic coast. New England had a 300% increase in number of breeding pairs between 1986 and 2006, while the southern unit (including Assateague Island) increased by 50% from 199 to 321 breeding pairs, where the target population is 400 breeding pairs (USFWS, 1996; Hecht and Melvin, 2009).

Piping plover (*Charadrius melodus*)

Photo: istockphoto.com

Piping plover have very specific habitat requirements, that include a combination of dry open nesting media along with unvegetated wetlands that are moist but not wet. Active over-wash habitat, a globally rare process and habitat type but fairly common on Assateague Island (Kochel and Wampfler, 1989), provides the unique combination of dry sandy areas with recently accreted sand, along with overwash deposition fans that terminate in fresh, brackish or salt water wetlands. Nesting habitat can include beach berms, gently sloping dunes, sparsely vegetated back dunes and, in some cases, dredge material placed for beach nourishment (ASIS, 2001; Kraus, 2006). The necessity for successful breeding on Assateague Island is, however, the availability of interior or bayside foraging habitat for the plover chicks. Piping plover chicks reared with access to the bayside beach and the island interior have higher survival, greater foraging rates and spend more time foraging than those confined to the ocean beach (Loegering and Frazer, 1995). To access these foraging grounds chicks move from the ocean beach nest sites to bay beach and interior foraging areas via overwash paths, free from vegetation (Loegering and Fraser, 1995). Extended periods without storm overwash can result in these important pathways becoming overgrown and limit access to productive foraging grounds by chicks.

The goals of the Assateague Island National Seashore Piping Plover Management program include monitoring populations, minimizing human disturbance, and protection from predators in order to promote reproductive success (ASIS, 2001). Predators have been identified as a major factor in nest loss, accounting for 91% of all failed nests in one study on the Seashore and include foxes, raccoons, crows, gulls, resident geese and migratory falcons (Patterson et al., 1991; ASIS, 2009). Another source of disturbance to breeding piping plovers on Assateague Island is the feral horse population (ASIS, 2009). Active management to enhance breeding success includes placing predator exclosures around nests; 77% of all nests were protected by exclosures over the most recent 10 breeding seasons (Kumer, 2010). Additional active predator management is carried out as necessary, such as trapping of foxes and addling of eggs from resident Canada geese (ASIS, 2009).

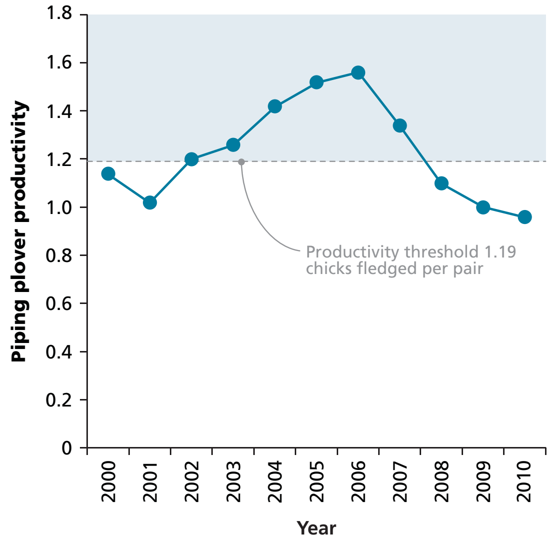


Figure 4.16. Productivity of piping plover (*Charadrius melodus*) within Assateague Island National Seashore, as a five year rolling mean, relative to reference condition (at least 1.19 fledged chicks per breeding pair).

Method

Data are collected through a series of population surveys, recording number of breeding pairs, hatching and fledging success, from which the annual fecundity is calculated as the number of chicks fledged per breeding pair (ASIS, 2010). Data from 2000-2010 were used for the assessment of condition and from 1986 – 2010 for assessment of trend (ASIS, 2009). For each year of data, comparison was made to the reference condition and a percent attainment was then calculated.

Reference condition

The U.S. Fish and Wildlife Service established conservation goals for the Atlantic coast population of piping plovers including a breeding population of 2,000 pairs, 400 in the southern recovery unit (Delaware –North Carolina, including Assateague Island), and a five–year average productivity rate of 1.5 fledged chicks per breeding pair (USFWS, 1996). This productivity level was calculated using viability analysis based on age-specific survival rates and varying levels of fecundity (USFWS, 1996). Data collected between 1989 and 2006 was used to reflect on the earlier projections and to model levels of productivity necessary to sustain populations based on each recovery unit separately (Hecht and Melvin, 2009). Those data document the overall population moving from 48% to 87% of the goal, with the southern unit increasing from 50% to 80% of its targeted population. For the years in review, the southern unit was able to sustain its population with a productivity rate of 0.93 chicks per breeding pair, while the average productivity rate responsible for the population increase was 1.19 chicks per pair. Productivity data from Assateague for 1986-2009 also had an average rate of 1.19 fledglings per pair. The authors recognized that for any unit, productivity was variable and there were no sustained trends. This could be due to the fact that plover breeding success is influenced by changing habitat condition, annual weather events, and unpredictable depredation pressures (Kumer, 2010). From 1986 to 2009, the Assateague Island breeding plover population has experienced dramatic changes due to all of these conditions. In response, the plovers have adjusted by selecting the best available breeding habitat. With breeding birds able to move breeding location within the recovery unit, the important annual strategy at each site is to achieve a level of productivity that supports an increase to the overall population. A 5-year running mean of 1.19 fledged chicks per breeding pair annual productivity was therefore used as the reference condition for this assessment.

Current condition

Between 2000 and 2010, piping plover productivity on the Seashore ranged from 0.4 to 1.9, with a 5-year running mean attaining the desired reference condition of ≥1.19 fledged chicks per breeding pair in

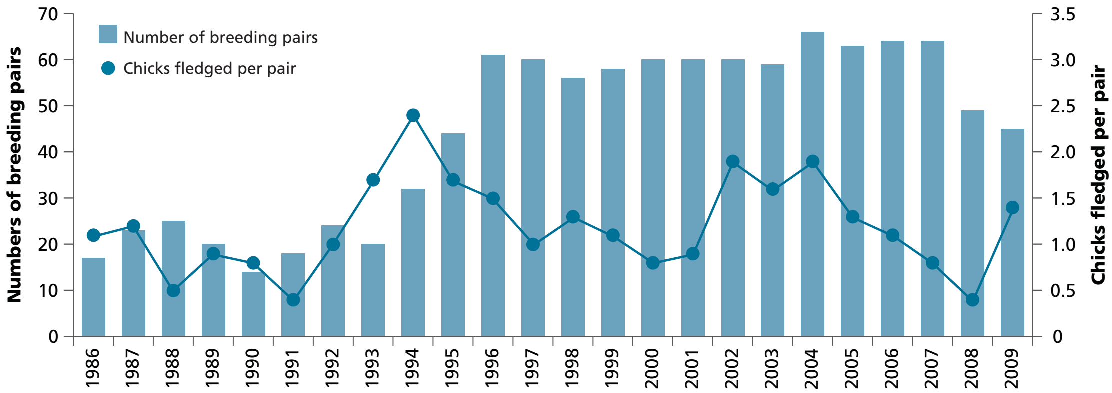


Figure 4.17. Abundance of breeding pairs and fledgling success for piping plover (*Charadrius melodus*) within Assateague Island National Seashore. (Source; ASIS, 2010; annual piping plover monitoring reports 1996-2010).

six of eleven time periods, attaining 54% of reference condition (Figure 4.16; Table 4.21).

Trend

While the population of breeding pairs of piping plovers on Assateague Island had a two to three fold increase over the years 1986-2008 (Kraus, 2006), the rate of successfully fledged chicks per pair, while being well within reference condition between 1993-1996 and 2002-2005, has been generally below reference condition during other years (Figure 4.17). Between 1986-2006, the total number of breeding pairs for the entire Atlantic population has increased from 790 to 1749, and successful chick fledging per breeding pair has shown steady increase from approximately 0.8 in 1986 to approximately 1.8 in 2006 (Hecht and Melvin, 2009). Piping plovers have been observed to respond to changes in habitat structure and availability. Studies in both Rhode Island and Long Island recorded increases in populations after major hurricanes in 1938 and 1954 which created overwash nesting habitat, and declines after WWII with major dune stabilization efforts and vacation home construction (Wilcox, 1959; USFWS, 1996). Habitat availability is also the likely explanation for the trends within the Seashore, with large storm events in the early 1990's expanding overwash fans and therefore foraging habitat for breeding birds, resulting in the rapid expansion of population during the period 1993-1996. Another storm event in the late 1990's maintained the availability of this breeding habitat (Figure 4.17). While predation and drought have had some impact upon fledging success, lack of storms during the 2000's and therefore lack of island overwash has allowed re-growth of vegetation, limiting the ability of young chicks to access food on the bay side flats is likely a major contributing factor in the low fledging success observed since 2006 (Patterson et al., 1991; Loegering and Fraser, 1995; Figure 4.17).

Data gaps and confidence in assessment

Current monitoring of piping plover fledging success is appropriate to assess this resource.

Confidence in assessment of current condition was high and confidence in assessment of trend was high.

Sources of expertise

Carl Zimmerman, Resource Management Specialist, Assateague Island National Seashore

Jack Kumer, Resource Management Specialist, Assateague Island National Seashore

Tami Pearl, Biological Science Technician, Assateague Island National Seashore

Literature cited

ASIS. 2001. Piping plover (*Charadrius melodus*) management plan Assateague Island National Seashore. National Park Service. U.S. Department of the Interior.

ASIS. 2009. Management and monitoring of the piping plover, *Charadrius melodus*, 2009 breeding season. Natural Resource Report, Assateague Island National Seashore. September 2009.

ASIS. 2010. Assateague Island National Seashore data repository. In: National Park Service Natural Resource Information Portal. **https://nrinfo.nps.gov/Home.mvc** Accessed December 2010.

Haig, S.M. and Oring, L.W. 1985. Distribution and status of the piping plover throughout the annual cycle. *Journal of Field Ornithology* 56(4): 334-345.

Hecht, A. and Melvin, S.M. 2009. Population trends of Atlantic coast piping plovers, 1986-2006. *Waterbirds* 31(2): 64-72.

IUCN. 2010. IUCN Red List of threatened species. Version 2010.3. **www.iucnredlist.org** Downloaded on 27 September 2010.

Kochel, R.C. and Wampfler, L.A. 1989. Relative role of overwash and Aeolian processes on washover fans, Assateague Island, Virginia-Maryland. **Journal of Coastal Research** 5(3): 453-475.

Kraus, N.C. 2006. Understanding piping plover population dynamics through mathematical model, with application to northern Assateague Island, Maryland, and Long Island, New York, barrier beaches. *Shore and Beach* 74(1): 3-9.

Kumer, J. 2010. Personal communication. Resource Management Specialist, Assateague Island National Seashore.

Loegering, J.P. and Fraser, J.D. 1995. Factors affecting piping plover chick survival in different brood-rearing habitats. *Journal of Wildlife Management* 59(4): 646-655.

Patterson, M.E., Fraser, J.D. and Roggenbuck, J.W. 1991. Affecting piping plover productivity on Assateague Island. *The Journal of Wildlife Management* 55(3): 525-531.

U.S. Fish and Wildlife Service. 1985. Endangered and threatened wildlife and plants; determination of endangered and threatened status for the piping plover: Final Rule. Federal Register 50(238) 50726-50734.

U.S. Fish and Wildlife Service. 1996. Piping Plover (*Charadrius melodus*), Atlantic Coast Population, revised recovery plan. Hadley Massachusetts. 258pp.

Wilcox. L. 1959. A twenty year banding study of the piping plover. *Auk* 76:129-152.

4.3.5 Seagrass area

Relevance and context

Seagrass meadows are declining globally, at a rate of 110 km^{-2} yr since 1980, with a documented loss of nearly 30% of the known areal extent since the first known records in 1879 (Waycott et al., 2009). Declining water quality is recognized as being the greatest cause of global seagrass decline, however seagrass has been shown to be resilient and responsive to reduced nutrient input with recovery of areal coverage (Orth et al., 2010).

The dominant seagrass in the coastal bays inland of Assateague Island is *Zostera marina* (Eelgrass), which anecdotal reports suggest was very abundant in these bays in the early 1900's (Orth et. al., 2006). During the 1930's major declines in *Z. marina* abundance occurred throughout the north Atlantic as a result of wasting disease. The coastal bays of Maryland and Virginia were no exception, and by the 1950's Chincoteague Bay was still almost devoid of seagrass (Cottam and Munro, 1954). Areal extent was still low when annual monitoring of these bays was commenced in 1986 (Orth et al., 2006a).

Seagrass provides many ecosystem services including significant carbon sequestration (Duarte et al., 2010) and support of higher trophic levels in both marine and terrestrial environments (Heck et al., 2008). Seagrass in general, and *Z. marina* specifically, provides food and habitat structure supporting a diversity of waterbirds, finfish, bivalves and crustaceans, including many commercially and recreationally important species (Orth et al., 2006b; Moore and Short, 2006). One, well documented, example within Chincoteague Bay is the Bay Scallop (*Argopecten irradians*), which was sufficiently abundant in 1931 to support a moderate commercial fishery (CFV, 1931; Tarnowski, 2004). However, in recognition that *A. irradians* used *Z. marina* meadows as protective habitat, there were concerns that the loss of *Z. marina* would have a major impact on *A. irradians* abundance (CFV, 1932). These losses occurred as predicted, and by 1933 abundances were so low that *A. irradians* no longer warranted status as a viable fishery by the Virginia Commission of Fisheries (CFV, 1933). Since the mid 1990's, small numbers of bay scallops have been consistently reported in Chincoteague Bay, although densities remain low and it is uncertain if current densities represent a viable long-term population (Tarnowski, 2004).

Zostera marina (Eelgrass) in the Coastal Bays.

Photo: Tim Carruthers, IAN Image Library

Method

Annual aerial surveys taking black and white photos at a scale of 1:24,000 were used to identify visible seagrass beds, and verified with ground surveys by Virginia Institute of Marine Science staff and cooperators (Table 4.19, Orth et al., 2004; www.vims.edu/bio/sav/). The measured aerial coverage for each bay in each year between 2000 and 2008 was compared to the desired reference condition to calculate a percentage attainment.

Reference condition

Potential seagrass habitat for Chincoteague and Sinepuxent Bays, the two bays adjacent to Assateague Island, was determined using criteria of < 1.5 m mean water depth (based on a composite seagrass layer from 1986-2003 which showed that 93% of all seagrasses were growing in water less than 1.3 m deep) and a silt/clay content of < 35% (E.M. Koch, unpublished data; Wazniak et al., 2007). This resulting reference condition was an area of 1226 ha (3,031 acres) of potential seagrass habitat in Sinepuxent Bay and 8,256 ha (20,400 acres) of potential seagrass habitat in Chincoteague Bay

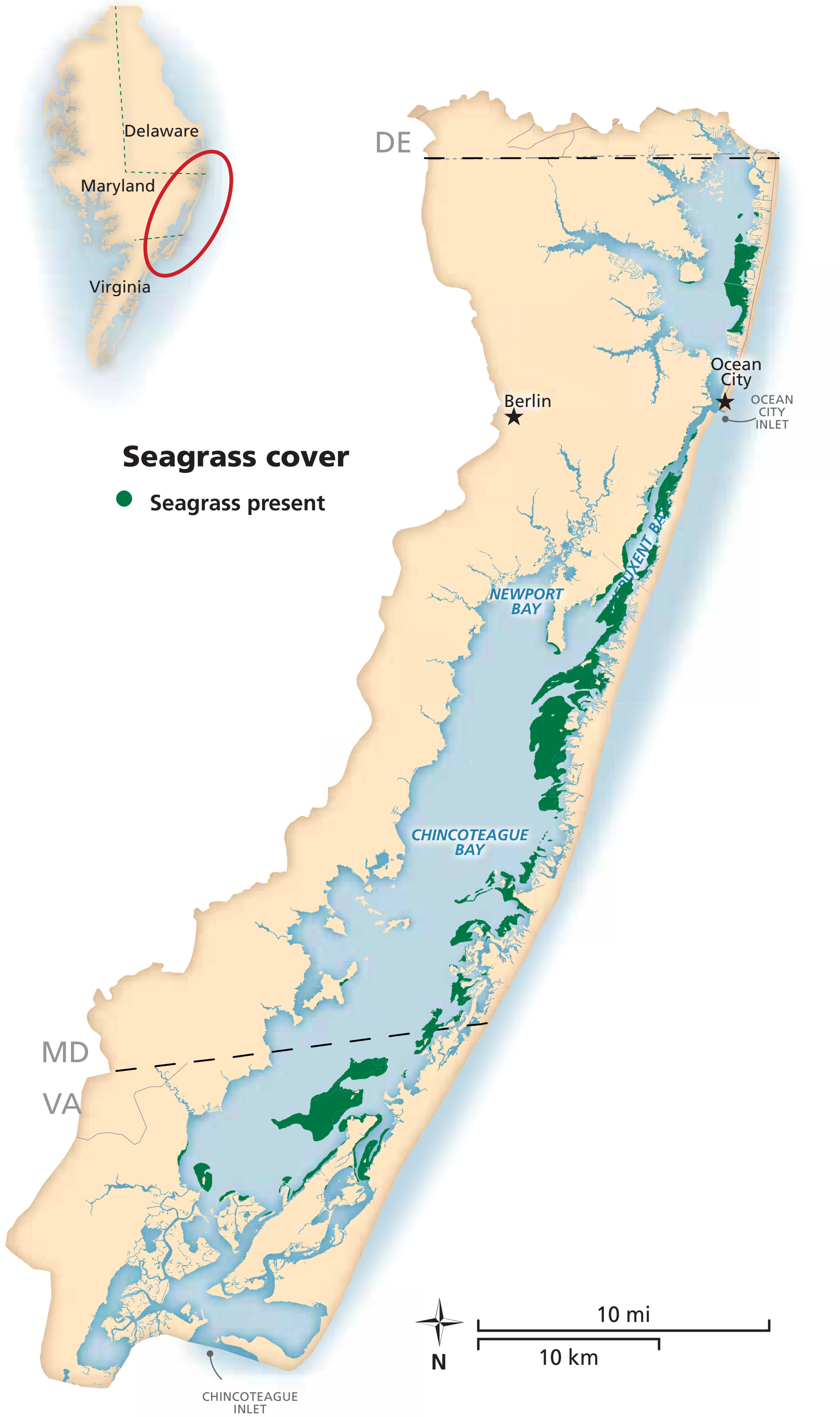


Figure 4.18. Seagrass distribution throughout the Coastal Bays for 2009.

Data source: EcoCheck http://www.eco-check.org/reportcard/mcb/2009/indicators/seagrass/#_Data_Map

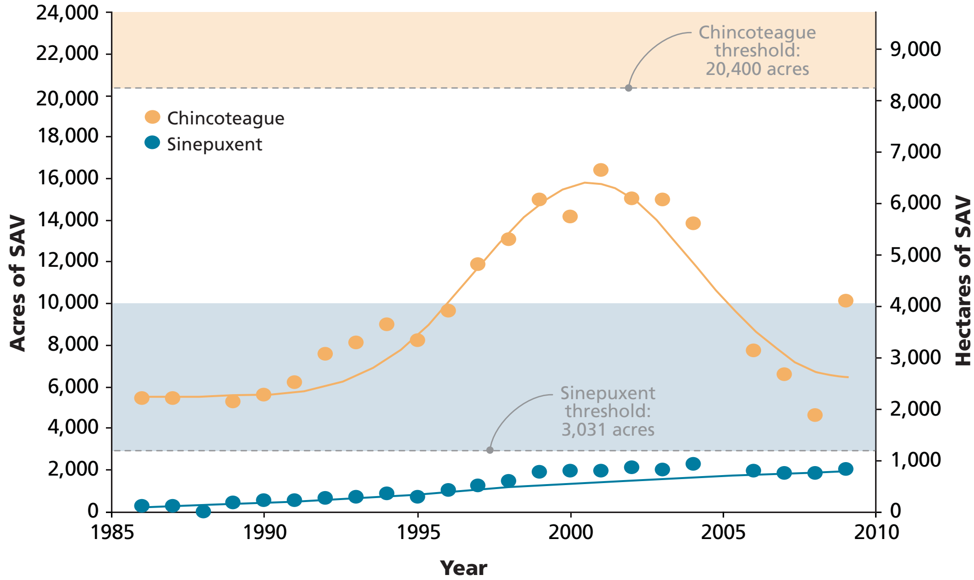


Figure 4.19. Historical trends in seagrass in Chincoteague and Sinepuxent Bays, adjacent to Assateague Island National Seashore (source: Virginia Institute of Marine Science; http://web.vims.edu/bio/sav).

(Figure 4.18; Table 4.20). This resource was assessed from the eastern to western shore of each bay, even though the Seashore boundary only extends a maximum of 1.5 km (0.9 mi) into the bays. The justification of this approach was that the resource functions at a system or bay-wide scale, and changes at this broader scale have implications to many natural resources within Seashore.

Current condition

Over the ten years of data considered (2000-2009), Seagrass abundance overall was in a good condition, attaining 61% of the reference condition (Table 4.21). Areal extent of seagrass in Chincoteague Bay ranged from a minimum of 1,874 ha (4,631 acres) in 2008 up to 6,616 ha (16,349 acres) in 2001, attaining 56% of the reference condition, during the decade, indicating a fair condition. Sinepuxent Bay, with a range from 738 ha (1,824 acres) in 2007 to 923 ha (2,282 acres) in 2004, attained 66% of the reference condition during the decade, resulting in an assessment of very good condition for this resource (Figure 4.19).

Trend

After four to five decades of minimal seagrass occurrence, starting in the mid 1980's and continuing through the 1990's, seagrass area in Chincoteague Bay tripled and in Sinepuxent Bay increased by some forty times (Figure 4.19; Wazniak et al., 2004; Orth et. al., 2006a). Relatively low genetic diversity in these meadows suggests that the re-growth was from a few remnant populations as well as, perhaps, intentional but undocumented transplantations (Williams and Orth, 1998). However, seagrass area in Chincoteague reached a maximum in 2001 and has subsequently been generally, once again, declining, a change which this time has been linked to the recent declines in water quality throughout the coastal bays and several years of record high summer water temperatures (Orth et. al., 2010a; Wazniak et. al., 2007). In 2009, the area of seagrass in Chincoteague Bay once again doubled from the 2008 area, in nearby Chesapeake Bay the mid-bay sections have been increasingly variable in seagrass abundance, over the past decade (Orth et al., 2010b).

Data gaps and confidence in assessment

Current annual monitoring is appropriate to assess this resource and should be continued. Meadow scale monitoring would enhance the ability to interpret causes of trends and potentially detect early signs of stress, and assessment of species would be beneficial as Chesapeake Bay has seen a historical shift from *Zostera marina* (Eelgrass) to *Ruppia maritima* (Widgeongrass) in the med-section of the Bay.

Confidence in assessment of current condition was high and in assessment of trend was high.

Sources of expertise

Evamaria Koch, Associate Professor, University of Maryland Center for Environmental Science

Robert Orth, Professor of Marine Science, Virginia Institute of Marine Science

William Dennison, Vice President for Science Applications, University of Maryland Center for Environmental Science

Tim Carruthers, Associate Research Scientist, University of Maryland Center for Environmental Science

Michael Williams, Associate Research Scientist, University of Maryland Center for Environmental Science

Cathy Wazniak, Environmental Program Manager, Maryland Department of Natural Resources

Literature cited

Commission of Fisheries of Virginia. 1931. Thirty third annual report for the fiscal year ending June 30, 1931. Richmond: division of purchasing and printing.

Commission of Fisheries of Virginia. 1932. Thirty fourth annual report for the fiscal year ending June 30, 1932. Richmond: division of purchasing and printing.

Commission of Fisheries of Virginia. 1933. Thirty fifth annual report for the fiscal year ending June 30, 1933. Richmond: division of purchasing and printing.

Cottam, C. and Munro, D.A. 1954. Eelgrass status and environmental relations. *Journal of Wildlife Management* 18(4): 449-460.

Duarte, C.M., Marba, N., Gacia, E., Fourqurean, J.W., Beggins, J., Barron, C. and Apostolaki, E.T. 2010. Seagrass community metabolism: assessing the carbon sink capacity of seagrass meadows. *Global Biogeochemical Cycles* 24 GB4032, 8 PP., doi:10.1029/2010GB003793

Heck Jr., K.L., Carruthers, T.J.B., Duarte, C.M., Hughes, A.R., Kendrick, G., Orth, R.J. and Williams, S.W. 2008. Trophic transfers from seagrass meadows subsidize diverse marine and terrestrial consumers. *Ecosystems* 11: 1198-1210.

Moore, K.A. and Short, F.T. 2006. Zostera: biology, ecology and management. **In:** Larkum, A.W.D., Orth, R.J. and Duarte, C.M. (Eds). *Seagrasses: biology, ecology, and conservation.* Springer, Dordrecht, The Netherlands. 691pp.

Orth, R.J., Wilcox, D.J., Nagey, L.S., Owens, A.L., Whiting, J.R. and Serio, A. 2004. 2003 distribution of submerged aquatic vegetation in Chesapeake Bay and Coastal Bays. Virginia Institute of Marine Sciences, Cloucester, Virginia, USA. (**www.vims.edu/bio/sav/sav03/index.html**).

Orth, R.J., Luckenback, M.L., Marion, S.R., Moore, K.A. and Wilcox, D.J. 2006a. Seagrass recovery in the Delmarva Coastal Bays, USA. *Aquatic Botany* 84: 26-36.

Orth, R.J., Carruthers, T.J.B., Dennison, W.C., Duarte, C.M., Fourqurean, J.W., Heck, K.L. Jr, Hughes, A.R., Kendrick, G.A., Kenworhy, W.J., Olyarnik, S., Short, F.T., Waycott, M. and Williams, S.L. 2006b. A global crisis for seagrass ecosystems. *Bioscience* 56(12):987-996.

Orth, R.J., Marion, S.R., Moore, K.A. and Wilcox, D.J. 2010a. Eelgrass (*Zostera marina L.*) in the Chesapeake Bay Region of Mid-Atlantic coast of the USA: challenges in conservation and restoration. *Estuaries and Coasts* 33: 139-150.

Orth, R.J., Williams, M.R., Marion, S.R., Wilcox, D.J., Carruthers, T.J.B., Moore, K.A., Kemp, W.M., Dennison, W.C., Rybicki, N., Bergstrom, P. and Batiuk, R.A. 2010b. Long-term trends in submersed aquatic vegetation (SAV) in Chesapeake Bay, USA, related to water quality. *Estuaries and Coasts* 33:1144-1163.

Tarnowski, M.L. 2004. Status of shellfish populations in the Maryland Coastal Bays. **In:** *Maryland's Coastal Bays ecosystem health assessment.* MD DNR-12-1202-0009. Chapter 8.4 pp 8/52 – 8/73.

Waycott, M., Duarte, C.M., Carruthers, T.J.B., Orth, R.J., Dennison, W.C., Olyarnik, S., Calladine, A., Fourqurean, J.W., Heck Jr., K.L., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Short, F.T. and Williams, S.L. 2009. Accelerating loss of seagrass across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Science* 106(30): 12377-12381.

Wazniak, C., Karrh, L., Parham, T., Naylor, M., Hall, M., Carruthers, T. and Orth, R. 2004. Seagrass abundance and habitat criteria in the Maryland Coastal Bays **In:** *Maryland's Coastal Bays ecosystem health assessment.* MD DNR-12-1202-0009. Chapter 6.1 pp 6/2 – 6/17.

Wazniak, C.E., Hall, M.R., Carruthers, T.J.B., Sturgis, B., Dennison, W.C. and Orth, R.J. 2007. Linking water quality to living resources in a mid-Atlantic lagoon system, USA. *Ecological Applications* 17(5S): 64-78.

Williams, S.L. and Orth, R.J. 1998. Genetic diversity and structure of natural and transplanted eelgrass populations in the Chesapeake and Chincoteague Bays. *Estuaries* 21(1): 118-128.

4.3.6 Horseshoe Crabs

Relevance and context

Horseshoe crabs in the mid-Atlantic region are an important economic and ecological resource, providing a link in near-shore food webs and a food source for migratory shorebirds (Botton et al., 1994, USFWS, 2003). Horseshoe crab eggs are a major source of food for Red Knots (*Calidris canutus*), a migratory shorebird of conservation concern whose population decline has reflected that of their food source (Botton et al., 1994, Karpanty et al., 2006). In an economic context, horseshoe crabs have become important for bait fisheries, biomedical uses, and ecotourism in the Mid Atlantic region, especially in the 1990's as they became valuable and overfished for use as American Eel (*Anguilla rostrata*) and Whelk (*Busycon spp.*) bait (Manion et al., 2000). The Atlantic States Marine Fisheries Commission (ASMFC) established an interstate fishery management plan for the horseshoe crab in 1998 (Schrading et. al., 1998). The aim of the plan is to maintain a spawning stock biomass sufficient for use by the fishing and non fishing public, migrating shorebirds, and other dependent wildlife, including sea turtles (Schrading et. al., 1998).

Method

At three sites on the north end of Assateague Island, counts of horseshoe crabs in a waterline belt transect were carried out two days before and after the new and full moon during May and June from 2006 to 2009 (Doctor and Cain, 2009; Michels et al., 2007). Data for each site was analyzed to determine change in abundance between years, which was then assessed against reference condition (Table 4.19).

Horseshoe crabs spawning on the beach.

Photo: istockphoto.com

Table 4.8. Density of horseshoe crabs (crabs m^{-2}) on beaches at the north end of Assateague Island, between 2006 and 2009 (standard deviation across all samples, 0.08, was used to assess reference condition).

Year	Site 1	Site 2	Site 3
2006	0.03	0.05	0.06
2007	0.03	0.15	0.28
2008	0.05	0.13	0.10
2009	-	0.21	-

Reference condition

There is currently no established indicator or reference for horseshoe crab populations. In this assessment, in recognition of the currently high fishing pressure and historical declines in abundance (Berkson and Shuster, 1999), and the long time to reach maturity in these organisms (nine to ten years, Schuster and Botton, 1985), the reference condition was for horseshoe crab density to not decline from one year to the next (Table 4.20). A decline was defined as a reduction in mean horseshoe crab density by > 1 standard deviation, where standard deviation was calculated across all samples (Table 4.20).

Current condition

Horseshoe crab density at three reproductive beaches between 2006 and 2009, varied from 0.03 to 0.28 crabs m^{-2}, with sites not showing a decrease in 86% of cases, indicating a very good condition for this resource (Table 4.8, 4.21).

Trend

No assessment of trend was possible.

Data gaps and confidence in assessment

Assateague Island National Seashore does not currently collect data on horseshoe crab abundance. The available data was collected by volunteers associated with the Maryland

Coastal Bays Program. A comprehensive survey of all potential breeding habitat within the Seashore, and continued annual monitoring of horseshoe crab density at the existing reference sites is a key data gap, and would allow future assessment of status and trends of this valuable natural resource.

Confidence in assessment of current condition is limited due to limited data from a small number of sites and an assessment of trend was not possible.

Sources of expertise

Carol Cain, Technical Coordinator, Maryland Coastal Bays Program

Literature cited

Berkson, J. and Shuster, C.N. 1999. The horseshoe crab: the battle for a true multiple-use resource. *Fisheries* 24(11): 6-10.

Botton, M.L., R.E. Loveland, and T.R. Jacobsen 1994. Site selection by migratory shorebirds in Delaware Bay, and its relationship to beach characteristics and abundance of horseshoe crab (*Limulus polyphemus*) eggs. *Auk* 111(3): 605-616.

Doctor. S. and Cain, C. 2009. Horseshoe Crab Spawning Activity in Maryland Coastal bays: 2002-2009. Maryland Coastal Bays Program.

Karpanty, S.M., J.D. Fraser, J. Berkson, L.J. Niles, A. Dey, and E.P. Smith. 2006. Horseshoe crab eggs determine red knot distribution in Delaware Bay habitats. *Journal of Wildlife Management* 70(6): 1704-1710.

Manion, M.M., R.A. West, and R.E. Unsworth. 2000. Economic assessment of the Atlantic coast horseshoe crab fishery. Prepared for the Division of Economics, U.S. Fish and Wildlife Service, Arlington, VA by Industrial Economics, Inc. Cambridge, MA.

Michels, Stewart, D. Smith, and S. Bennett. 2007. Horseshoe Crabs Spawning Activity in Delaware Bay: 1999-2007. Report to the Atlantic Sates Maine Fisheries Commission's Horseshoe Crab Technical Committee.

Schrading, E., O'Connell, T., Michels, S. and Perra, P. 1998. Interstate Fishery Management Plan for horseshoe crab. Fishery management report No 32. of the Atlantic States Marine Fisheries Commission.

Schuster, C.N., Jr. and M.L. Botton. 1985. A contribution to the population biology of horseshoe crabs, *Limulus polyphemus* (L.) in Delaware Bay. *Estuaries* 8 (4): 363-372.

U.S. Fish and Wildlife Service. 2003. Delaware Bay shorebird- horseshoe crab assessment report and peer review. Migratory Bird Publication R9-03/02. USFWS, Arlington, VA.

4.3.7 Clam density

Relevance and context

Hard clams (*Mercenaria mercenaria*) are just one of a diverse range of invertebrates in Chincoteague and Sinepuxent Bays that have shown historical variation in abundance related to changes in salinity and hydrology resulting from channel openings through Assateague Island, as well as variations in the abundance of the seagrass, *Zostera marina*, and commercial harvest pressure.

A historical comparison study of mollusks within Chincoteague Bay found that of 82 species of bivalve and gastropod recorded in 1914, 50 species remained in 1989 (two species were found to be identical, and combined), and 25 new species were recorded. At least some of these changes were attributed to the storm opening of the Ocean City Inlet in 1933, which has been maintained since that time (Counts and Bashmore, 1991). Oyster bars of the Eastern Oyster (*Crassostrea virginica*) were supported in lower Chincoteague Bay in the early 1900's, with distribution being restricted by salinity, however the opening of the Ocean City Inlet and subsequent influence of predators and disease led to the decline of the oyster population, which remains unviable (Tarnowski, 2004).

Hard clam (*Mercenaria mercenaria*) populations within the Maryland Coastal Bays expanded dramatically with the increased salinity following the opening of the Ocean City Inlet in 1933, and by the 1950's had become a valuable commercial and recreational resource (Wells, 1957; Boynton, 1970; Tarnowski, 2004). Harvests in the mid-1990's were below 25,000 lbs y^{-1}, however successful recruitment resulted in a sharp increase in landings, exceeding 100,000 lbs in 1999 and peaking at 163,000 lbs in 2002 (MDNR, 2002). Due to large declines in abundance through the early 2000's and public concern over the impacts of hydraulic dredging on aquatic habitats and water quality, in September, 2008, the Maryland Legislature prohibited harvest of hard clams in the coastal bays by hydraulic escalator dredge, power dredge or any other mechanical means, which in effect eliminated the commercial industry (Butowski et al., 2010).

A handful of hard clams (*M. mercenaria*).

Photo: United States Department of Agriculture

Method

Data is from Maryland Department of Natural Resources annual dredge surveys, sampling an equivalent of 58.1 m^{-2} (625 square feet) at each site and a total of 142 sites in the Maryland portion of Chincoteague Bay and 21 sites in Sinepuxent Bay in 2008 (Homer, 1997; Tarnowski, 2004; Fig 4.20; Table 4.19). Each sampling site was compared to the reference condition and an overall assessment was carried out for Chincoteague and Sinepuxent Bays combined.

Reference condition

The reference condition for a sustainable population of hard clams was established as 1.34 clams m^2, the historic high mean density for Chincoteague Bay measured in 1952 (Tarnowski, 2004; Table 4.20).

Current condition

Mean hard clam density in 2008 was 0.24±0.02 throughout Sinepuxent Bay and 0.14±0.01 throughout the Maryland portion of Chincoteague Bay, with an overall mean density in the coastal bays adjacent to Assateague Island of 0.16±0.01. Hard clam abundance throughout Chincoteague and Sinepuxent Bays was therefore in a very degraded to degraded condition with only 12 of 163 sampling sites in 2008 above the reference condition of ≥1.34 clams m^{-2} (18%

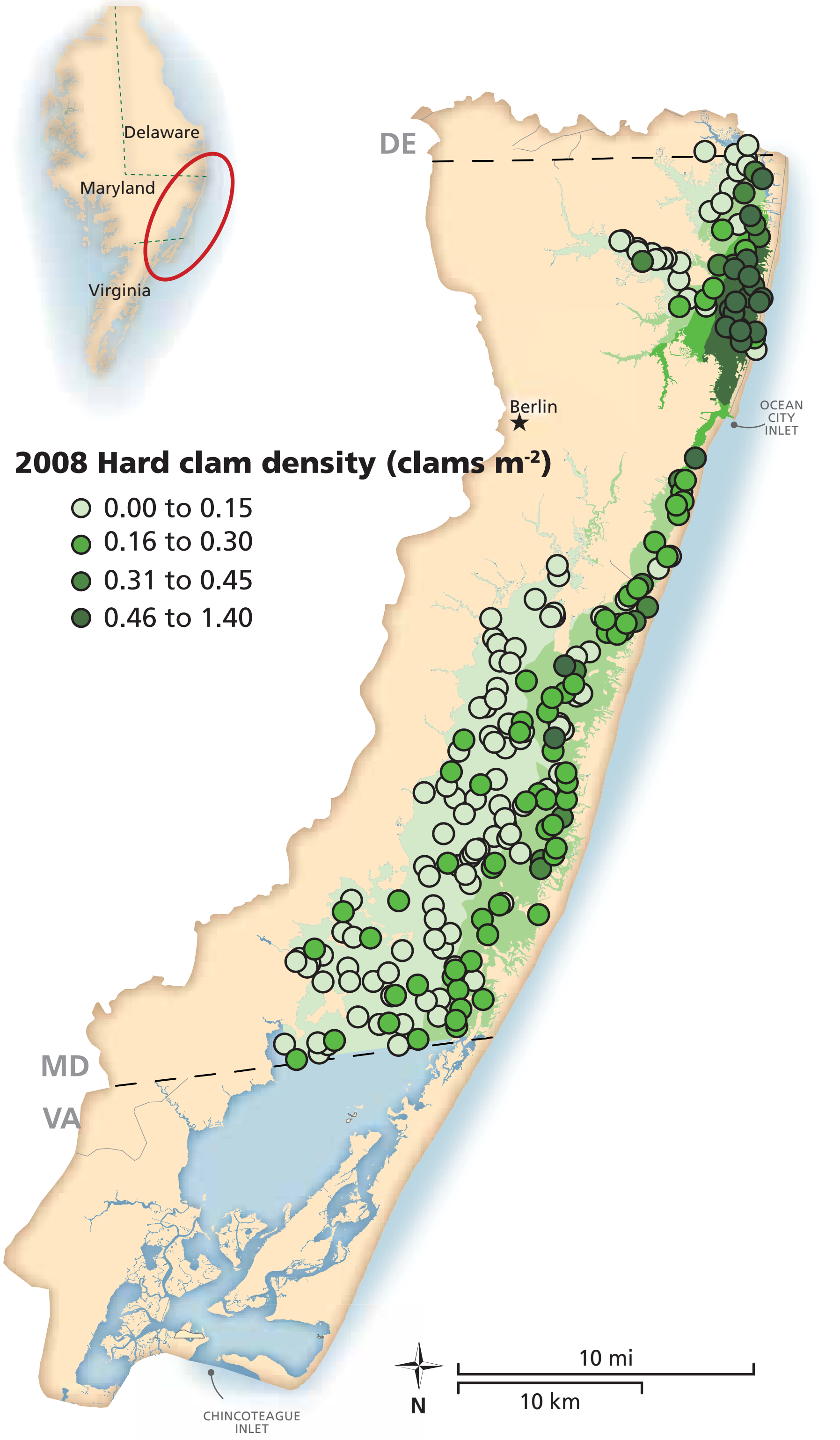
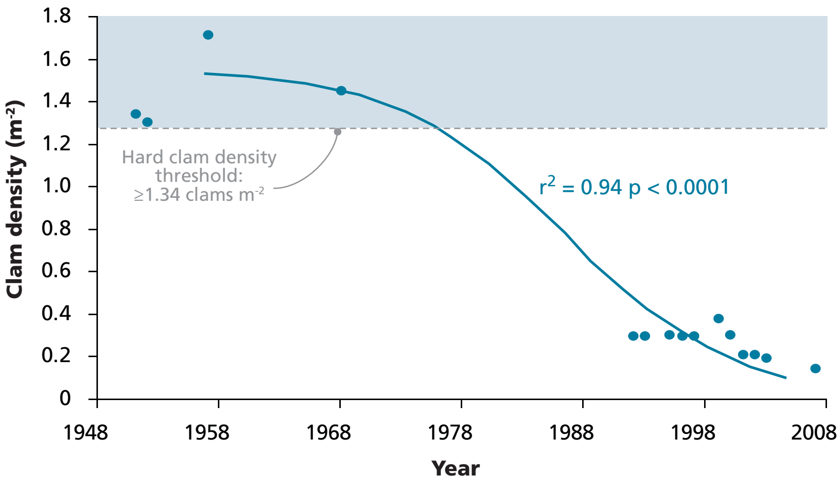


Figure 4.20. Hard clam (*Mercenaria mercenaria*) density throughout Maryland Coastal Bays for 2008.

Data source: Maryland Department of Natural Resources

Figure 4.21. Historical trends in hard clam (Mercenaria mercenaria) abundance in Chincoteague and Sinepuxent Bays, Maryland, the two coastal bays adjacent to Assateague Island National Seashore (Data source: MD DNR).



attainment of reference condition; Table 4.21). The waters within the Seashore (a maximum of 1.5 km from Assateague Island) contained the highest abundances of hard clams within both bays.

Trend

The long-term trend of hard clam densities has shown a significant decrease from 1952 to 2008 (Wells, 1957, Homer, 1997). However, while populations of hard clams in Chincoteague and Sinepuxent bays are low in density, they have remained stable during the 1990's and 2000's and may increase in abundance now that commercial harvest has been discontinued. (Butowski et al., 2010; Figure 4.21).

Data gaps and confidence in assessment

Annual monitoring provides excellent data for the assessment of this resource.

Confidence in assessment is high and confidence in assessment of trend is high.

Sources of expertise

Carl Zimmerman, Resource Management Specialist, Assateague Island National Seashore

Mitchell Tarnowski, Maryland Department of Natural Resources

Literature cited

Boynton, W. 1970. The commercial fisheries of Chincoteague Bay- past, present, and future. In: University of Maryland Natural Resources Institute. *Assateague Ecological Studies, Part I: Environmental Information.* Contribution no. 446.

Butowski, N., Morin, R. and Topolski, M. 2010. Fishery Management Plans Report to the Legistlative Committees. Maryland Department of Natural Resources, Fisheries Service. MSAR #2047

Counts, C.L. and Bashmore, T.L. 1991. Mollusca of Assateague Island, Maryland and Virginia – a reexamination after 75 years. *Veliger* 34(2): 214-221.

Homer, M.L. 1997. Hard Clam Survey. In: M.L. Homer, M.L. Tarnowski, R. Bussell & C. Rice. Coastal Bays Shellfish Inventory. Final Report to Coastal Zone Management Div., MDNR, Contract No. 14-96-134-CZM010, Grant No. NA570Z0301. Annapolis, MD. 206 pp.

Maryland Department of Natural Resources and Coastal Bays Fishery Advisory Committee. 2002. Coastal Bays Hard Clam Fishery Management Plan.

Tarnowski, M.L. 2004. Status of shellfish populations in the Maryland Coastal Bays. **In:** *Maryland's Coastal Bays ecosystem health assessment.* MD DNR-12-1202-0009. Chapter 8.4 pp 8/52 – 8/73.

Wells, H.W. 1957. Abundance of the hard clam, *Mercenaria mercenaria*, in relation to environmental factors. *Ecology* 38: 123-128.

4.3.8 Tiger Beetle abundance

Relevance and context

Two species of state listed rare beetles occur on Assateague Island; both are tiger beetles (*Cicindela sp.*) and both depend on ocean fronting beach and dune habitats (Knisley, 2009a). *Cicindela dorsalis media* is the less abundant of the two species and is found only on the north end of the island and a small area just north of the Maryland-Virginia state line. This species forages along the ocean high tide line and lays eggs in the upper beach, as larvae and adults require microhabitats created by regular tidal and wave action (Knisley, 2009a). *C. d. media* populates sandy coastal beaches along the Atlantic coast that lack significant human disturbance and is generally considered an indicator of relatively pristine beach habitat (Knisley, 1986; Knisley and Hill, 1990). *Cicindela lepida* is typically found in sparsely vegetated dunes with dry, loose sand (Boyd, 1978, Glaser, 1984, Larochelle, 1974). On Assateague Island the species occupies the primary dune areas, including dune blowouts and overwash channels and flats (Knisley, 2009a).

Both species respond negatively to human disturbance from erosion control structures, development, over-sand vehicles, or high pedestrian use (Knisley and Hill, 1990). Abundance of *C. d. media* may also be related to storm frequency and abundance, with reduced population size during years of greater overall storm intensity and abundance (Knisley, 2009b). The abundance of populations of tiger beetle species along the Atlantic beaches of North America has declined. *C.d. media* was last recorded on Fenwick Island in 1926, and has subsequently been extirpated at that location (Knisley and Hill, 1990; Knisley, 2009a).

Method

Annual walking or vehicle based visual surveys counting total abundance of both species were carried out between 2001 and 2009 (not every year for *Cicindela lepida*), resulting in total annual counts for each species (ASIS, 2010; Table 4.19). Rolling two-year mean abundance was calculated, as tiger beetles generally have a two year life cycle (Knisley and Hill, 1992), which was then compared to the reference condition. The comparison was conducted for each of the two species separately, and then the mean attainment of both species was combined to represent the overall condition of tiger beetles on Assateague Island.

Tiger beetle (*Cincindela dorsalis media*) on the sand.

Reference condition

Due to small population size and reducing numbers of populations of both *Cicindela dorsalis media* and *Cicindela lepida* along the Atlantic coast of the US (Knisley, 2009), reference condition was established as no decrease in the two-year rolling mean abundance for each species (Table 4.20).

Current condition

Tiger beetle populations were assessed to be in fair condition on Assateague Island, attaining the reference condition of no decline in two year rolling mean abundance in 44% of cases. Mean total population size on Assateague Island over all sampled years between 2001 and 2009 was 508±92 individuals of *Cicindela lepida* and 222±74 individuals for *Cicindela dorsalis media* (Table 4.21; Figure 4.22).

Trend

There has been no detectable trend in the number of either *Cicindela dorsalis media* or *Cicindela lepida* on Assateague Island National Seashore between 1985 and 2009, although population size has been highly

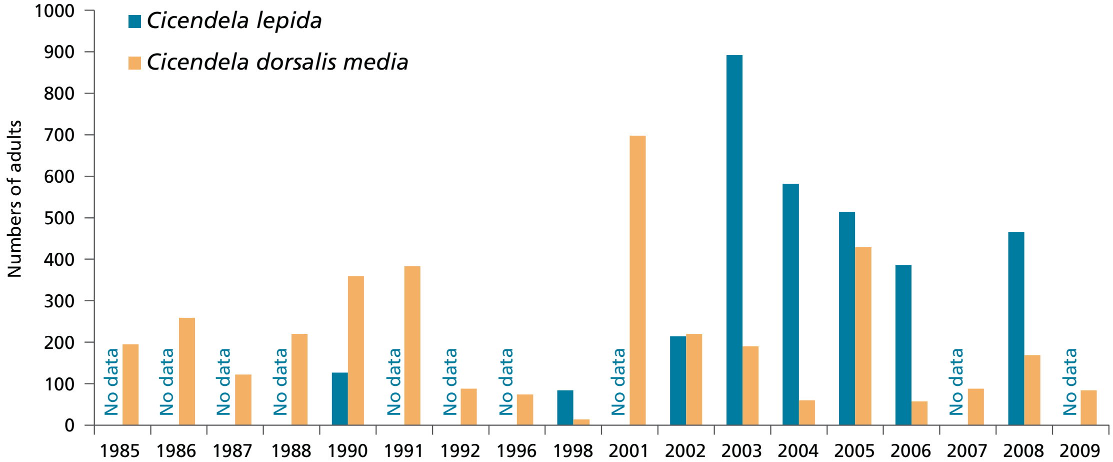


Figure 4.22. Trends in abundance of two tiger beetle species, *Cicindela lepida* and *Cicindela dorsalis media* on Assateague Island, 1985-2008) (Knisley, 2009a; ASIS, 2010).

variable during that period for *C. d media* and reasonably stable for *C. lepida* (Knisley, 2009a; 2009b; Figure 4.22).

Data gaps and confidence in assessment

Continued monitoring using annual population surveys of both tiger beetle species are required to assess this resource. Additionally, studies to better understand the direct causes of the extreme variability in population size from year to year would be beneficial. Confidence in assessment of condition is fair, primarily due to limits in defining reference condition, and confidence in assessing trend is fair.

Sources of expertise

Carl Zimmerman, Resource Management Specialist, Assateague Island National Seashore.

Jack Kumer, Resource Management Specialist, Assateague Island National Seashore.

Literature cited

ASIS. 2010. Assateague Island National Seashore data repository. In: National Park Service Natural Resource Information Portal. **https://nrinfo.nps.gov/Home.mvc** Accessed December 2010.

Boyd, H. P. 1978. The tiger beetles (Coleoptera: Cicindelidae) of New Jersey with special reference to their ecological significance. *Transactions of the American Entomological Society* 104: 191-242.

Glaser, J. D. 1984. The Cicindelidae (Coleoptera) of Maryland. *Maryland Entomologist* 2: 65-76.

Knisley, C. B. 1986. Status survey of two candidate species of tiger beetles, *Cicindela puritana* G. Horn and *C. dorsalis* Say. Final report to U. S. Fish and Wildlife Service.

Knisley, C. B. and J. M. Hill. 1990. Distribution and abundance of two tiger beetles *Cicindela dorsalis media* and *C. lepida* at Assateague Island, Maryland, 1990. Final report to Maryland Department of Natural Resources, Natural Heritage Program. 27 p.

Knisley, C. B. and J. M. Hill. 1992. Effects of habitat change from ecological succession and human impact on tiger beetles. *Virginia Journal of Science* 43: 335-340.

Knisely, C.B. 2009a. Distribution and abundance of two rare tiger beetles, *Cicindela dorsalis media* and *C. lepida*, at Assateague Island National Seashore in 2008. Submitted to Assateague Island National Seashore March 7, 2009.

Knisely, C.B. 2009b. Distribution and abundance of *Cicindela dorsalis media* at Assateague Island National Seashore in 2009. Submitted to Assateague Island National Seashore August 2, 2009.

4.3.9 Seabeach Amaranth abundance

Relevance and context

The dune annual, *Amaranthus pumilus* (Seabeach Amaranth), was historically distributed from Massachusetts down the Atlantic coast of the US to South Carolina, however it is now listed as federally threatened, Maryland state endangered, and globally rare (MNHP, 2010; USFWS, 1993; Weakley et al., 1996). Water front development, beach stabilization, and other activities resulting in habitat degradation are the main reasons for the decline of Seabeach amaranth populations (Weakley et al., 1996). Seabeach amaranth is a pioneer species that is largely restricted to the upper beach and overwash habitats that characterize undeveloped barrier islands, in general, and Assateague Island specifically (Kochel and Wampfler, 1989; Lea et al., 2003).

On Assateague Island, seabeach amaranth was first recorded in a 1967 botanical survey, but subsequently extirpated as the result of dune construction and stabilization activities during the 1960's and 70's. It was not documented again until some 30 years later when two plants were discovered near the north end of the Island in 1998, presumed to have grown from a persistent seed bank (Tyndall et al., 2000). A subsequent restoration project, undertaken by the Seashore, resulted in the re-introduction of over 5,000 individual plants (Lea et al., 2003).

Studies conducted on the re-introduced population have found that the physical size of seabeach amaranth is exponentially correlated to seed production (Lea et al., 2003). Direct grazing on seabeach amaranth by the Island's feral horses (*Equus caballus*), native white tail deer (*Odocoileus virginianus*), and introduced sika deer (*Cervus nippon*) has been shown to reduce plant survival by 27% and reduce mean plant size by 58%, making grazing one of the major threats to the survival and expansion of seabeach amaranth populations on Assateague Island (Sturm, 2008).

Method

Annual surveys were conducted of all *Amaranthus pumilus* individuals by Seashore staff (ASIS, 2010a; Table 4.19), providing the total population of wild Amaranth (those growing from seed produced by the original re-introduced plants and subsequent generations) by year, which was then used to apply to the reference condition.

Reference condition

Given the uncertainty regarding historic abundance, the current management goal for *Amaranthus pumilus* was a stable or increasing population (Lea et al., 2003). As a result, and in recognition of the species' protected status, the reference condition was determined to be no decrease in the three-year rolling mean for wild plant *A. pumilus* abundance (Table 4.20).

Photo: James Carleton

Seabeach Amaranth (*Amaranthus pumilus*).

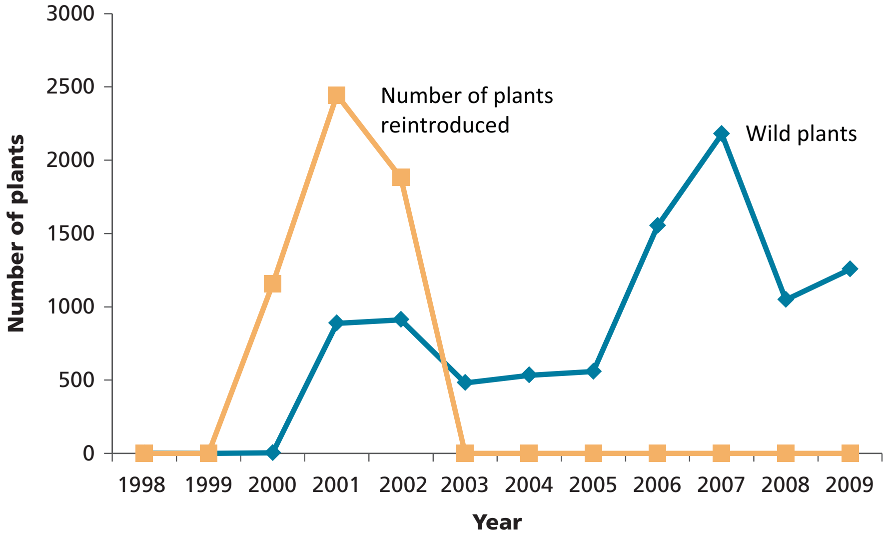


Figure 4.23. Abundance of individual seabeach amaranth (Amaranthus pumilus) plants on Assateague Island National Seashore, between 1998 and 2009.

Current condition

Condition of wild populations of *Amaranthus pumilus* on the Seashore was assessed as being in good condition, attaining reference condition of stable or increasing three-year rolling mean in six of nine (67%) of sampled years, between 2000 and 2009. The mean population size between 2000 and 2009 was a total of 1,489±74 individuals (Table 4.21).

Trend

Subsequent to the large re-introductions between 2000 and 2002, the population retained a size between 1000 and 2000 from 2006 through 2009 (Figure 4.23).

Data gaps and confidence in assessment

Annual monitoring of total plant numbers or a validated index of population size is appropriate to assess the condition of this species.

Confidence in the assessment is fair, limited by the reference condition, and the assessment of current trend is also fair, due to the relatively short time period of population data.

Sources of expertise

Carl Zimmerman, Resource Management Specialist, Assateague Island National Seashore.

Jonathan Chase, vegetation technician, Assateague Island National Seashore.

Literature cited

ASIS. 2010a. Assateague Island National Seashore data repository. In: National Park Service Natural Resource Information Portal. **https://nrinfo.nps.gov/Home.mvc** Accessed December 2010.

Kochel, R.C. and Wampfler, L.A. 1989. Relative role of overwash and Aeolian processes on washover fans, Assateague Island, Virginia-Maryland. *Journal of Coastal Research* 5(3): 453-475.

Lea, C., M. Sturm, H. Hamilton, S. Weller, S. King, and B. McIntyre. 2003. Assateague Island National Seashore Seabeach amaranth Restoration, Assateague Island National Seashore, Berlin, MD. Final Report-2002.

Maryland Natural Heritage Program. 2010. Rare, Threatened and Endangered Plants of Maryland. April 2010 edition. Maryland Department of Natural Resources, Wildlife and Heritage Service, Annapolis, Maryland.

Sturm, M. 2008. Saving the Seabeach Amaranth. *Park Science* 25(1).

Tyndall, R.W., Tamsey, S. and Lea, C. 2000. The federally threatened *Amaranthus pumilus* Raf. (seabeach amaranth, Amaranthaceae) rediscovered on Assateague Island after 31 years. *Castanea* 65(2):165-167.

U.S. Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants; determination of seabeach amaranth (*Amaranthus pumilus*) to be a threatened species. *Federal Register* 58(65) 18035-18042.

Weakley, A., M. Bucher, and N. Murdock. 1996. Recovery plan for seabeach amaranth (*Amaranthus pumilus*) Rafinesque. U.S. Fish and Wildlife Service. Atlanta, GA.

4.3.10 Atlantic Surfclam

Relevance and context

The Atlantic surfclam (*Spisula solidissima*) has a distribution extending along the western north Atlantic Ocean from the southern Gulf of St Lawrence to Cape Hatteras, including the marine waters of Assateague Island National Seashore (Cargnelli et al., 1999). Atlantic surfclams live in sandy continental shelf habitats, from the surf zone down to a maximum depth of 128 m (420 ft), although generally less than 40 m (131 ft). In the waters off Assateague Island the highest densities occur between 18 and 36 m (59 and 118 ft) (Ropes, 1978).

The commercial surfclam fishery grew from a small bait fishery prior to World War I to the predominant source of clam meat in the United States between 1970 and 1974 (Ropes 1980; 1982). High fishing intensity off the Delmarva peninsula (including Assateague Island) during the late 1970's resulted in population declines, however over the subsequent decades Atlantic surfclam biomass in the region has rebounded (Clark, 1998).

The Atlantic surfclam is sensitive to bottom water hypoxia and organic loading from human waste dumping, as indicated in a major event in the spring and summer of 1976 over the clam beds between Cape May, New Jersey and Long Island New York's South Shore. The result was mass mortality of an estimated 62% of the New Jersey surfclam stock across an estimated area of 6750 km^2 (Steimle and Sindermann, 1978).

A Fishery Management Plan was developed for the Atlantic surfclam after passage of the Fishery Conservation and Management Act of 1976, which included annual and quarterly quotas, effort restrictions, closure of specific areas to protect young clams, and a minimum clam size of 14 cm (Murawski and Serchuk, 1981).

Method

NOAA's National Marine Fisheries Service, Northeast Fisheries Science Center conducts a survey once every three years to independently assess trends in surfclam biomass (Table 4.19, Jacobson and Weinberg, 2006; NFSC, 2010).

Reference condition

The reference condition is based on a stock biomass threshold of 272,000 metric tons (mt) of clam meat, estimated as ¼ the 1999 biomass for clams with at least 120 mm shell length, and the 0.15 y^{-1} fishing mortality rate threshold indicating the point at which

Table 4.9. Atlantic surfclam data, compiled by the NOAA Northeast Fisheries Commission, 3-200 nautical miles from the Mid-Atlantic coast. Numbers are in 1000 metric tons.

Year	Quota	Landings[1,2,3]	Biomass[3,4]	Fishing mortality[2,3]	Recruitment
2000	19.8	19.7	1074	0.019	95
2001	22	22	1059	0.022	94
2002	24.2	24	1037	0.025	89
2003	25.1	25	1012	0.026	87
2004	26.2	24.2	984	0.026	84
2005	26.2	21.2	955	0.023	82
2006	26.2	23.6	931	0.027	82
2007	26.2	24.9	905	0.029	81
2008	26.2	22.5	878	0.027	80
		Mean:	**982**	**0.025**	

1 Landings not adjusted for incidental mortality, which is assumed to be ≤12% of landings. Discards have been very low since 1992.
2 Fishing mortality is an annual rate assuming that incidental mortality was 12% of landings.
3 See assessment for regional estimates.
4 For shell lengths 120mm+.

Photo: © Andrew J. Martinez

Atlantic surfclam (*Spisula solidissima*).

a stock is being overfished (Jacobson and Weinberg, 2006). The desired reference condition is for the annual population to pass both of these thresholds (Table 4.20).

Current condition

Current condition of this resource is very good (100% attainment of reference condition) with a 2000 -2008 mean of 982,000 mt meat biomass and a fishing mortality of 0.025 yr^{-1} with biomass being relatively high and fishing mortality relatively low (Table 4.9; Jacobson and Weinberg, 2006).

Trend

There have declines in Atlantic surfclam biomass, in southern areas, during the 2000's, largely resulting from reduced recruitment rates and slow growth rates associated with warm water conditions (Jacobson and Weinberg, 2006).

Data gaps and confidence in assessment

Data for assessing this resource are sufficient.

Confidence in assessment of current condition is high and in assessment of trend is high.

Sources of expertise

National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service, Northeast Fisheries Science Center.

Literature cited

Cargnelli, L.M., Griesbach, S.J., Packer, D.B. and Weissberger, E. 1999. Essential fish habitat source document: Atlantic surfclam, *Spisula solidissima*, life history and habitat characteristics. NOAA technical memorandum NMFS-NE-142.

Clark SH, Editor. 1998. Status of Fishery Resources off the Northeastern United States for 1998. US Dep Commer, NOAA Tech Memo NMFS NE 115; 149 p.

Jacobson, L. and Weinberg, J. 2006. Atlantic surfclam (*Spisula solidissima*). Report on status of fishery resources off the Northeastern US NEFSC – resource evaluation and assessment division.

Murawski, S. A., and F. M. Serchuk. 1981. Assessment and current status of offshore surf clam populations off the Middle Atlantic coast of the United States. U.S. Natl. Mar. Fish. Serv., Northeast Fisheries Center, Woods Hole Lab. Ref. No. 82-43. 25 pp.

Northeast Fisheries Science Center. 2010. 49th Northeast Regional Stock Assessment Workshop Assessment Summary Report. NOAA Document 10-01, January 2010.

Ropes, J.W. 1978. Biology and distribution of surf clams (*Spisula solidissima*) and ocean quahogs (*Arctica islandica*) off the northeast coast of the United States. **In:** *Proceedings of northeast clam industries: management for the future.* April 27-28, 1978, Hyannis, MA.

Ropes. J. W. 1980. Biological and fisheries data on the Atlantic surf clam, *Spisula solidissima*. NOAA, NMFS, Northeast Fisheries Center Technological Service Report No. 24. 91 pp.

Ropes, J . W. 1982. The Atlantic coast surf clam fishery, 1965-1974. U.S. National Marine Fisheries Service. *Marine Fisheries Review* 44(8): 1-14.

Steimle, F. W., Jr., and C. J. Sindermann. 1978. Review of oxygen depletion and associated mass mortalities of shellfish in the Middle Atlantic Bight in 1976. U.S. National Marine Fisheries Service. *Marine Fisheries Review* 40(12): 17-25.

4.4 LANDSCAPES

4.4.1 Over-sand vehicle trails

Relevance and context

Over-sand vehicle (OSV) use can directly damage dune vegetation, turn over and dry out organic drift lines that support seed germination and new dune development, prevent colonization, and impact habitat quality for rare species (Godfrey and Godfrey, 1981, Schlacher et al., 2008). OSV use within dune habitat compacts and displaces significant volumes of sand (Schlacher and Thompson, 2008), reduces growth of protective foredunes, and may lead to erosion (Anders and Leatherman, 1987). On Assateague, vehicles have been used in dune and beach habitat since the late 1920's, peaking in the "beach buggy" decade of the 1960's. The National Park Service initiated a permit system in 1975, limiting access to the Maryland OSV route to 145 vehicles at any time (Mackintosh, 1982). In the early 1980's, Odum and Dueser studied the ecological effects of OSV use in the Virginia portion of Assateague Island, concluding that the vehicles were having a direct negative impact upon developing dune lines at Tom's Cove Hook and a secondary impact on dunes and vegetation at Fox Hill Levels by affecting dune geomorphology, plant growth, and groundwater salinity (Odum and Dueser, 1982). OSV use on Assateague Island is also known to limit the abundance of the state listed rare tiger beetle (*Cicindela dorsalis media*) (Knisley and Hill, 1990), and reduce the species richness and abundance of migratory shorebirds and the size and number of roosts (Forgues, 2010). Migrating shorebirds also spend less time foraging in the presence of OSVs (Forgues, 2010).

Method

The total area of dune and grassland habitat in the Maryland section of Assateague Island National Seashore was calculated (Table 2.3). For every known dune crossing, the length of the dune crossing was measured, using GIS, and multiplied by an assumed 10 m (33 ft) width, to calculate the area of dune and grassland with vehicle impacts. For beach and intertidal habitat, the total length of shoreline accessible to OSV use was compared to the total length of shoreline (Table 4.19; Table 4.10; ASIS, 2010).

Reference condition

Historically, a large proportion of the sand dune and grassland habitats of Assateague Island were used by over-sand vehicles (OSV's) (Mackintosh, 1982). A management goal has been to reduce vehicle use in these habitats, by closing trails and minimizing dune crossings. The reference condition is that the area of dune and grassland habitats accessible to OSV's is minimized, and attainment was calculated as the percent of dune and grassland habitat in the Maryland portion of the Seashore closed to OSV traffic (Table 4.20). For the beach and intertidal habitat, reference condition is beach not accessed by OSV traffic, attainment of reference condition was calculated as the percentage of Maryland shoreline not currently accessed by OSV traffic.

Current condition

Currently, <1% of the total area of dune and grassland habitat is open to over-sand vehicles, so this resource is currently assessed as in very good condition, attaining 99.8% of the desired reference condition (Table 4.21). Within beach and intertidal habitat, within the Maryland portion of the seashore, 19.3 km (12 mi) of the total 35.4 km (22 mi) are accessible to OSV traffic, attaining 45% of reference condition with an assessment of fair condition.

Former back road no longer accessible to OSVs.

Photo: NPS ASIS

Table 4.10. Extent of two key habitats on Assateague Island National Seashore that are accessible to over-sand vehicle use.

Habitat		Total length (km)	OSV Access Area (ha)	Habitat Area (ha)	% Closed to OSVs
Dune and grassland	Length of dune crossing	1.2 (0.74 mi)	1.2 ha	627.7	99.8%
Beach and intertidal	Length of MD shoreline	35.4 (22 mi)	x	x	45.0%

Trend

The trend since the establishment of Assateague Island National Seashore has been to greatly limit the area of sand habitat available to OSV use, over the past 3-4 decades some 22.5 km (14 mi) of backcountry roads for OSV use have been closed, half of these in dune and grassland habitat, suggesting that condition has improved from 2.2% of this habitat accessible to OSV use down to just 0.2%.

Data gaps and confidence in assessment

If changes in the size of the over-sand vehicle zone, or number and length of dune crossings occur, this metric should be re-calculated.

Confidence in assessment of current condition was high, assessment of trend was limited to historical accounts.

Sources of expertise

Carl Zimmerman, Resource Management Specialist, Assateague Island National Seashore

Jack Kumer, Resource Management Specialist, Assateague Island National Seashore

Courtney Schupp, Coastal Geologist, Assateague Island National Seashore

Neil Winn, Geographer, Assateague Island National Seashore

Literature cited

Anders, F. & S. Leatherman. 1987. Effects of off-road vehicles on coastal foredunes at Fire Island, New York, USA. *Environmental Management* 11(1): 45-52.

ASIS. 2010. Assateague Island National Seashore data repository. In: National Park Service Natural Resource Information Portal. **https://nrinfo.nps.gov/Home.mvc** Accessed December 2010.

Forgues, K. 2010. The Effects of Off-Road Vehicles on Migrating Shorebirds at a Barrier Island in Maryland and Virginia. Masters Thesis. Trent University, Peterborough, Ontario, Canada. 83 pp.

Godfrey, P. & M. Godfrey. 1981. Ecological effects of off-road vehicles on Cape Cod. *Oceanus* 23: 56-67.

Knisley, C. B. and J. M. Hill. 1990. Distribution and abundance of two tiger beetles *Cicindela dorsalis media* and *C. lepida* at Assateague Island, Maryland, 1990. Final report to Maryland Department of Natural Resources, Natural Heritage Program. 27 p.

Mackintosh, B. 1982. Assateague Island National Seashore: An Administrative History. History Division, National Park Service, Washington D.C.

Odum, W.E. and R. Dueser. 1982. Draft Final Report, Natural and Recreational Influences on Fox Hill Levels and Toms Cove Hook, Assateague Island, Va.

Schlacher, T.A., D. Richardson, and I. McLean. 2008. Impacts of Off-Road Vehicles (ORVs) on Macrobenthic Assemblages on Sandy Beaches. *Environmental Management* 41(6): 878-892.

4.4.2 Sediment contaminants

Relevance and context

Heavy metal contamination in aquatic sediments is of concern due to the potential for toxicity in benthic organisms and, through bioaccumulation, other components of the food chain. Certain contaminants may be an indicator of current or historical industrial waste inputs (U.S. EPA, 2005). Although the main influences on the chemical and nutrient status of Chincoteague and Sinepuxent Bays are sources on the mainland subwatersheds in Maryland and Virginia, some sources may occur on Assateague Island, including an abandoned 24 km (15 mile) section of road, constructed on the island with oil waste during the 1950's (Kopp et al., 2002; Cooper and Borjan, 2010). Although the watersheds have no heavy industry, contaminants from suburban development, row crop agriculture, poultry operations and atmospheric deposition enter the coastal bays adjacent to Assateague Island and accumulate in the sediments due to the system's slow flushing and turnover rates (Pritchard, 1960, Boynton et. al., 1996; Cooper and Borjan, 2010). Heavy metals pose a risk of contamination in both the water column and sediments, with potentially large direct effects on aquatic organisms, as well as on the ecological balance of species (Farombi et al., 2007, Clarkson, 1998, Ashraj, 2005). Accumulating in higher trophic level fish (Boynton et al., 1996), heavy metal pollution can also lead to toxin and carcinogen exposure in humans (Sunderland, 2007).

Method

Data from two sources was used for the assessment of condition, reporting concentrations of heavy metals and pollutants in sediments. Data from two sites collected in 1993, one in Chincoteague Bay (VA93-634) and one in Sinepuxent Bay (VA93-641) was obtained from the EPA EMAP National Coastal Database (www.epa.gpv/emap; Cooper and Borjan, 2010). Additionally, data from 10 sites surveyed through Chincoteague and Sinepuxent bays during 1996 was used to assess condition (Zimmerman, 1996; Cooper and Borjan, 2010). Each sample and metric was compared to the respective reference condition, to calculate a combined assessment of condition (Table 4.11). To assess trends, Mussel data from one long term sampling site adjacent to Chincoteague Island and collected by NOAA National Status and Trends Program was used (NOAA, 2006; Cooper and Borjan, 2010; Table 4.19).

Reference condition

The U.S. EPA (2005) uses a benchmark of Threshold Effect Levels (TEL) to evaluate concentrations of heavy metals, as well as other contaminants, that may cause adverse health effects. They have been derived from a database of synoptic contaminant concentrations, sediment toxicity bioassays, and benthic community metrics. The values for each TEL are calculated as the geometric mean using the full suite of information from the database, including non-toxic samples, and have been compiled into Screening Quick Reference Tables (SQuiRT) cards for reference (Buchman 2008). The desired reference condition was to achieve EPA, TEL standards and the percentage of samples meeting these standards was used to determine overall condition.

Photo: NPS ASIS

NPS staff sampling estuarine sediments in the Coastal Bays.

Table 4.11. Sediment heavy metals and contaminants for Chincoteague Bay (Cooper and Borjan, 2008, Zimmerman, 1996). Values that are above the threshold (EPA Threshold Effect Level (TEL)) are in bold.

Contaminant	TEL	VA93-634	VA93-641	Zimmerman 1996
Arsenic	7,240	**12,100**	2,400	**1,590-16,900**
Cadmium	676	70	-	**200-5,000**
Chromium	52,300	**61,000**	4,430	520-31,770
Copper	18,700	10,800	-	570-12,250
Lead	30,240	24,000	6,560	5,000-15,000
Mercury	130	50	-	<100
Nickel	15,900	**17,400**	-	**740-21,420**
Silver	730	70	20	100-200
Zinc	124,000	86,300	190	4,690-81,400
HMW PAHs	655,340	179	-	<190
LMW PAHs	311,700	82.3	-	<29
Total PAHs	1,684,060	261	-	<219
4-4'-DDE	2,070	**5,500**	-	-
Total DDT	3,890	1,090	-	-
Total PCBs	21,550	1.41	-	<10

Current condition

Current condition was good, attaining reference condition in 77% of contaminant samples, which agrees with the conclusions of Cooper and Borjan (2010; Table 4.11, 4.21).

Trend

Trend data since 1998 for one site in lower Chincoteague Bay (Figure 4.24) indicate that PCB's have declined, reflecting the US ban on commercial use (Figure 4.25), low and high molecular weight PAH's have remained low, indicating little or no petroleum based pollution (Figure 4.26, 4.27) and concentrations of DDT have also declined (Figure 4.28). However, both silver and mercury concentrations have shown an increase, with significantly greater concentrations since 1996 and 1995 respectively (Figure 4.29, 4.30; Cooper and Borjan, 2010).

Data gaps and confidence in assessment

Data density is limited, high intensity mapping surveys that are currently being concluded will meet this data need for heavy metals.

Confidence in assessment of current condition was fair and assessment of trend was limited (due to only one sampling location in the south of Chincoteague Bay).

Sources of expertise

Carl Zimmerman; Resource Management Specialist, Assateague Island National Seashore.

Literature cited

Ashraj, W. 2005. Accumulation of heavy metals in kidney and heart tissues of Epinephelus microdon fish from the Arabian Gulf. *Environmental Monitoring Assessment* 101 (1-3): 311-316.

Boynton, W.R., Murray, L., Hagy, J.P., Stokes, C. and Kemp, W.M. 1996. A comparative analysis of eutrophication patterns in a temperate coastal lagoon. *Estuaries* 19(2B): 408-421.

Buchman, M.F. 2008. NOAA Screening Quick Reference Tables. NOAA OR&R Report 08-1, Seattle WA, Office of Response and Restoration Division. National Oceanic and Atmospheric Administration. 34 pp.

Clarkson, T. W. 1998. Human toxicology of mercury. *Journal of Trace Elements in Experimental Medicine* 11 (2-3): 303-317.

Figure 4.24.
Contaminant sampling sites throughout the Coastal Bays.

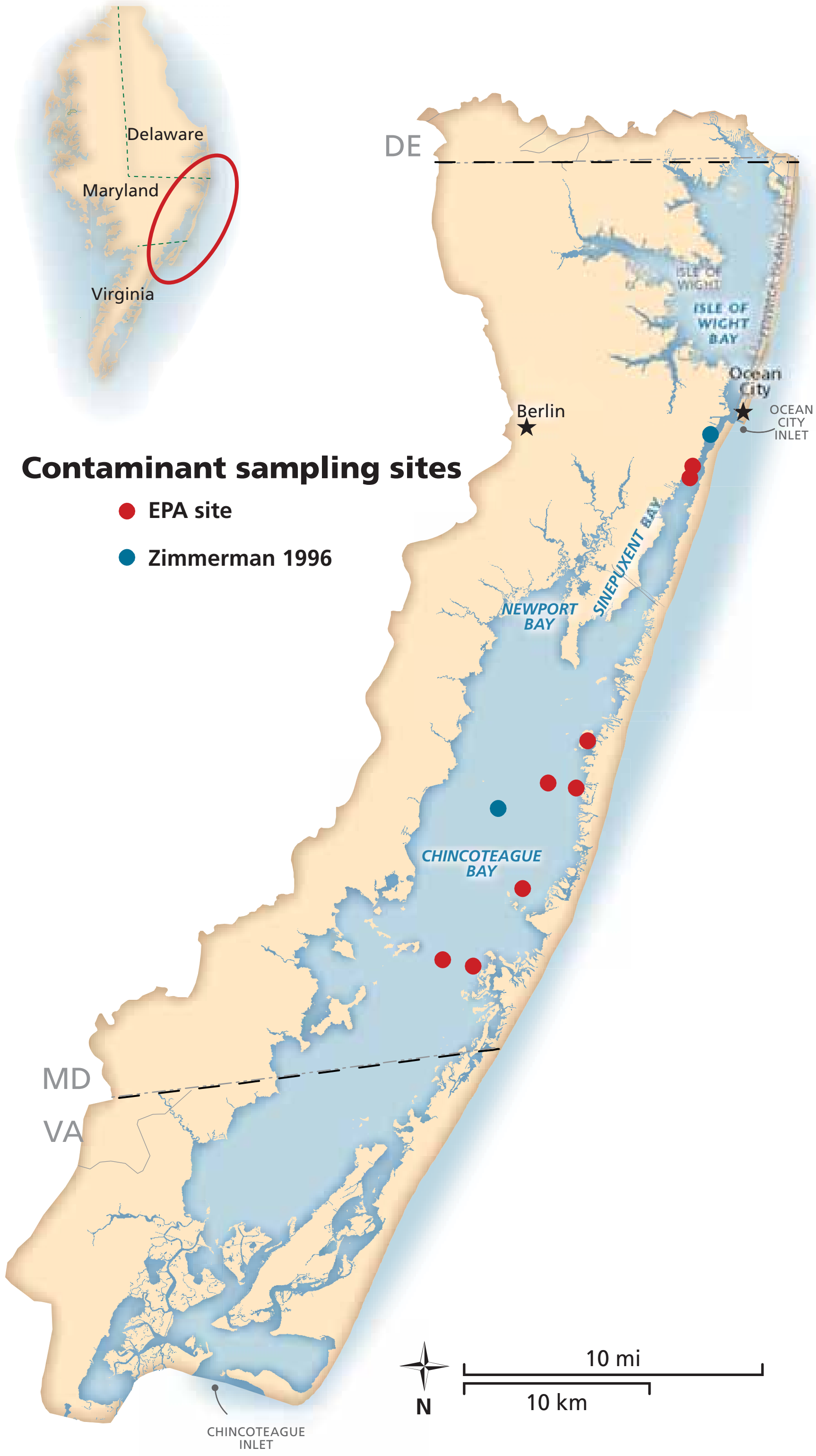


Figure 4.25. Total PCB concentration ng/g dry weight) in tissues (1988 - present).

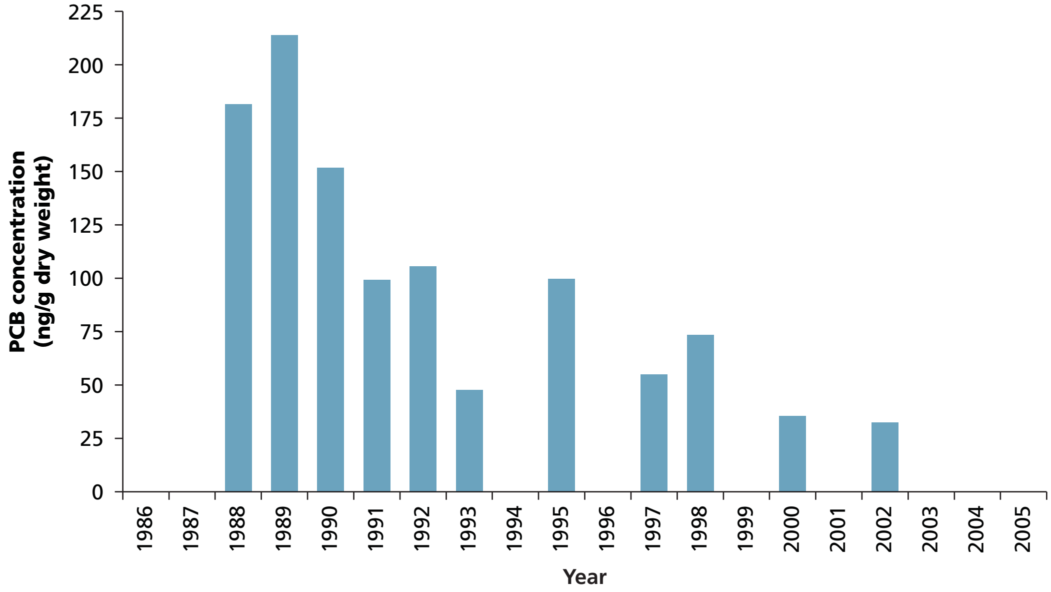


Figure 4.26. Total PAH (lmw) (2-3 Rings) concentration ng/g dry weight) in tissues (NOAA 2006).

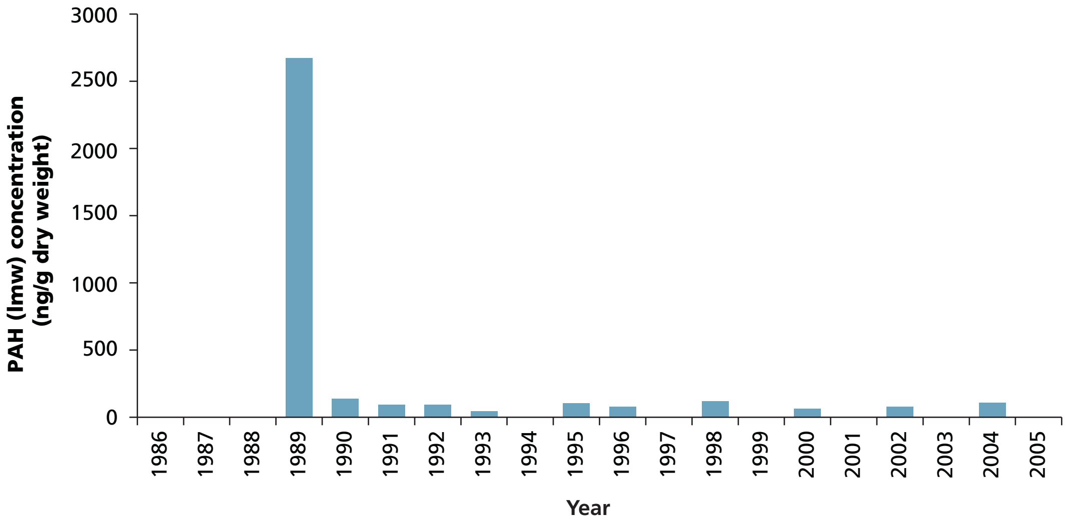
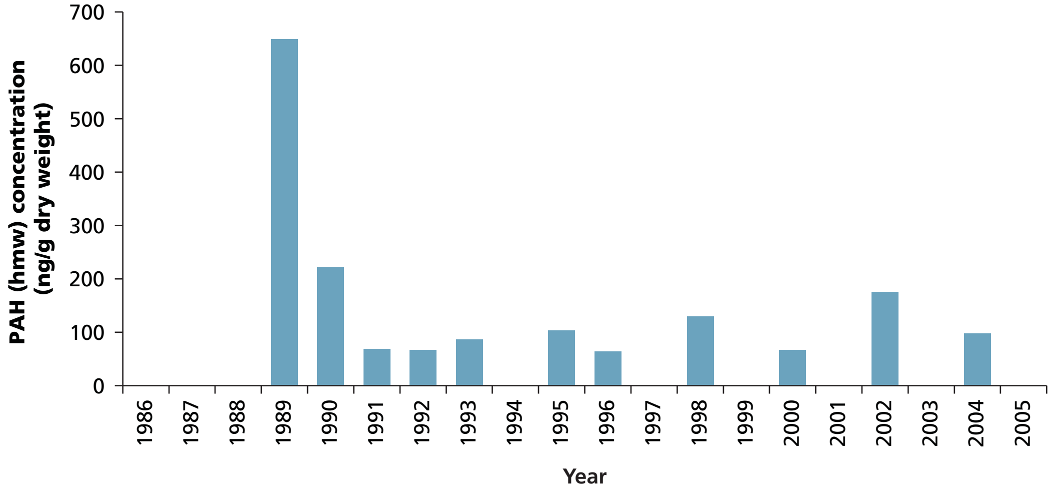


Figure 4.27. Total PAH (hmw) (4 or more rings) concentration ng/g dry weight) in tissues (NOAA 2006).



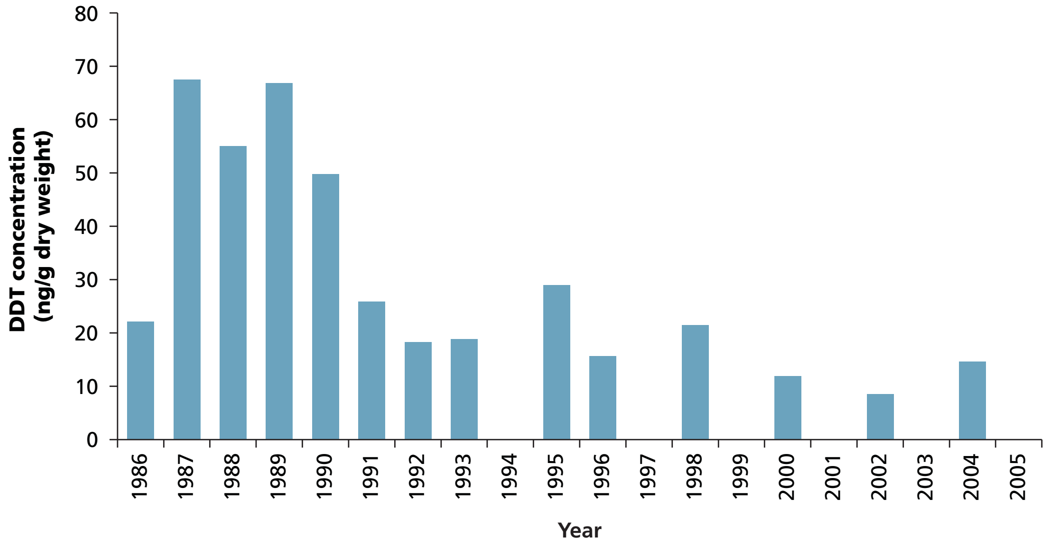


Figure 4.28. Total DDT concentration (ng/dry g) in tissue (NOAA 2006).

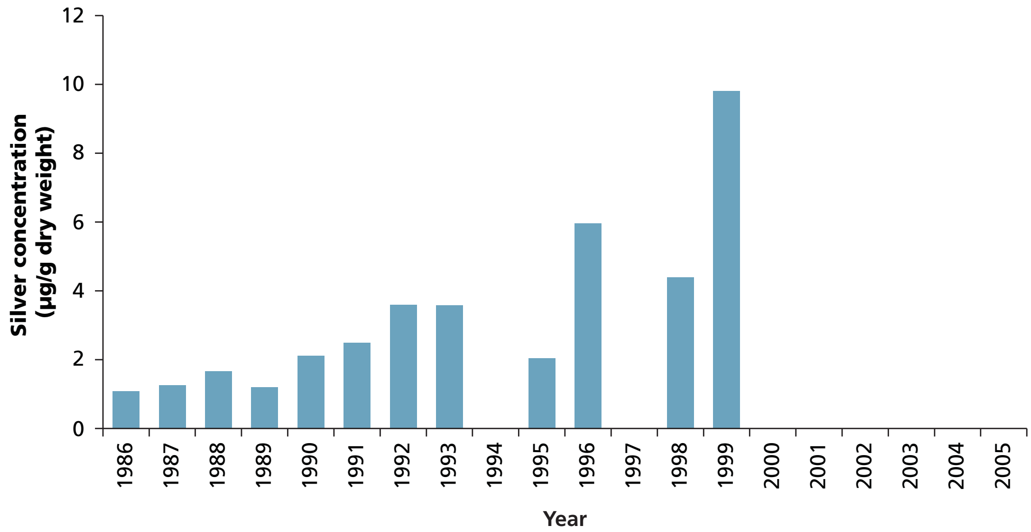


Figure 4.29. Silver concentration ug/g dry weight) in tissues (NOAA 2006).

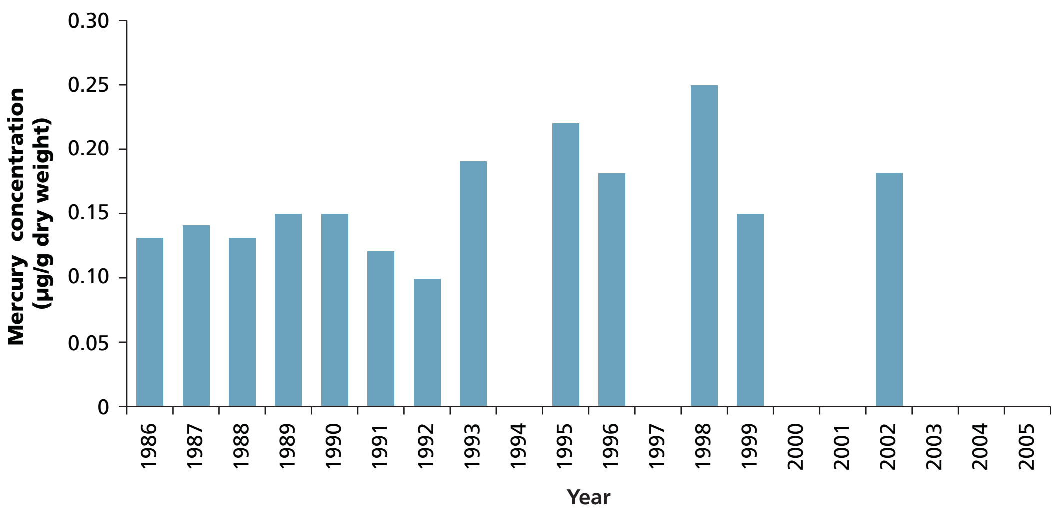


Figure 4.30. Mercury concentration ug/g dry weight) in tissues (NOAA 2006).

Cooper, M., and K. Borjan. 2010. Northeast Coastal and Barrier Network Assessment of Contaminant Threats – Assateague Island National Seashore. Natural Resource Technical Report NPS/NCBN/NRTR – 2010/348.

Farombi, E. O.; Adelowo, O. A.; Ajimoko. Y. R. 2007. Biomarkers of oxidative stress and heavy metal levels as indicators of environmental pollution in African Cat fish (*Clarias gariepinus*) from Nigeria ogun river. *International Journal of Environmental Research and Public Health* 4 (2), 158-165.

Kopp, B.S., Neckles, H.A., and Nixon, S.W. 2002. Draft Report: Candidate Variables for Monitoring Estuarine Nutrient Enrichment within the NPS Coastal and Barrier Network. National Park Service, Northeast Coastal and Barrier Network.

National Oceanic and Atmospheris Associations (NOAA). National Ocean Service. Coastal Monitoring. Mussel Watch. Updated January 27, 2006. Available on-line at: **http://oceanservice.noaa.gov/#monitoring**

Pritchard,D. W. 1960. Salt balance and exchange rate for Chincoteague Bay. *Chesapeake Science* 1 :48-57.

Sunderland, E. M. 2007. Mercury exposure from domestic and imported estuarine and marine fish in the US seafood market. *Environmental Health Perspectives* 115: 235-242. DOI: 10.1289/ehp.9377

U.S. EPA. 2005. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver and Zinc). EPA-600-R-02-011. Office of Research and Development. Washington, DC.

Zimmerman C.S. 1996. Assateague Island National Seashore An Inventory of Estuarine Sediments for Contaminants Final Report. Geochemical and Environmental Research Group Analytical Report (#8990032), 72 pp.

4.4.3 Mosquito ditch density

Relevance and context

Ditching of salt marshes for the control of mosquito populations was prevalent in the mid-Atlantic region, including the Maryland portion (only) of Assateague Island, prior to the 1950's (Mackintosh, 1982; Kennish, 2001). Mosquitoes were not controlled, but marsh hydrology was severely altered, disrupting the natural flow of tidal water into and out of the marsh. Many of these ditches remain, and can reduce foraging area for wading and shorebirds (Clarke et al., 1984), as well as degrading estuarine water quality by increasing nutrient export from marshes (Koch and Gobler, 2009).

Method

Using a GIS layer of known mosquito ditches within the Seashore, total length of open mosquito ditch was calculated (ASIS, 2010; Table 4.19). Active management since 2008 has begun filling these ditches and the known length of filled ditch was calculated as a percentage of the overall length of ditches, to establish the current condition.

Table 4.12. Percentage of historic mosquito ditches that have been filled, on Assateague Island National Seashore. (ASIS, 2010).

Ditch type	Length (m)	Percent
Filled	4,767	10
Viable	43,509	90
TOTAL	**48,276**	**100**

Reference condition

Reference condition was defined to be marshes not containing mosquito ditches. The current management goal of Assateague Island National Seashore is to restore natural marsh hydrology by infilling the remaining open ditches, where the reference condition would be met (100% attainment) once all remaining ditches have been filled (Table 4.20).

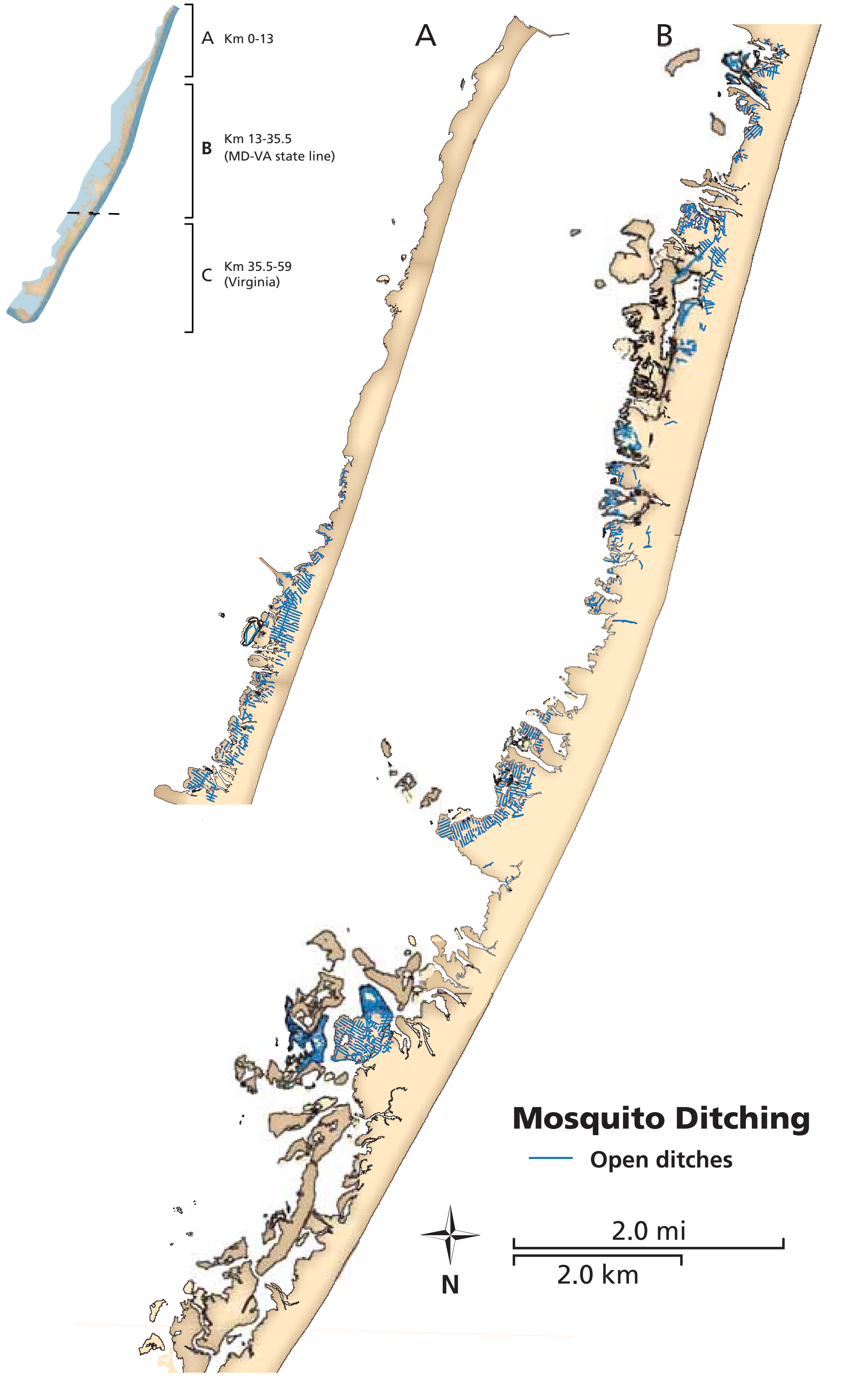
Current condition

The current condition is very degraded, with 4,767 m (15,640 ft) of marsh mosquito ditches currently filled of a total ditch length of 48,276 m (158,386 ft), representing a 10% attainment of reference condition (Figure 4.31; Table 4.12; Table 4.21).

Mosquito ditches and saltmarsh on Assateague Island.

Photo: Jane Thomas, IAN Image Library

Figure 4.31. Location of open, historical mosquito ditches in the Maryland portion of Assateague Island National Seashore in 2003.



Data source: ASIS, 2010: 2003 ASIS-NPS GIS mosquito ditch layer.

Trend

Current management strategy is active ditch infilling, therefore total length of viable ditches is decreasing.

Data gaps and confidence in assessment

During the process of mosquito ditch filling, active monitoring will allow interpretation of the overall positive and negative effects of infilling open mosquito ditches in the marshes of Assateague Island.

Confidence in assessment of condition is fair and confidence in assessment of trend was fair.

Sources of expertise

Brian Sturgis; Ecologist, Assateague Island National Seashore.

Carl Zimmerman; Resource Management Specialist, Assateague Island National Seashore.

Neil Winn, Geographer, Assateague Island National Seashore

Photo: NPS ASIS

A recently filled mosquito ditch.

Literature cited

ASIS. 2010. Assateague Island National Seashore data repository. In: National Park Service Natural Resource Information Portal. **https://nrinfo.nps.gov/Home.mvc** Accessed December 2010.

Clarke, J.A., Harrington, B.A., Hruby, T. and Wasserman, F.E. 1984. The effect of ditching for mosquito control on salt marsh use by birds in Rowley, Massachusetts. *Journal of Field Ornithology* 55(2): 160-180.

Kennish, M.J. 2001. Coastal salt marsh systems in the U.S.: a review of anthropogenic impacts. *Journal of Coastal Research* 17(3): 731-748.

Koch, F., and C.J. Gobler. 2009. The effects of tidal export from salt marsh ditches on estuarine water quality and plankton communities. *Estuaries and Coasts* 32 (2): 261-275.

Mackintosh, B. 1982. Assateague Island National Seashore: An Administrative History. History Division, National Park Service, Washington D.C.

Photo: NPS ASIS

Impervious surface includes roads, parking lots, rooftops, and transport systems.

4.4.4 Impervious surface

Relevance and context

Impervious surface is a representation of human impact on the landscape and directly correlates to land development (Conway, 2007). It includes roads, parking lots, rooftops and transport systems that decrease infiltration, water quality, and habitat while increasing runoff. A study in coastal New Jersey revealed that impervious surface as low as 2% may have significant effects on pH and specific conductance in streams, and recommended a threshold between 2.4% and 5.1% (Conway, 2007).

Method

A GIS layer of paved surfaces, developed by Worcester County from aerial photography, was used to calculate the area of impervious surface within the Maryland portion of Assateague Island National Seashore, including roadways and parking lots within Assateague State Park, as well as within each particular habitat type (Figure 4.32; Table 4.19, Table 4.20). This was compared to total area, converted to a percentage and compared to the reference condition.

Reference condition

Ecosystem components such as floral and faunal communities show considerable impact when impervious surface comprises 10% or more of habitat area, therefore the reference condition was for total impervious surface to be less than 10% (Arnold and Gibbons, 1996, Lussier et al., 2008, Table 4.20).

Current condition

Current condition is very good with less than 1% of the total land area in the Maryland portion of Assateague Island National Seashore covered with impervious surface, resulting in a 100% attainment of reference condition (Table 4.13).

Trend

No assessment of trend was possible.

Data gaps and confidence in assessment

Future determinations of impervious surface would be beneficial to allow for updated assessment of this metric, as roads and facilities change within the Seashore. Confidence in assessment of condition is high. No assessment of trend was possible.

Table 4.13. Percentage of impervious surfaces (paved, rooftops, parking lots, boardwalks) in park habitats and the Maryland portion of Assateague Island. Data was extracted using the 2003 ASIS-NPS GIS layer of impervious surfaces and 2004 Worcester County land use GIS layer.

Habitat	Impervious Area (m^2)	% Total Habitat	% MD Habitat
Bay subtidal and mudflats	9,393	0.44	7.20
Beach and intertidal	9,260	0.10	0.20
Dunes and grassland	241,591	2.66	3.85
Forest and shrubland	43,944	0.15	0.31
Salt marsh	2,860	0.01	0.03
Inland wetlands	0	0	0
TOTAL	**307,048**	**0.22**	**0.33**

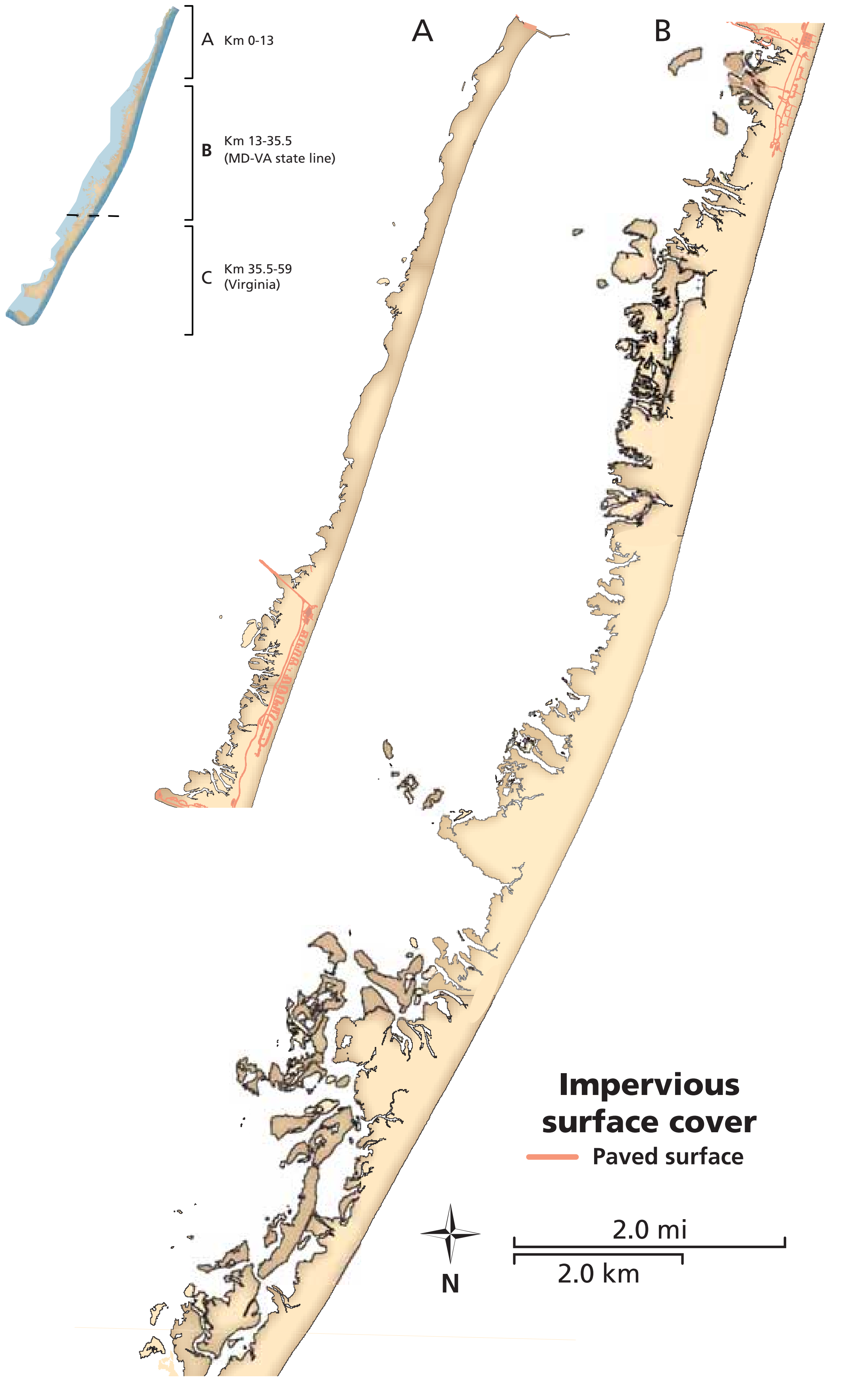


Figure 4.32. Impervious surface on Assateague Island, Maryland.

Data source: roads located on Assateague Island National Seashore and Assateague State Park in 1996; ASIS, 2010)

Sources of expertise

Natural resource management staff, Assateague Island National Seashore.

Neil Winn, Geographer, Assateague Island National Seashore

Literature cited

Arnold Jr, C.L. and C.J. Gibbons. 1996. Impervious surface coverage. *Journal of the American Planning Association* 62(2): 243-269.

Conway, T.M. 2007. Impervious surface as an indicator of pH and specific conductance in the urbanizing coastal zone of New Jersey, USA. *Journal of Environmental Management* 85:308-316.

Lussier, S.M., da Silva, S.N., Charpentier, M., Heltshe, J.F., Cormier, S.M., Klemm, D.J., Chintala, M. and Jayaraman, S. 2008. The influence of suburban land use on habitat and biotic integrity of coastal Rhode Island streams. *Environmental Monitoring and Assessment* 139: 119-136.

4.4.5 Overwash accessibility

Relevance and context

Overwash processes are important to the biological and geomorphological functions of barrier islands. Overwash plays an important role in the response of barrier islands to storm events and sea level rise by transporting sand from the beach to island interiors, replenishing back-barrier marshes, and creating overwash fans (Leatherman, 1979; Kochel and Wampfler, 1989), a dynamic habitat that supports rare island flora and fauna. Overwash areas provide suitable habitat conditions for the threatened piping plover (*Charadrius melodus*) and the threatened dune annual, seabeach amaranth (*Amaranthus pumilus*) (Loegering and Frazer, 1995; Weakley et al., 1996; Lea et al., 2003).

In response to storm hazards and impacts over the past eight decades, management actions by multiple agencies have changed the naturally dynamic geomorphological processes of Assateague Island, resulting in long-term influences on the Seashore's natural resources including some impediments to natural island overwash processes. With the initiation of development and land subdivision in the 1950's on Assateague Island, an artificial dune was constructed along the length of the island to protect private lands from future storm damage (Mackintosh, 1982). The legacy of this artificial dune line persists today, as remnants of it continue to prevent the natural processes of sand overwash along portions of Assateague Island, including a maintained dune in the park's Developed Zone to protect infrastructure such as buildings and roads. In early 1998, two extra-tropical cyclones passed over Assateague Island, producing extremely large waves that threatened to breach the north end of the island (USGS, 1999). As a temporary measure to prevent a breach from occurring, a 2.4 km (1.5 mi) emergency storm berm was constructed, starting 5.0 km (3.1 mi) south of the Ocean City Inlet. The persistent structure continues to prevent overwash along this section of the north end but is being actively modified in order to allow westerly overwash to occur at a rate similar to other areas in the north of the island (ASIS, 2008b).

Method

A map of areas where human activity has impeded natural overwash processes (Figure 4.33) was created by combining existing datasets including a 2004 lidar survey (ASIS, 2010), a USGS geomorphological map (Morton et al., 2007), and ASIS datasets of historic roadways, dune crossings, and other similarly modified areas (ASIS, 2010). The percentage areal extent of areas attaining reference condition were then calculated for the entire Seashore as well as individual habitats.

Reference condition

The reference condition was no anthropogenic impediments (both actively managed and remnant structures) to natural overwash processes.

Current condition

Current condition is good, with 79% of the land area in the Maryland portion of the Seashore being free of human structures that would impede natural overwash processes (Figure 4.33, Table 4.14).

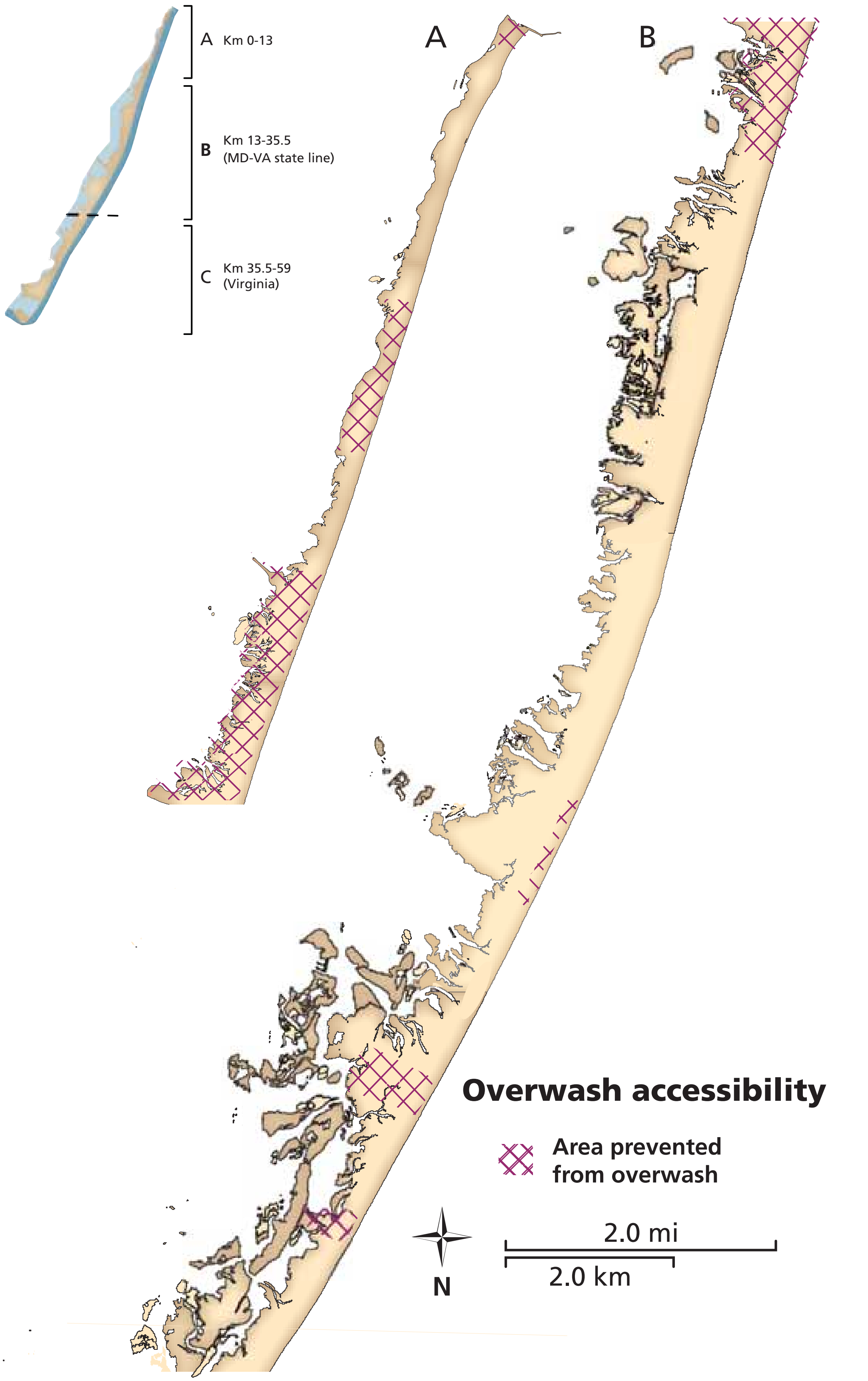
Trend

Construction of the 1950's artificial dune and the 1998 emergency storm berm reduced the ability for natural overwash processes to occur on Assateague Island, but large storms during the 1990's and recent management actions have restored natural overwash processes to large areas of the Seashore.

Overwash event that almost reached Sinepuxent Bay.

Photo: NPS ASIS

Figure 4.33. Areas prevented from natural overwash processes due to human modifications to island structure on Assateague Island National Seashore.



Data source: Morton et al., 2007; http://pubs.usgs.gov/of/2007/1388/start.html#3.

Table 4.14. Areas and percentages of land in the Maryland portion of Assateague Island National Seashore prevented from natural overwash by human structures, as total area and by different habitat types (Data Source: 2003-2004 ASIS-GIS layer of LIDAR geomorphology; ASIS, 2010).

Habitat	Total MD habitat (m^2)	Area Prevented from Overwash (m^2)	% Prevented from Overwash
Beach and intertidal	4,556,868	633,970	13.9
Dunes and grassland	6,277,472	1,579,109	25.2
Forest and shrubland	14,136,885	3,220,959	22.8
Salt marsh	9,848,657	1,843,460	18.7
Inland wetlands	1,064,662	152,499	14.3
TOTAL	**35,884,543**	**5,586,537**	**20.7**

Data gaps and confidence in assessment

Tracking the area of the island where human structures impede natural overwash processes will allow assessment of the effectiveness of current management actions (ASIS, 2008b).

Confidence in the assessment of current condition is high, and in the current assessment of trend is high.

Sources of expertise

Carl Zimmerman; Resource Management Specialist, Assateague Island National Seashore.

Courtney Schupp, Coastal Geologist, Assateague Island National Seashore.

Jack Kumer, Resource Management Specialist, Assateague Island National Seashore.

Neil Winn, Geographer, Assateague Island National Seashore

Literature cited

ASIS. 2008b. Proposal to create flow paths through the constructed berm at Assateague Island National Seashore. Assateague Island National Seashore. National Park Service.

ASIS. 2010. Assateague Island National Seashore data repository. **In:** National Park Service Natural Resource Information Portal. **https://nrinfo.nps.gov/Home.mvc** Accessed December 2010.

Kochel, R.C. and Wampfler, L.A. 1989. Relative role of overwash and Aeolian processes on washover fans, Assateague Island, Virginia-Maryland. *Journal of Coastal Research* 5(3): 453-475.

Lea, C., M. Sturm, H. Hamilton, S. Weller, S. King, and B. McIntyre. 2003. Assateague Island National Seashore Seabeach amaranth Restoration, Assateague Island National Seashore, Berlin, MD. Final Report-2002.

Leatherman, S.P. 1979. Migration of Assateague Island, Maryland, by inlet and overwash processes. *Geology* 7: 104-107.

Loegering, J.P. and Fraser, J.D. 1995. Factors affecting piping plover chick survival in different brood-rearing habitats. *Journal of Wildlife Management* 59(4): 646-655.

Mackintosh, B. 1982. Assateague Island National Seashore: An Administrative History. History Division, National Park Service, Washington D.C.

Morton, R.A., J.E. Bracone, and B. Cooke. 2007. Geomorphology and Depositional Sub-environments of Assateague Island MD/VA. USGS Open File Report 2007-1388. **http://pubs.usgs.gov/of/2007/1388**

Weakley, A., M. Bucher, and N. Murdock. 1996. Recovery plan for seabeach amaranth (*Amaranthus pumilus*) Rafinesque. U.S. Fish and Wildlife Service. Atlanta, GA.

4.5 GEOLOGY & SOILS

4.5.1 Salt marsh erosion

Relevance and context

The bayside shoreline of Assateague Island is subject to erosion by wave action and potential subsidence from sea level rise (Krantz et al., 2009). Barrier islands have a natural tendency for sand erosion on the ocean side, both offshore as a result of long shore drift, and across the island, depositing sand on the bay side due to storm overwash (Godfrey, 1970; Kochel and Dolan, 1986). In Sinepuxent Bay and northern Chincoteague Bay, 75% of the sand entering the bays has been estimated to come from either storm overwash or blown by winds crossing Assateague Island, while the remaining 25% is from shoreline erosion (Wells et al., 2003). Bay side salt marsh communities rely on an adequate sediment supply to maintain surface elevation, provide nutrients for plant growth, and counteract erosional processes (Gleason et al., 1979). The erosion of sediment from marsh edges can lead to the suspension of finer-grained sediments, reduced water clarity, and the release of nitrogen and phosphorus as well as heavy metals into the water column (Wells et al., 2003; Wells et al., 2008). In Sinepuxent Bay, with a small watershed relative to surface water area and therefore relatively low overland water flow, 14% of the total nitrogen and 30% of the total phosphorus delivered annually to this bay comes from shoreline erosion (Wells et al., 2003). In Sinepuxent and northern Chincoteague Bays, 12% of the annual lead load and 24% of the annual zinc load also comes from eroding shoreline including marshes (Wells et al., 2003). Another consequences of marsh edge erosion is a change in sediment structure, the eroded peat increases sediment organic content and can preclude the growth of the seagrass *Zostera marina*, in hydrodynamically active areas (Wicks et al., 2009).

Erosion from wave action and sea level rise showing exposed salt marsh roots.

Photo: Adrian Jones, IAN Image Library

Method

Digitized shorelines throughout the Maryland Coastal Bays from 1942 and 1989 were compared, by Maryland Geological Survey, to calculate the rate and direction of shoreline change over that period (Wells et al., 2003; Wells et al., 2008; Table 4.19). Sediment samples were taken at multiple locations and analyzed for nutrients and heavy metals to estimate loading rates from shoreline erosion. Shoreline rates of change for sampling polygons along the shores of Assateague Island in Sinepuxent Bay and Chincoteague Bay, including small associated islands (polygons P18-P23, P32-37), were compared to the reference condition (Wells et al., 2003; Wells et al., 2008).

Reference condition

Desired reference condition was for bayside shorelines to be overall stable, although it is recognized that Assateague Island has complex and dynamic geomorphology, more data to calculated a historic baseline or reference rate of change was not available (Table 4.20).

Current condition

The mean linear rate of shoreline change along the bay shoreline of Assateague Island between 1942 and 1989 was a loss of 0.20±0.04 m year^{-1}, with a range from -0.02 to -0.41 m year^{-1} (Table 4.15; 4.21). This represents a very degraded condition, attaining 0% of the desired reference condition.

Table 4.15. Bayside salt marsh erosion on Chincoteague and Sinepuxent Bay (Wells et al., 2003). Values not attaining the reference condition are in bold. SE is the standard error of the mean.

Polygon	1942 Water area (m^2)	1989 Water area (m^2)	1989 Shoreline length (m)	Change in land area (m^2)	Change per m shoreline	Annual change ($m\ yr^{-1}$)
P18	6,438,192	6,504,264	67,398	-66,072	-0.98	**-0.02**
P19	1,127,835	1,239,148	7,029	-111,314	-15.84	**-0.34**
P20	2,030,608	2,058,063	6,069	-27,455	-4.52	**-0.10**
P21	124,143	132,165	1,092	-8,022	-7.35	**-0.16**
P22	296,532	309,080	1,775	-12,548	-7.07	**-0.15**
P23	51,811	58,040	1,884	-6,229	-3.31	**-0.07**
P32	7,023,215	7,690,443	34,838	-667,228	-19.15	**-0.41**
P33	4,181,824	4,801,583	36,284	-619,758	-17.08	**-0.36**
P34	1,831,652	1,886,690	4,606	-55,037	-11.95	**-0.25**
P35	7,297,229	7,544,979	40,360	-247,750	-6.14	**-0.13**
P36	1,886,555	2,040,887	15,247	-154,332	-10.12	**-0.22**
P37	7,309,883	7,562,159	39,897	-252,276	-6.32	**-0.13**
					Mean	**-0.20**
					SE	**0.04**

Trend

No trend assessment was possible. However, it should be noted that between the mid 1960's and early 1990's, an artificial dune line running the length of the Seashore effectively prevented all substantive storm overwash. As a result, none of the bay side salt marshes received any sediment input from overwash, which has likely contributed to the observed rates of shoreline erosion.

Data gaps and confidence in assessment

Future assessments at more frequent time intervals would enhance understanding of variability, as well as trends in rates of bayside shoreline change.

Confidence in the assessment of condition was high, no assessment of trend was possible.

Sources of expertise

Carl Zimmerman, Resource Management Specialist, Assateague Island National Seashore.

Courtney Schupp, Coastal Geologist, Assateague Island National Seashore.

Darlene Wells, Geologist, Department of Natural Resources, Maryland Geological Survey Division.

Literature cited

Godfrey, P.J. 1970. Oceanic overwash and its ecological implications on the Outer Banks of North Carolina. Office of Natural Science Studies, National Park Service, Washington D.C. 44pp.

Kochel, R.C. and Dolan, R. 1986. The role of overwash on a mid-Atlantic coasta barrier island. *The Journal of Geology* 94(6): 902-906.

Krantz, D.E., C.A. Schupp, C.C. Spaur, J.E. Thomas, & D.V. Wells. 2009. Chapter 12: Dynamic systems at the land-sea interface. **In:** Dennison, W.C., J.E. Thomas, C.J. Cain, T.J.B. Carruthers, M.R. Hall, R.V. Jesien, C.E. Wazniak, & D.E. Wilson. *Shifting Sands: Environmental & Cultural Change in Maryland's Coastal Bays.* IAN Press, Cambridge, Maryland.

Gleason, M.L., D.A. Elmer, N.C. Pien, and J.S. Fisher. 1979. Effects of stem density upon sediment retention by salt marsh cordgrass, *Spartina alterniflora* Loisel. *Estuaries* 2: 271-273.

Wells, D.V., Hennessee, E.L., and Hill, J.M., 2003, Shoreline erosion as a source of sediments and nutrients, northern coastal bays, Maryland (Coastal and Estuarine Geology File Report No. 02-05): Maryland Geological Survey, Baltimore, Md., on Compact Disk (CD-ROM).

Wells, D.V., E.L. Hennessee, J.M. Hill and S. Van-Ryswick. 2008. Shoreline Erosion as a Source of Sediments and Nutrients, Southern Coastal Bays, Maryland - Phase II: Sample Analysis and Interpretation. Maryland Department of Natural Resources and National Oceanic and Atmospheric Administration. NOAA ward No. NA05NOS4191142.

Wicks, E.C., Koch, E.W., O'Neil, J.M. and Elliston, K. 2009. Effects of sediment organic content and hydrodynamic conditions on the growth and distribution of *Zostera marina*. *Marine Ecology Progress Series* 378: 71-80.

4.5.2 Beach shoreline rate of change

Relevance and context

Assateague Island experiences the natural barrier island processes of ocean shoreline erosion and island rollover caused by the movement of sediment both alongshore (to be deposited on the downdrift end of the island, the accreting Toms Cove spit) and landward (to be deposited on the island's surface, marsh shoreline, and in the bay), resulting in the island's overall landward and southward migration (Krantz et al., 2009). Storm-driven waves rapidly move large volumes of sediment in several directions: alongshore, offshore, and over the top of the island. Fair-weather waves gradually replenish sediment along ocean beaches. The resulting coastline modifications provide new opportunity for habitat (Fisher, 1967). Sea level rise may intensify natural erosion beyond normal rates and deplete sand resources that naturally replenish island habitat (Bruun, 1962). The shoreline also responds to human modifications such as jetties, beach nourishment projects, berms, and dunes, which may prevent or increase erosion in localized areas (Rosati and Ebersole, 1996). The rock jetties that maintain Ocean City Inlet, which separates Ocean City from Assateague Island, interrupt longshore sediment transport to the island and have resulted in sediment starvation along the island's northern 13 kilometers, exacerbating the vulnerability of the North End to destabilization and breaching (Rosati and Ebersole, 1996; USACE, 1998). The shoreline change rate southward of this 13-km section, where the effects of the rock jetties have not been documented, is controlled by a different set of processes (Krantz et al., 2009), including natural alongshore sediment transport and contribution of sediments from managed and remnant dunes.

Method

Shoreline position data was compiled (ASIS, 2010) from biannual shoreline surveys collected by ASIS 1997-2008, and from historic shorelines from NOS T-sheets (1849-1980), U.S. Coast and Geodetic Survey T-sheets, and 1980 National Ocean Service aerial photography. A baseline was drawn parallel to the general trend of the compiled shoreline data sets (ASIS, 2010). The shoreline change rate was then calculated using the Digital Shoreline Analysis System (Thieler et al., 2005), which cast shore-perpendicular transects at 50 m intervals between the user-defined baseline and each shoreline position (ASIS, 2010).

The rock jetties (indicated by arrows) in Ocean City Inlet interrupt longshore sediment transport to Assateague island.

Photo: Jane Thomas, IAN Image Library

Table 4.16. Beach shoreline rate of change for two regions of Assateague Island National Seashore. Reference condition is based on data from 1849-1908 for km 1-13 (-0.986 ± 1.963 m yr^{-1}). Rates were calculated from 258 transect points for km 1-13, and 682 transect points for km 13-26. Current condition was assessed using data from 1997-2008.

Region	Year Range	Mean Rate (m y^{-1})	SE	# years
Km 1-13	1849-1908	-0.986	1.963	1.963
	1908-1933	-3.607	1.469	1.469
	1933-1942	-1.773	5.523	5.523
	1942-1962	-6.307	5.740	5.740
	1962-1997	-2.788	2.524	2.524
	1997-2008	**-0.840**	**1.795**	**1.795**
Km 13-26	1849-1908	0.658	0.525	0.525
	1908-1933	-0.902	1.146	1.146
	1933-1942	3.629	3.062	3.062
	1942-1962	-2.216	0.891	0.891
	1962-1997	-0.044	0.524	0.524
	1997-2008	**-0.793**	**0.744**	**0.744**

The DSAS output table included the distance of each shoreline from the baseline at each transect; these distances and the associated shoreline years were used to calculate an end-point rate for each transect and each pair of consecutive shoreline survey dates. For each year range (each pair of consecutive shoreline survey dates), the end point rates of all transects (258) within the northern 13 km were averaged to result in one mean shoreline change rate for the North End; the process was repeated for all transects (682) between km 13 and km 26. The standard error of the mean rate of shoreline change within each year range was calculated for both island sections.

Reference condition

The Ocean City Inlet and rock jetties have altered sediment transport processes, causing unnatural sediment deprivation along the northern 13 km of Assateague Island, accelerating the natural erosion rate from an estimated pre-inlet rate (1850-1933) of -1.5 m yr^{-1} to a post-inlet rate (1942-1997) of -3.70 m yr^{-1}, and causing associated habitat degradation (Schupp et al., 2007). For this assessment, the historic, pre-inlet and pre-jetty erosion rate along the north end (1-13 km) for the 1849-1908 era (-0.986 m yr^{-1}) was used as the reference condition for both sections of the island. Erosion rates for subsequent time periods that were within one standard deviations (± 1.963 m yr^{-1}) of this historic rate for the north end were assessed as attaining desired reference condition (Table 4.20).The north end rate for this period was applied to both beach regions because of the confounding effect of intermittent inlet openings and closures between km 13 and km 26 between 1849 and 1908.

Current condition

The recent shoreline rate of change is in very good condition, attaining the reference condition for 100% of the measured shoreline. Compared to the reference condition as calculated for the 1849-1908 era, between km 1-13 (-0.986 m yr^{-1}), erosion during the 1997-2008 era has slowed along both the northern 13 km (-0.84 m yr^{-1}) and between km 13 and km 26 (-0.793 m yr^{-1}).

Trend

The recent (1997-2008) era indicates that the shoreline continues to erode but at a slower rate than seen during the 1849-1908 era. Shoreline change rates for each era are closely correlated to the storm events captured by the end point shoreline surveys. For example, the 1942-1962 era reflects the impacts of the 1962 Ash Wednesday storm, while the 1962-1997 rate captures some post-1962 shoreline recovery followed by the erosion from the 1991 and 1992 storms. The reduction in erosion during the recent 1997-2008 era results from the relatively calm weather during this period and, along the North End, the placement of large volumes of sediment in the nearshore area as part of the North End Restoration Project to mitigate the impacts of the Ocean City Inlet on sediment transport (Schupp et al., 2007).

Data gaps and confidence in assessment

Current monitoring efforts are sufficient to assess this metric. However, care must be used in interpreting the shoreline data that are collected. Intermittent events, such as strong storms (as occurred in 1933, 1962, 1991, 1992, and 1998) and inlet openings and closures, (including the 1849-1908 time period) can significantly influence shoreline change rates, particularly in the case of end point rates which do not incorporate shoreline changes within the date range. Therefore, the choice of end points to use for each year range can have a significant impact on the resulting rate for that era. Sometimes this influence is unavoidable, such as for historic time periods when shoreline surveys were done only once every decade or two and often following strong storms. Storm-driven shoreline change adds significant variability to shoreline change rates, particularly those calculated for short time periods, when storm signals can obscure longer-term shoreline change trends. Shoreline position data include multiple measurement uncertainties including the mapmaker's determination of the high water line, the correlation of the high water line to the wet dry line (which may vary with weather conditions, such as wind pushing the water higher or lower on the beach face), and digitization errors in delineating shorelines from photographs and hardcopy maps (Table 4.16) (Moore, 2000).

Confidence in assessment of current condition is high and in assessment of trend is fair, due to historical sampling being largely events based.

Sources of expertise

Courtney Schupp, Coastal Geologist, Assateague Island National Seashore

Neil Winn, Geographer, Assateague Island National Seashore

Literature cited

ASIS. 2010. Assateague Island National Seashore data repository. In: National Park Service Natural Resource Information Portal. **https://nrinfo.nps.gov/Home.mvc** Accessed December 2010.

Bruun, P. 1962. Sea level rise as a cause of shore erosion. *Journal of Waterways and Harbors Division, American Society of Civil Engineers Proceedings* 88:117-130.

Fisher, J.J. 1967. Origin of barrier island shorelines: Middle Atlantic States. *Geological Society of America, Special Paper* 115: 66-67.

Krantz, D.E., C.A. Schupp, C.C. Spaur, J.E. Thomas, & D.V. Wells. 2009. Chapter 12: Dynamic systems at the land-sea interface. **In:** Dennison, W.C., J.E. Thomas, C.J. Cain, T.J.B. Carruthers, M.R. Hall, R.V. Jesien, C.E. Wazniak, & D.E. Wilson. *Shifting Sands: Environmental & Cultural Change in Maryland's Coastal Bays.* IAN Press, Cambridge, Maryland.

Moore, L.J. 2000. Shoreline Mapping Techniques. *Journal of Coastal Research* 16(1) pp. 111-124.

Rosati, J.D. and B.A. Ebersole. 1996. Littoral impact of Ocean City Inlet, Maryland, USA. Edge, Billy L. ed. Coastal Engineering 1996: Proceedings of the 25th International Conference. 3: 2779-2792. American Society of Civil Engineers.

Schupp, C.A., Bass, G.P., and Grosskopf, W.G. 2007. Sand bypassing restores natural processes to Assateague Island National Seashore. **In:** Kraus, N.C. and Rosati, J.D. (Eds.). *Proceedings of Coastal Sediments '07.* Reston, VA: ASCE, pp. 1340-1353.

Thieler, E.R., Himmelstoss, E.A., Zichichi, J.L., and Miller, T.L., 2005, Digital Shoreline Analysis System (DSAS) version 3.0: An ArcGIS extension for calculating shoreline change: U.S. Geological Survey Open-File Report 2005-1304.

U.S. Army Corps of Engineers. 1998. Ocean City, Maryland, and Vicinity Water Resources Study Final Integrated Feasibility Report and Environmental Impact Statement, Appendix D. Restoration of Assateague Island. Baltimore, MD.

4.5.3 Upland elevation change

Relevance and context

On Assateague Island, dunes are formed naturally when storms are not frequent or intense and beach grass is allowed to capture blowing and overwashed sand (Wilson et al., 2009). Dunes are relatively stable elements in the system and aid in retaining and accumulating sand, as well as building the upland regions of the island (Dolan, 1972). Dune presence increases island resilience to storm impacts because they function as sand reservoirs, dissipate wave energy, and serve as barriers to storm waves and swash (Leatherman, 1979). Loss of overall sand volume in upland areas may reduce the overall stability of the island and may indicate accelerated erosion due to changes in sea level, increased storm frequency or intensity, shoreline modifications in updrift areas (e.g., rock jetties), or degradation of dune vegetation (Seliskar, 1997, Krantz et al., 2009, Anders and Leatherman, 1987). Both the spatial extent of the dunes and the total volume of sediment contained within the dunes contribute to island resilience.

Method

To incorporate measurements of the changes in upland volume and area, the elevation change per year was calculated for three island regions: North End (km 1-13), Developed Zone (km 13-16), and OSV Zone (km 16-35). The upland volumes were summed within each island region for each year (Table 4.17), and the differences of these measurements between survey dates were then calculated. Total spatial extent (area) of upland was also calculated as a percentage of total area of the island region in order to provide context (Table 4.17). To integrate these changes into one metric (elevation change per year), the change in volume was divided by the upland area of consideration (in order to allow comparison between island regions) and was then normalized by the number of years (three) between measurements (Table 4.18). The natural storm berm is considered to be upland, while overwash fans are too low to be considered upland. Both features have been surveyed at ASIS (using lidar and ground-based methods) over a period of 10 years, and their elevations have varied; the minimum surveyed height of the natural storm berm is 1.8 m NAVD88, and the average maximum elevation of overwash fans is 2.2 m NAVD88 (Table 4.20). The base elevation of upland area was approximated as 2.0 m NAVD88, the mid-point between the average maximum elevation of overwash fans and

Table 4.17. Island upland volume and area change calculations[1] from lidar datasets (ASIS-NPS). The Maryland portion of Assateague Island National Seashore was divided into three regions (North End, Developed, and OSV) to measure changes in island volume and area.

Region	Year	Volume Above ~2 m (cm*m²)	Total Area Considered (m²)	Area with Height above 2m (m²)	% of Total Area above 2 m
North End km 1-13	2002	16,686,744	3,950,414	297,538	8%
	2005	28,331,273	3,950,414	589,246	15%
	2008	30,083,230	3,950,414	535,975	14%
Developed km 13-16	2002	48,504,959	4,616,027	430,686	9%
	2005	54,080,274	4,616,027	505,627	11%
	2008	52,713,969	4,616,027	492,753	11%
OSV km 16-35	2002	93,404,721	16,131,904	1,493,483	9%
	2005	136,195,956	16,131,904	2,354,256	15%
	2008	128,286,458	16,131,904	1,883,460	12%

Volume and area were calculated after lidar grids were adjusted for suspected vertical offsets of up to 0.35 m. Suspected offsets were calculated by comparing elevations of known surveyed points (parking lots, rooftops) to the lidar grid elevation at those points.

the minimum elevation of the natural storm berm. Interpolated grids of the upland surface area and elevations in 2002, 2005, and 2008 were then created by processing bare-earth lidar surveys using ArcGIS Spatial Analyst (Table 4.19).

Reference condition

The reference condition for this assessment is a stable or increasing (accreting) elevation change per year within a given island region. Upland volume and spatial extent (area) provide stability to the island by strengthening its physical integrity and resiliency to storms. The calculations of total upland volume change and percent upland area change (Table 4.17) provide context for the metric, such as whether upland area is expanding, or whether individual dunes are simply increasing in height without adding stability to other areas of the island.

Current condition

The threshold condition (increased or stable upland elevation change per year) was attained in all three sections between 2002 and 2005, but was not met in the Developed Zone or the OSV Zone between 2005 and 2008, resulting in an overall attainment of reference condition in 67% of cases (Table 4.18; 4.21).

Trend

In all three island sections, elevation change per year increased between 2002 and 2005 as a result of increases in both upland area and volume. Although the calculated values of change may seem small (fractions of centimeters), these changes over a large area (such as the entire OSV zone) equate to large volumes of sediment. Between 2005 and 2008, upland area and volume both decreased in the OSV Zone, resulting in an overall elevation loss per year; this may have been related to storm events in 2006 that created new overwash fans. Within the North End during the same time period, upland volume increased while upland area decreased, resulting in a smaller but still accretional elevation change per year; consistent increases in the upland volumes of the North End are due mainly to the recurring nearshore sediment placement related to the North End Restoration project (Schupp et al., 2007) and to the sand-trapping effects of the constructed berm. Changes in upland areas and volumes within the Developed Zone are related almost entirely to dune management practices.

Photo: NPS ASIS

Sediment accretion and erosion contributes to upland elevation change.

Data gaps and confidence in assessment

Current monitoring efforts (lidar surveys) are sufficient to assess this metric.

Confidence in assessment of condition is high and assessment of trend is fair (due to small number of measurement points).

Table 4.18. Island upland elevation change per year for three regions within Assateague Island National Seashore. Changes were calculated using the upland volumes and areas calculated within each region for each of three survey years (Table A-32).

Year range	North end elevation change per year (cm y^{-1})	Developed Zone Elevation Change per year (cm y^{-1})	OSV Zone Elevation Change per year (cm y^{-1})
2002-2005	0.98	0.40	0.88
2005-2008	0.15	-0.10	-0.16

Sources of expertise

Jack Kumer, Resource Management Specialist, Assateague Island National Seashore

Courtney Schupp, Coastal Geologist, Assateague Island National Seashore

Neil Winn, Geographer, Assateague Island National Seashore

Carl Zimmerman; Resource Management Specialist, Assateague Island National Seashore

Literature cited

Anders, F. & S. Leatherman. 1987. Effects of off-road vehicles on coastal foredunes at Fire Island, New York, USA. *Environmental Management* 11(1): 45-52.

Dolan, R. 1972. Barrier dune system along the Outer Banks of North Carolina: a reappraisal. *Science* 172: 286-288.

Krantz, D.E., C.A. Schupp, C.C. Spaur, J.E. Thomas, & D.V. Wells. 2009. Chapter 12: Dynamic systems at the land-sea interface. **In:** Dennison, W.C., J.E. Thomas, C.J. Cain, T.J.B. Carruthers, M.R. Hall, R.V. Jesien, C.E. Wazniak, & D.E. Wilson. *Shifting Sands: Environmental & Cultural Change in Maryland's Coastal Bays.* IAN Press, Cambridge, Maryland.

Leatherman, S.P. 1979. Migration of Assateague Island, Maryland, by inlet and overwash processes. *Geology* 7: 104-107.

Schupp, C.A., Bass, G.P., and Grosskopf, W.G. 2007. Sand bypassing restores natural processes to Assateague Island National Seashore. **In:** Kraus, N.C. and Rosati, J.D. (Eds.). *Proceedings of Coastal Sediments '07.* Reston, VA: ASCE, pp. 1340-1353.

Seliskar, D. 1997. The Effect of Grazing by Feral Horses on American Beachgrass at Assateague Island National Seashore. Final Report. University of Delaware.

Wilson, D.E., C.E. Wazniak, D.M. Boward, T.J.B. Carruthers, R.J. Chalmers, D.H. Clearwater, W.C. Dennison, A.B. Hairston-Strang, M.R. Hall, F.M. Irani, R.V. Jesien, W.M. Knapp, E.W. Koch, K.L. Kyde, A.E. Luscher, M.D. Naylor, R.J. Orth, C.C. Spaur, M.L. Tarnowski, E.C. Wicks, and C.S. Zimmerman. 2009. Chapter 15: Habitats of the Coastal Bays and Watershed. **In:** Dennison, W.C., J.E. Thomas, C.J. Cain, T.J.B. Carruthers, M.R. Hall, R.V. Jesien, C.E. Wazniak, & D.E. Wilson. *Shifting Sands: Environmental & Cultural Change in Maryland's Coastal Bays.* IAN Press, Cambridge, Maryland.

Table 4.19. Ecological monitoring framework data provided by agencies and specific sources included in the assessment of Assateague Island National Seashore.

Metric (by category)	Agency	Reference/Source
Air & Climate		
Wet nitrogen deposition	NPS ARD	NPS 2010 http://nadp.sws.uiuc.edu/sites/ntnmap.asp
Wet sulfate deposition	NPS ARD	NPS 2010 http://nadp.sws.uiuc.edu/sites/ntnmap.asp
Ozone	NPS ARD	NPS 2010
Visibility	NPS ARD	NPS 2010
Particulate matter (PM 2.5)	IMPROVE	http://www.epa.gov/airexplorer/
Mercury deposition	MDN-NADP	http://nadp.sws.uiuc.edu/mdn/
Night viewshed	NPS ARD	T. Jiles, NPS Night Sky Team 2009
Water Quality		
Water quality index (WQI)	NPS ASIS	ASIS 2010
Water pH	NPS ASIS	Hall 2005
Bacterial abundance	ASIS	Sherry 2007a,b
Biological Integrity		
Phragmites	ASIS	ASIS 2010
Horse abundance	ASIS	ASIS 2010
Deer density	ASIS	Sturm 2007
Piping Plover fecundity	ASIS	ASIS 2010
Seagrass area	VIMS	MCBP, Orth et al., 2005. http://web.vims.edu/bio/sav
Horseshoe Crabs	MCBP	MCBP 2009
Clam density	MD DNR	2008 MDDNR Hard Clam Survey
Tiger Beetle abundance	ASIS	Knisley 2009
Seabeach Amaranth abundance	ASIS	ASIS-NPS 2010
Atlantic Surfclam	NOAA	49th Northeast Regional Stock Assessment Summary Report, 2010
Landscapes		
Over-sand vehicle trails	ASIS	ASIS 2010
Sediment contaminants	ASIS, EPA, NOAA	Cooper and Borjan. 2008, Zimmerman 1996
Mosquito ditch density	ASIS	ASIS 2010
Impervious surface	Worcester County	ASIS, 2010; Worcester County 2004 Land Cover
Overwash accessibility	ASIS, USGS	ASIS, Morton et al., 2007
Geology & Soils		
Salt marsh erosion	MGS	Wells et al., 200; 2008
Shoreline rate of change	ASIS	Schupp, 2009,
Upland elevation change	ASIS	ASIS LIDAR 2002, 2005, 2008

Table 4.20. Reference condition for Assateague Island National Seashore resource condition assessment.

Metric (by category)	Reference condition	Sites	Samples	Period
Air & Climate				
Wet nitrogen deposition	< 1 kg $ha^{-1}y^{-1}$	Park	1	2003-2007
Wet sulfate deposition	< 1 kg $ha^{-1}y^{-1}$	Park	1	2003-2007
Ozone	< 0.06 ppm	Park	1	2003-2007
Visibility	< 2 dv	Park	1	2003-2007
Particulate matter (PM 2.5)	< 15 mg m^{-3}	2	2272	2000-2009
Mercury deposition	< 2 ng L^{-1}	2	226	2005-2010
Night viewshed	> 21.5 mag sq-arc-sec^{-1}	Park	6	2009
Water Quality				
Water quality index (WQI)	TN < 46 mM; TP < 1.2 mM; Chl *a* < 15 mg L^{-1}	18	54	2006-2008
Water pH	6.0 ≥ pH ≤ 8.5	11	231	2003-2004
Bacterial abundance	< 104 MPN/100 ml	3	48	2006
Biological Integrity				
Phragmites	< 2% area	Park	1	2008
Horse abundance	population of 80-100 horses	Park	10	2000-2009
Deer density	< 8 deer km^{-2}	Park	16	2003-2006
Piping Plover fecundity	≥ 1.19 chicks per pair, 5 year rolling mean	Park	11	2000-2010
Seagrass area	≥ 3,031 acres Sinepuxent, ≥ 20,400 acres Chincoteague	2	9	2000-2009
Horseshoe crabs	no decline in yearly abundance	3	10	2007-2009
Clam density	≥ 1.34 clams m^{-2}	163	1	2008
Tiger Beetle abundance	no decrease in 2-year rolling mean	44	193	2001-2009
Seabeach Amaranth abundance	no decrease in 3- year rolling mean	Park	12	1998-2009
Atlantic Surfclam	272,000 mt meat biomass and 0.15 y^{-1} fishing mortality rate	Surveys & model	9	2000-2008
Landscapes				
Over-sand vehicle trails	% area of dune/grassland area closed to OSV use % length of beach/intertidal by length closed to OSV use	Park	1	2006
Sediment contaminants	TEL (Threshold Effect Level) for each of 9 metals	12	12	1993, 1996
Mosquito ditch density	all viable ditches filled	Park	1	2003
Impervious surface	<10%	Park	1	2004
Overwash accessibility	% habitat accessible to potential overwash	Park	1	1993, 2003, 2004
Geology & Soils				
Salt marsh erosion	marsh stable	5	5	1942-1989
Shoreline rate of change	within 1 SD of km 1-13 1849-1908 basal rate	2	469	1849-2008
Upland elevation change	accretion	3	6	2002, 2005, 2008

Table 4.21. Summary of Vital Signs ecological reporting unit resource condition assessment of Assateague Island National Seashore.

Metric (by category)	Mean	Reference condition % Attainment	Condition
Air & Climate			
Wet nitrogen deposition	4.5 kg ha^{-1} yr^{-1}	0	very degraded
Wet sulfate deposition	5.4 kg ha^{-1} yr^{-1}	0	very degraded
Ozone	0.08 ppm	0	very degraded
Visibility	12.86 dv	0	very degraded
Particulate matter (PM 2.5)	13.6 mg m^{-3}	100	very good
Mercury deposition	10.9 ng L^{-1}	0	very degraded
Night viewshed	21.7 mag $arc\text{-}sec^{-2}$	100	very good
Water Quality			
Water quality index (WQI)	TN < 46mM; TP < 1.2mM; Chl *a* < 15 mg L^{-1}	63	good
Water pH	$4.8 \geq pH \leq 8.0$	54	fair
Bacterial abundance	43.65 MPN Bayside, 7.81 MPN Atlantic	98	very good
Biological Integrity			
Phragmites	5.6% of MD Park	0	very degraded
Horse abundance	151 horses	31	degraded
Deer density	15.2	0	very degraded
Piping Plover fecundity	1.2 chicks fledged per pair	60	good
Seagrass area	11,487 acres Chincoteague, 2,011 acres Sinepuxent	61	good
Horseshoe crabs	0.13 crabs m^{-2}	86	very good
Clam density	0.16 clams m^{-2}	18	very degraded
Tiger Beetle abundance	222 Cicindela dorsalis media, 508 C. lepida	44	fair
Seabeach Amaranth abundance	1489 plants	67	good
Atlantic Surfclam	982,000 mt meat biomass, 0.02 y^{-1} mortality	100	very good
Landscapes			
Over-sand vehicle trails	1% dunes, 29% beach length	85	very good
Sediment contaminants	multiple	73	good
Mosquito ditch density	48276 m viable ditches in park	10	very degraded
Impervious surface	30.7 ha in MD Park	99	very good
Overwash accessibility	743 ha prevented in MD Park	79	good
Geology & Soils			
Salt marsh erosion	-0.2 m y^{-1}	0	very degraded
Shoreline rate of change	1997-2008 average rates for North End: -0.840 m y^{-1} Below Km 13: -0.793 m y^{-1}	100	very good
Upland elevation change	North End: 0.57m y^{-1} Developed Zone: 0.15 m y^{-1} OSV: 0.36 m y^{-1}	67	good

Photo: Jane Thomas, IAN Image Library

Chapter 5: Discussion

5.1 ASSATEAGUE ISLAND CONTEXT FOR ASSESSMENT

A discussion of natural resource condition for Assateague Island National Seashore needs to consider the dynamic geomorphology and unique history of the Island. Barrier islands are naturally dynamic ecosystems with longshore drift resulting in a continual sand erosion and deposition cycle. They are also subject to significant changes from storms that cause island overwash, breaching, or new inlet formation (Chapter 2). These dynamic processes create the unique habitats, flora and fauna that are key features of Assateague Island (including overwash areas, piping plover and seabeach amaranth); however, they also have the potential to dramatically change fundamental aspects of the island. This assessment includes metrics intended to account for the resource value of maintaining these dynamic processes, such as area available to natural storm overwash processes (Chapter 4).

The unique history of Assateague Island, preceding the establishment of the National Park in 1965, provides important context to an assessment of natural resource condition. In terms of the geomorphology of the island, significant impacts include the hard stabilization of Ocean City inlet, which was opened by the 1933 storm, the construction of an artificial protective dune along much of the island following the 'Ash Wednesday Storm' in 1962, and the creation of an emergency storm berm at the north end of the island after two extra-tropical cyclones in 1998 threatened to breach the island (Chapter 2). To mitigate the long-term impacts of two of these actions, park resource managers have been engaged in a long-term mechanical sand bypass project to alleviate sand starvation of the island from the stabilized inlet, and to restore natural overwash processes to the north end of Assateague Island affected by the storm berm. Two significant biological introductions, horses and sika deer, while non-native species to the area, have both become significant cultural park resources. Accordingly, this assessment includes these metrics in the context of stressors when populations are extreme, but in recognition that sustainable populations are also the desired condition (Chapter 4).

5.2 PARK NATURAL RESOURCE CONDITION

Overall, the natural resources of Assateague Island National Seashore were assessed to be in fair condition, attaining 56% of desired reference condition with a fair to high confidence in this assessment. Salt marsh and forest and shrubland habitats were assessed to be in degraded condition. Inland wetlands, dunes and grasslands were assessed as fair, while bay subtidal and mudflats, beach and intertidal as good, and Atlantic subtidal to be in very good condition.

Habitat	Reference condition attainment	Current condition	Confidence in assessment
Bay subtidal and mudflats	67%	Good	High
Salt marsh	35%	Degraded	Fair
Forest and shrubland	23%	Degraded	Fair
Inland wetlands	42%	Fair	Limited
Dunes and grassland	53%	Fair	High
Beach and intertidal	73%	Good	High
Atlantic subtidal	99%	Very good	Very limited
Assateague Island National Seashore	**56%**	**Fair**	**Fair/high**

Photo: NPS ASIS

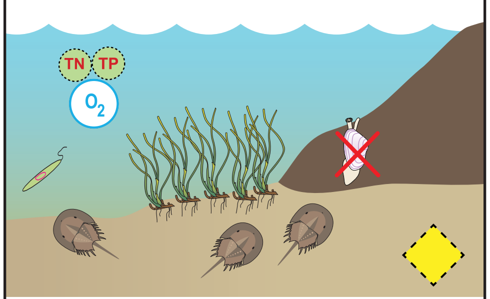
Bay subtidal and mudflat habitat.

Bay subtidal and mudflat habitat

Bay subtidal and mudflat habitats of Assateague Island National Seashore were assessed as being in good condition, attaining 67% of reference condition. Confidence in the assessment of this habitat was high due to abundant data quantity for appropriate indicators. Water quality in Chincoteague and Sinepuxent Bays, within and adjacent to Assateague Island National Seashore, was assessed as being in good condition. However, even though current conditions are good, long-term trends indicate significant declines in water quality since the turn of the century. Nutrient inputs from septic systems may be having local influence in some areas, but the broad scale increases in nitrogen within the Chincoteague and Sinepuxent Bay system as a whole have been linked to high poultry production in the surrounding watershed. Atmospheric sources are also significant in these shallow lagoons with their small watersheds relative to water surface area. Benthic communities, such as seagrass and clams, have shown declines over the last decade which are linked, in part, to deteriorating water quality conditions. Maintaining or improving water quality is crucial to support these important benthic communities, as is continuing the current clam dredging ban. The current monitoring of benthic communities should be continued, and it is recommended that standardized approaches be developed for monitoring other significant ecological and economic components of the ecosystem such as estuarine fin fisheries and horseshoe crabs.

BAY SUBTIDAL AND MUDFLATS

67% GOOD : CONFIDENCE HIGH

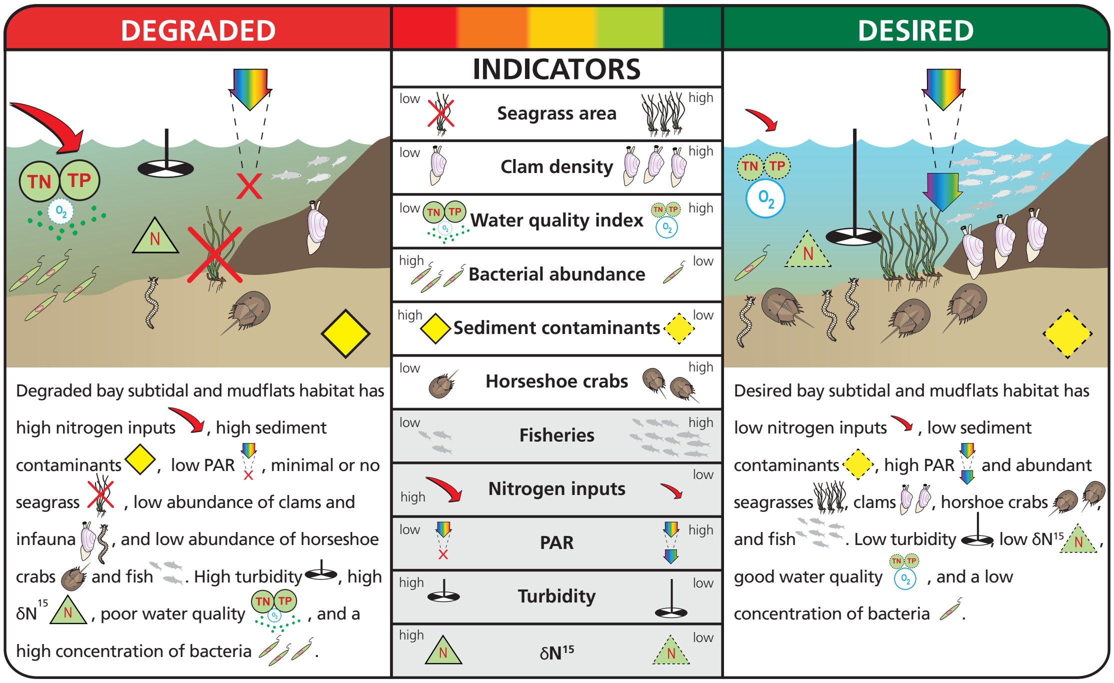


Assessed bay subtidal and mudflats habitat had abundant seagrasses, very degraded clam density, good water quality, a very low concentration of bacteria, low sediment contaminants, and a sustainable population of horseshoe crabs

Indicators	Reference condition attainment	Current condition	Trend in condition
Seagrass area	61%	Good	Declining
Clam density	18%	Very degraded	No trend
Water quality index	63%	Good	Declining
Bacterial abundance	99%	Very good	No trend
Sediment contaminants	77%	Good	Improving
Horseshoe crabs	86%	Very good	?
Bay subtidal and mudflat habitat	**67%**	**Good**	**-**

0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Very Degraded	Degraded	Fair	Good	Very Good

BAY SUBTIDAL AND MUDFLATS



Conceptual range of habitat condition from degraded to desired for Bay Subtidal and Mudflats habitat showing indicators appropriate to assess condition. No data was available in the current assessment for grayed out indicators.

Key findings	Recommendations
Bay subtidal and mudflat habitat	
• Water quality good but degrading	• Continue to monitor conditions and work collaboratively with federal, state and local partners to identify and reduce sources. • Investigate septic sources from Town of Chincoteague and Captains Cove community.
• Seagrass has recent declines and low genetic diversity	• Focus on maintaining water quality. • Continue NPS Vital Signs monitoring to assist in understanding processes to maintain resource.
• Low but stable clam populations	• Support, and monitor effects of, dredging ban.
• Status of horseshoe crabs uncertain	• Standardize and expand population monitoring.
• Difficulty in assessing fin-fisheries status	• Encourage development of status and trends data.

Key findings, management implications, and recommended next steps for Bay Subtidal and Mudflat habitat in Assateague Island National Seashore.

Photo: NPS ASIS

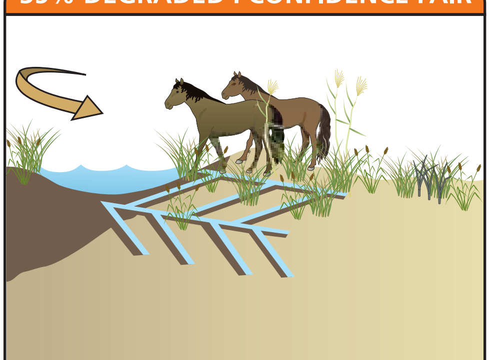
A Green Heron (*Butorides virescens*) in salt marsh on Assateague Island.

Salt marsh habitat

Salt marsh habitats of Assateague Island National Seashore were assessed as being in degraded condition, attaining 35% of reference condition. Confidence in the assessment of this habitat was fair, due to limited data availability. The invasive form of *Phragmites*, while present in the park and common in the region, has low coverage within Park salt marsh habitats. It is recommended that actions to control existing *Phragmites* populations and monitoring to detect new infestations be continued to maintain the current low coverage. The bayside shoreline is eroding, which results not only in loss of salt marsh habitat, but also in sediment and nutrient addition to subtidal and mudflat habitats, causing habitat degradation. Bayside shoreline erosion is further accelerated by the high number of historic mosquito ditches and limitations to natural sand overwash processes due to historically constructed dunes and berms, all of which will be exacerbated by sea level rise. To improve the natural resource condition of salt marsh habitat within the park, it is therefore recommended to continue experimentally infilling mosquito ditches, assessing the ecological impacts of infilling, and removing existing barriers to natural overwash processes. Salt marshes are also impacted by overgrazing and trampling by the feral horse population although the use of contraceptives has dramatically reduced the current size of the herd to near the desired condition. Future condition assessments of this habitat would be improved by the addition of metrics summarizing the nekton community, secretive marsh birds, sediment accretion rate and soil salinity throughout the marsh. Monitoring of salt marsh nekton and sediment accretion is underway but has not yet developed sufficient data to enable analysis.

SALT MARSH

35% DEGRADED : CONFIDENCE FAIR

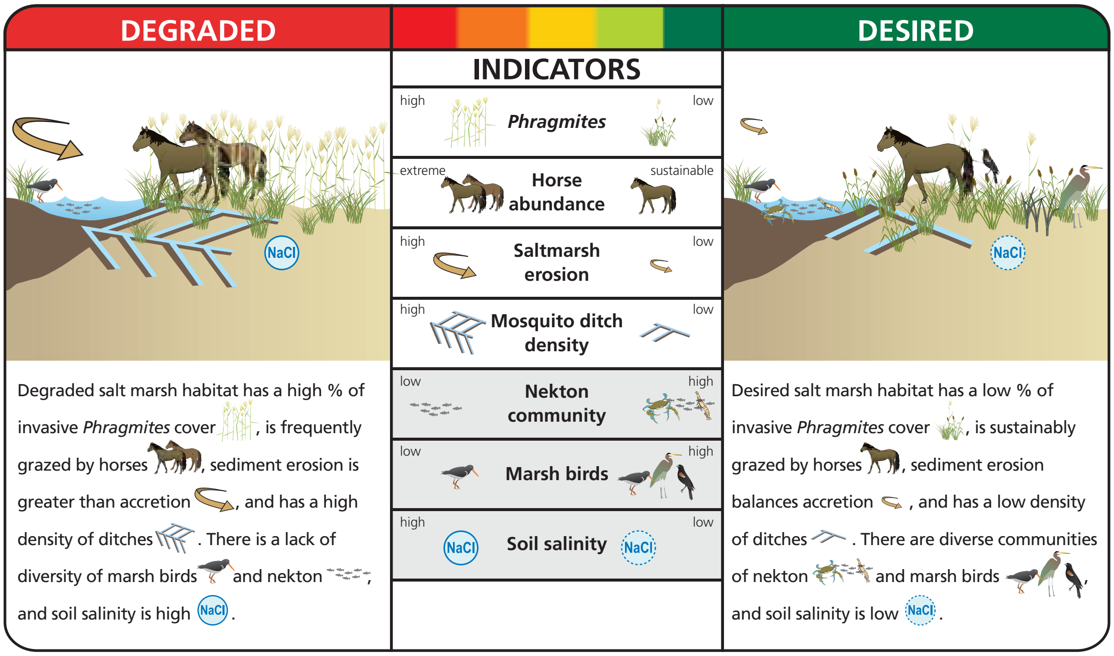


Assessed saltmarsh habitat had a low percentage of *Phragmites* cover, and a large horse population. The habitat experienced high shoreline erosion, and there is a high density of mosquito ditches.

Indicators	Reference condition attainment	Current condition	Trend in condition
Phragmites	100%	Very good	Improving
Horse abundance	31%	Degraded	Improving
Saltmarsh erosion	0%	Very degraded	?
Mosquito ditch density	10%	Very degraded	Improving
Salt marsh habitat	**35%**	**Degraded**	-

0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Very Degraded	Degraded	Fair	Good	Very Good

SALT MARSH



Conceptual range of habitat condition from degraded to desired for Salt Marsh habitat showing indicators appropriate to assess condition. No data was available in the current assessment for grayed out indicators.

Key findings	Recommendations
Saltmarsh habitat	
• Storm overwash is critical to balance shoreline erosion	• Minimize artificial impediments to natural island overwash processes.
• Salt marsh is susceptible to the effects of accelerating sea level rise	• Continue SET monitoring of marsh sedimentation/ subsidence processes
• Mosquito ditches are abundant	• Continue infilling ditches on experimental basis, monitoring ecosystem effects.
• Horses overgraze and trample the marsh	• Manage to minimum self-sustaining population size.
• Invasive *Phragmites* currently controlled in this habitat	• Continue *Phragmites* control efforts.
• Lack of knowledge on secretive marsh birds	• Monitor to inform management decision making.

Key findings, management implications, and recommended next steps for Salt Marsh habitat in Assateague Island National Seashore.

Photo: NPS ASIS

Forest on Assateague Island.

Forest and shrubland habitat

Forest and shrubland habitats of Assateague Island National Seashore were assessed as being in degraded condition, attaining 23% of reference condition. Confidence in the assessment of this habitat was fair, due to limited data availability. Within the Seashore, forest and shrubland habitats have a very low proportion of impervious surface; a positive measure of habitat integrity. However, several other stressors are acting to degrade habitat conditions. A high percent cover of the invasive form of *Phragmites* is present in this habitat and it is recommended that efforts to identify, map, and control these occurrences continue along with an assessment of the ecosystem impacts of treatment using herbicides and prescribed burning. The high numbers of both horses and deer utilizing the forest and shrubland habitats result in overgrazed and trampled vegetation, and may also be influencing forest regeneration by limiting seedling establishment. This impact will be reduced by the current management goal to reduce the feral horse population to a sustainable population of 80-100 individuals. However metrics of deer herbivory impacts on indicators of plant community health combined with a deer density index are needed to fully establish management goals for the native white tail and introduced sika deer populations. Many ozone-sensitive species are present within the forest and shrubland habitat and the periodically high ozone concentrations are contributing to the degraded condition. Limited data is currently available describing important forest resources, such as bird communities, and key ecological influences such as groundwater level and quality. Filling these data gaps would improve future assessments of resource condition for this habitat and better inform management decisions.

FOREST AND SHRUBLAND

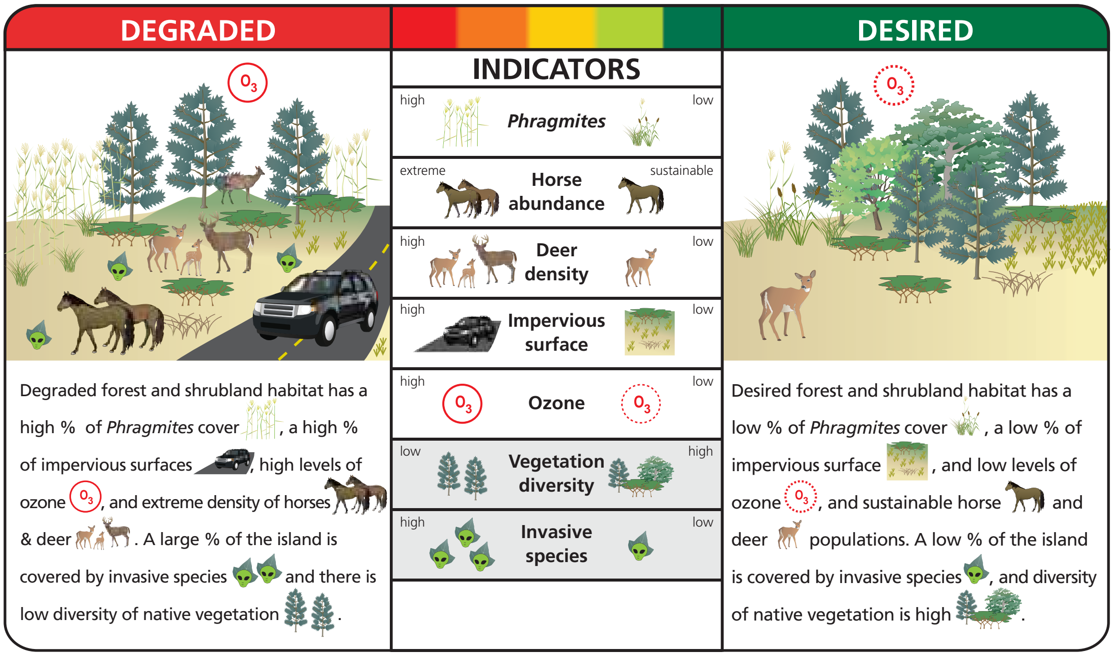
23% DEGRADED : CONFIDENCE FAIR

Assessed forest and shrubland habitat had a high % of *Phragmites* cover, a low % of impervious surfaces, a high abundance of horses and deer, and high levels of ozone O_3.

Indicators	Reference condition attainment	Current condition	Trend in condition
Phragmites	0%	Very degraded	Improving
Horse abundance	31%	Degraded	Improving
Deer density	0%	Very degraded	No trend
Impervious surface	85%	Very good	?
Ozone	0%	Very degraded	No trend
Forest and shrubland habitat	**23%**	**Degraded**	**-**

0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Very Degraded	Degraded	Fair	Good	Very Good

FOREST AND SHRUBLAND



Conceptual range of habitat condition from degraded to desired for Forest and Shrubland habitat showing indicators appropriate to assess condition. No data was available in the current assessment for grayed out indicators.

Key findings	Recommendations
Forest and shrubland habitat	
• Invasive *Phragmites* abundant	• Continue active *Phragmites* control, and monitor ecosystem impacts of treatment.
• Horses overgraze vegetation	• Manage to minimum self-sustaining population size.
• Deer overgraze vegetation	• Develop indices of deer herbivory on vegetation in conjunction with deer density index, to inform decision making.
• Invasive plant species influence native communities	• Continue to monitor, track, and eradicate invasive plant species.
• Limited knowledge of bird resource	• Inventory and monitor forest bird species.

Key findings, management implications, and recommended next steps for Forest and Shrubland habitat in Assateague Island National Seashore.

Photo: NPS ASIS

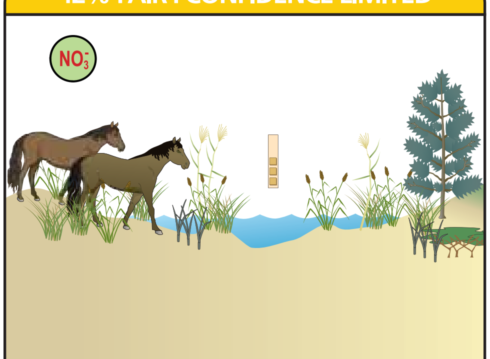
Inland wetland habitat.

Inland wetlands habitat

Inland wetland habitats of Assateague Island National Seashore were assessed as being in fair condition, attaining 42% of reference condition. Confidence in the assessment of this habitat was limited, due to low data availability. Low abundance of the invasive form of *Phragmites* and appropriate pH indicate desirable conditions within this habitat on Assateague Island. Poor air quality (very high wet nitrogen and sulfate deposition rates), however, has high potential to degrade sensitive wetland habitats by reducing pH and increasing nutrient concentrations. Horses also pose a threat to freshwater habitats by trampling, overgrazing and potentially the addition of nutrients. Should the ongoing horse population reduction not decrease impacts to an acceptable level, consideration should be given to limiting access to freshwater ponds showing signs of degradation. This habitat is particularly susceptible to climate change effects, particularly to increased salinity resulting from sea level rise; therefore better characterization and monitoring of salinity and groundwater conditions, as well as biological indicators (e.g. reptiles, amphibians, insects) would improve future condition assessments and may allow for the early identification of degradation from climate change.

INLAND WETLANDS

42% FAIR : CONFIDENCE LIMITED

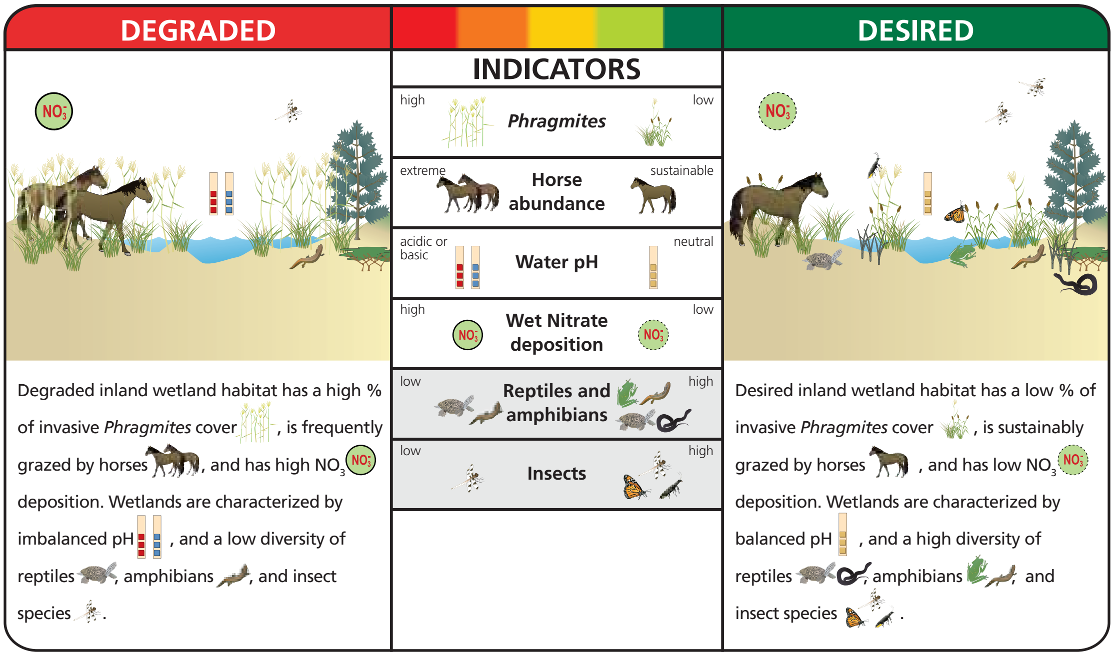


Assessed inland wetlands habitat had a low percentage of *Phragmites* cover, a large horse population, fair water pH, and high deposition of wet nitrogen NO_3^-.

Indicators	Reference condition attainment	Current condition	Trend in condition
Phragmites	82%	Very good	Improving
Horse abundance	31%	Degraded	Improving
Water pH	54%	Fair	?
Wet nitrogen deposition	0%	Very degraded	Improving
Inland wetland habitat	**42%**	**Fair**	**-**

0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Very Degraded	Degraded	Fair	Good	Very Good

INLAND WETLANDS



Conceptual range of habitat condition from degraded to desired for Inland Wetlands habitat showing indicators appropriate to assess condition. No data was available in the current assessment for grayed out indicators.

Key findings	Recommendations
Inland wetlands habitat	
• Poor air quality can impact these fragile habitats	• Initiate pond nutrient monitoring, and support regional air quality initiatives.
• Horses overgraze and trample limited freshwater pond resources	• Manage to minimum self-sustaining population size.
• Biotic resources inventoried, limited condition and trend information	• Develop indicators and techniques for assessing and monitoring biological integrity.
• Invasive plant species influence native communities	• Continue to monitor, track, and eradicate invasive plant species.
• These habitats are poorly characterized	• Study interrelationships with groundwater and storm overwash/flooding events, to inform management.

Key findings, management implications, and recommended next steps for Inland Wetlands habitat in Assateague Island National Seashore.

Photo: NPS ASIS

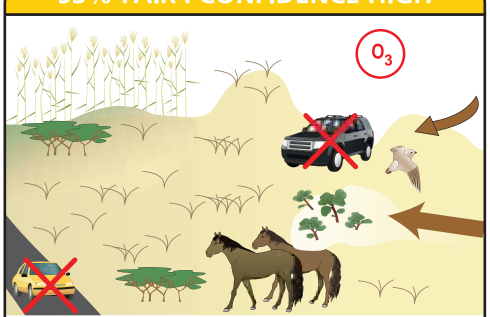
Dune and grassland habitat on Assateague Island.

Dunes and grassland habitat

Dunes and grassland habitats of Assateague Island National Seashore were assessed as being in fair condition, attaining 53% of reference condition. Confidence in the assessment of this habitat was high due to abundant data quantity for appropriate indicators. Low impervious surface, low number of over-sand vehicle trails, moderate to high overwash accessibility, and increases in island upland elevation are all indictors of positive natural resource conditions in dune and grassland habitat. These conditions can be maintained by continuing to control over-sand vehicle access and by reducing the extent of constructed dunes and berms to allow further ocean overwash during storms. On the negative side, a high percent cover of the invasive form of *Phragmites* is present in this habitat and it is recommended that efforts to identify, map, and control these infestations be continued, while assessing the effects of treatment. Poor air quality (high ozone) has the potential to degrade sensitive plant species in these open habitats and high horse populations pose a threat from trampling and overgrazing. Continued management to achieve a sustainable horse population is recommended.

DUNES AND GRASSLAND

53% FAIR : CONFIDENCE HIGH

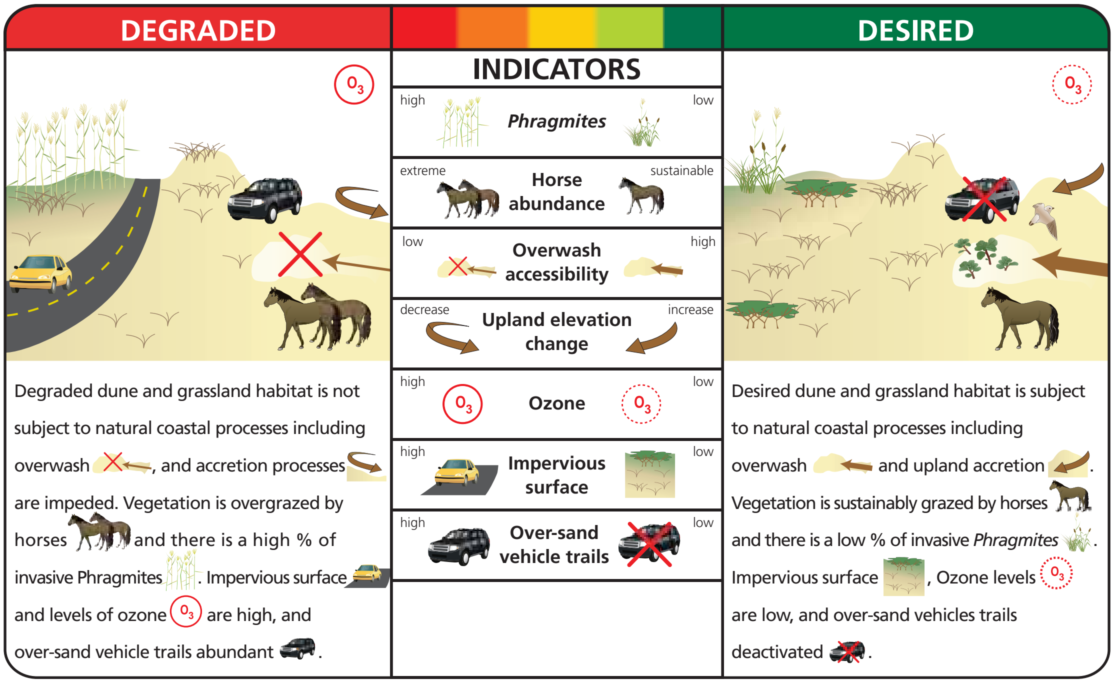


Assessed dunes and grassland habitat had a high percentage of *Phragmites* cover, and a large horse population. It was subject to natural coastal processes including overwash and upland accretion. Ozone levels (O_3) were high, impervious surface was low, and over-sand vehicle trails were minimal.

Indicators	Reference condition attainment	Current condition	Trend in condition
Phragmites	0%	Very degraded	Improving
Horse abundance	31%	Degraded	Improving
Overwash accessibility	79%	Good	Improving
Upland elevation change	67%	Good	No trend
Ozone	0%	Very degraded	No trend
Impervious surface	97%	Very good	?
Over-sand vehicle trails	99%	Very good	Improving
Dunes and grassland habitat	**53%**	**Fair**	**-**

0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Very Degraded	Degraded	Fair	Good	Very Good

DUNES AND GRASSLAND



Conceptual range of habitat condition from degraded to desired for Dunes and Grassland habitat showing indicators appropriate to assess condition. No data was available in the current assessment for grayed out indicators.

Key findings	Recommendations
Dunes and grassland habitat	
• Key biota impacted by poor air quality	• Support regional air quality initiatives, and monitor for specific impacts.
• Invasive *Phragmites* abundant	• Continue active *Phragmites* control, and monitor ecosystem impacts of treatment.
• Horses overgraze vegetation	• Manage to minimum self-sustaining population size.
• Dunes rely on natural shoreline processes	• Continue to minimize over-sand vehicle trails and minimize artificial impediments to natural island overwash processes.
• Invasive plant species influence native communities	• Continue to monitor, track, and eradicate invasive plant species.

Key findings, management implications, and recommended next steps for Dunes and Grassland habitat in Assateague Island National Seashore.

Photo: Tim Carruthers, IAN Image Library

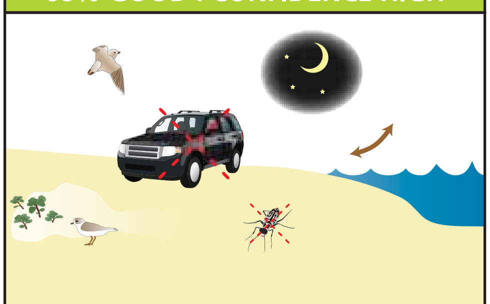
The Atlantic beach on Assateague Island.

Beach and intertidal habitat

Beach and intertidal habitats of Assateague Island National Seashore were assessed as being in good condition, attaining 68% of reference condition. Confidence in the assessment of this habitat was high due to abundant data quantity for appropriate indicators. Management of seabeach amaranth has been successful in increasing populations; however, further increases would be desirable to reach the U.S. Fish and Wildlife Service Recovery Plan's criteria for delisting this threatened species. Shoreline rate of change has been positively influenced by the sand bypassing management intervention, such that rate of change is close to natural historical rates in most years. It is recommended that the mechanical sand-bypassing project be continued to maintain this essential component of sediment transport to Assateague Island. Tiger beetles have very low abundance and may be experiencing long term decline. It is therefore recommended that as much of the shoreline as possible be maintained free of over-sand vehicle use. Piping plover populations show a sustainable fledgling rate in most years; however, their very specific habitat requirements for successful breeding (overwash created habitats) suggest that to maintain this species as a viable population, it will be necessary to minimize artificial impediments to natural storm overwash. High horse populations also pose a threat to this habitat by overgrazing sensitive plant species such as seabeach amaranth. Future condition assessments of this habitat would be improved by including data to assess intertidal biota diversity and abundance, migratory shorebird abundance, as well as measures of recreational activity in different sections of the beach to better understand the threats to sensitive species from visitor use.

BEACH AND INTERTIDAL

68% GOOD : CONFIDENCE HIGH

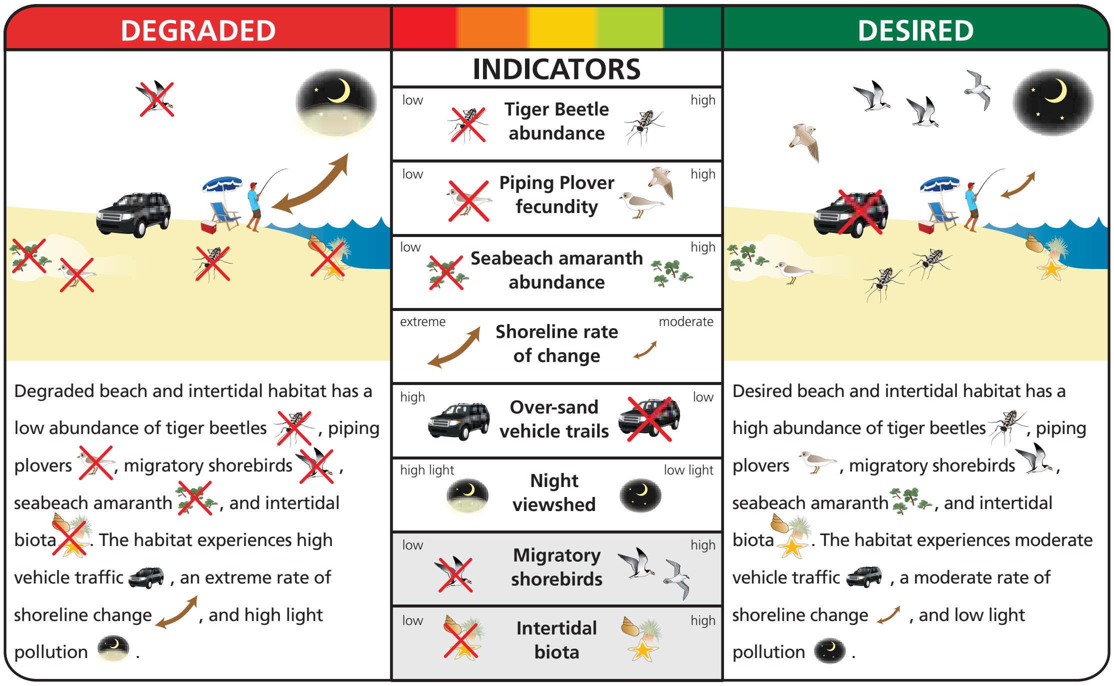


Assessed beach and intertidal habitat had a low abundance of tiger beetles, good piping plover fecundity, and good abundance of seabeach amaranth. The habitat was subject to a desirable rate of shoreline change, moderate OSV traffic, and low light pollution.

Indicators	Reference condition attainment	Current condition	Trend in condition
Tiger beetle abundance	44%	Fair	No trend
Piping plover fecundity	54%	Fair	No trend
Seabeach amaranth abundance	67%	Good	Improving
Beach shoreline rate of change	100%	Very good	Improving
Over-sand vehicle trails	45%	Fair	No trend
Night viewshed	100%	Very good	?
Beach and intertidal habitat	**68%**	**Good**	**-**

0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Very Degraded	Degraded	Fair	Good	Very Good

BEACH AND INTERTIDAL



Conceptual range of habitat condition from degraded to desired for Beach and Intertidal habitat showing indicators appropriate to assess condition. No data was available in the current assessment for grayed out indicators.

Key findings	Recommendations
Beach and intertidal habitat	
• Tiger beetle populations stable but low and limited in extent	• Minimize length of beach accessed by over-sand vehicles.
• Seabeach amaranth and piping plover require overwash habitat	• Minimize artificial impediments to natural island overwash processes.
• Shoreline rate of change is occurring at historical rates	• Maintain sand bypass to northern end of Assateague Island.
• Lack of current data on migratory shorebirds and intertidal biota	• Monitor to inform management decisions.

Key findings, management implications, and recommended next steps for Beach and Intertidal habitat in Assateague Island National Seashore.

Photo: NPS ASIS

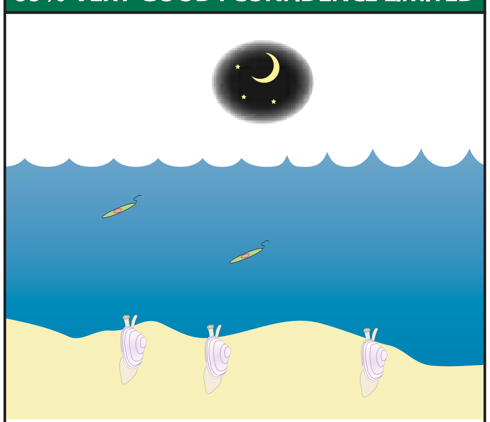
Pelicans on the beach at Assateague Island.

Atlantic subtidal habitat

Atlantic subtidal habitats of Assateague Island National Seashore were assessed as being in very good condition, attaining 99% of reference condition. Confidence in the assessment of this habitat was, however, very limited due to a lack of appropriate indicators, and baseline knowledge of this habitat. The night viewshed of Assateague Island is of high quality and increasingly rare along the eastern seaboard of the United States. It is recommended that working with regional partners and municipalities to protect this resource feature should be given a high priority. While the limited available indicators suggest that water quality and benthic fisheries are in a desirable condition, this habitat is the least known of all habitats within the park. Subsequent to benthic habitat characterization and mapping surveys currently underway, it is recommended that key indicators of habitat condition be established and monitored.

ATLANTIC SUBTIDAL

99% VERY GOOD : CONFIDENCE LIMITED

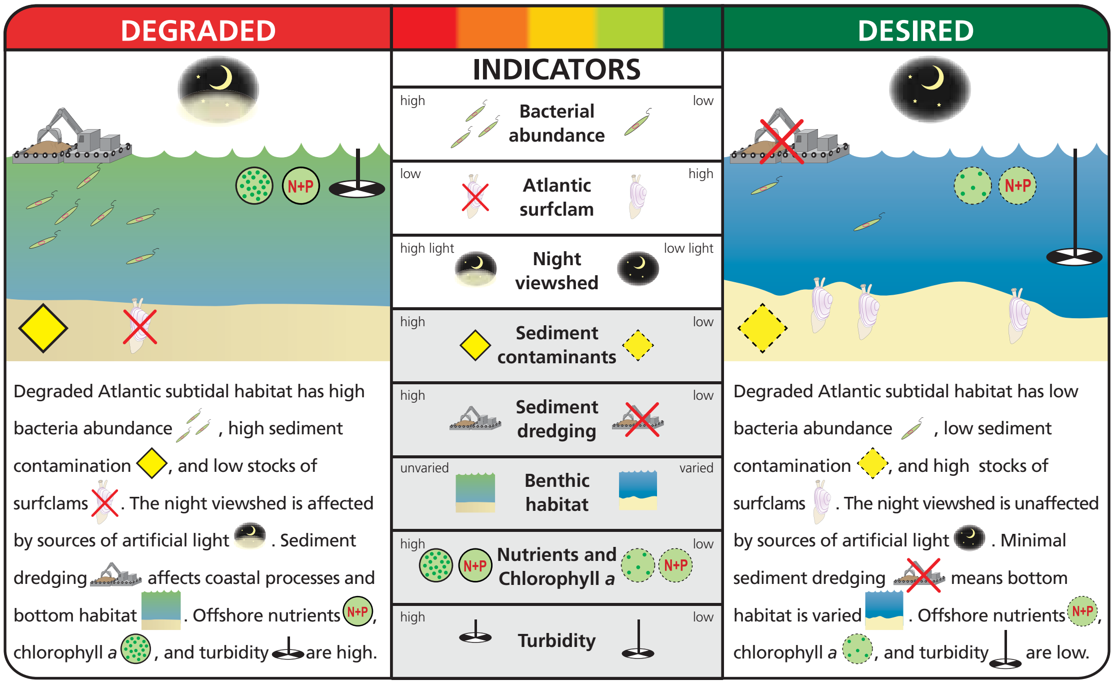


Assessed Atlantic subtidal habitat had low bacteria abundance, sustainable stocks of surfclams, and the night viewshed is unaffected by sources of artifical light.

Indicators	Reference condition attainment	Current condition	Trend in condition
Bacterial abundance	99%	Very good	No trend
Atlantic surfclam	100%	Very good	Declining
Night viewshed	100%	Very good	?
Atlantic subtidal habitat	**99%**	**Very good**	**-**

0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Very Degraded	Degraded	Fair	Good	Very Good

ATLANTIC SUBTIDAL



Conceptual range of habitat condition from degraded to desired for Atlantic Subtidal habitat showing indicators appropriate to assess condition. No data was available in the current assessment for grayed out indicators.

Key findings	Recommendations
Atlantic subtidal habitat	
• Critical lack of knowledge	• Baseline surveys of benthic habitats. • Identify sensitive areas and key resources. • Collaborate with other agencies to initiate monitoring of water quality, fisheries and benthic habitats.
• Regional development threatens night sky conditions	• Collaborate with regional partners to reduce existing and prevent new impacts to night sky darkness.

Key findings, management implications, and recommended next steps for Atlantic Subtidal habitat in Assateague Island National Seashore.

APPENDIX TABLES

Table A-1. Ecological monitoring framework data provided by agencies and specific sources included in the assessment of Assateague Island National Seashore.

Date	Meeting type	Topics Discussed	Attendees
6/5/2008	Proposal for Assessment	UMCES submission of proposal to NPS	UMCES-IAN: Bill Dennison, Tim Carruthers, Tom Fisher, and Michael Williams
12/17/2008	In-person	Overview of Assessment Process; Roles and Responsibilities of NPS Water Resources Division, NPS NE Region, ASIS staff, I & M Network, and UMCES; Review of available datasets and information; Focus of Assessment report	NPS-Other: Charles Roman, John Karish, Cliff McCreedy, Beth Johnson, Sara Stevens, UMCES-IAN: Tim Carruthers, Jane Thomas
2/23/2009	Conference Call		
3/30/2009	Conference Call		
5/13/2009	In-person	Summary of introduction material; Discussion of known data layers, template, trends; current habitat map; habitats and potential metrics; outline of goals, deliverables, status and timelines	NPS-ASIS: Brian Sturgis, Courtney Schupp, Carl Zimmerman, Jack Kumer, Neil Winn, NPS-Other: Charles Roman, UMCES-IAN: Bill Dennison, Tim Carruthers, Jane Thomas, Michael Williams, Tom Fisher
5/29/2009	Conference Call		
7/7/2009	Conference Call		NPS-ASIS: Charles Roman, Courtney Schupp NPS-Other: John Karish, Ellen Porter, Holly Salazer, UMCES-IAN: Tim Carruthers, Kris Beckert, Jane Thomas
7/23/2009	Park Interviews	Oral interviews with ASIS staff for background and historical observations/ trends	NPS-ASIS: Carl Zimmerman, Brian Sturgis, Jack Kumer, Courtney Schupp, UMCES-IAN: Bill Dennison, Kris Beckert
8/5/2009	Conference Call	Consolidation of habitats (combine mudflats and subtidal); finalize framework including I & M metrics; Metrics discussion including development of water quality index; search for fisheries data, sediment toxicity, horseshoe crab counts; salt marsh metrics and horse impacts	NPS-ASIS: Brian Sturgis, Jack Kumer, Courtney Schupp, Carl Zimmerman, NPS-Other: John Karish, Holly Salazer, Charles Roman, Sara Stevens, UMCES-IAN: Jane Thomas, Kris Beckert, Tim Carruthers, Tom Fisher, Michael Williams,
8/11/2009	Conference Call	Continued metrics discussion from 8/5/2009	NPS-ASIS: Carl Zimmerman, Courtney Schupp UMCES-IAN: Jane Thomas, Kris Beckert, Tim Carruthers,
9/16/2009	Conference Call		NPS-ASIS: Brian Sturgis, Jack Kumer, Courtney Schupp, Carl Zimmerman, UMCES-IAN: Kris Beckert, Tim Carruthers
10/5/2009	Meeting with Park Staff	Discussion of horse metrics, overwash areas, Phragmites, deer data, and shoreline erosion; compilation of GIS layers and data from Park	NPS-ASIS: Carl Zimmerman, Courtney Schupp, Jack Kumer, UMCES-IAN: Kris Beckert, Tim Carruthers
11/10/2009	Conference Call	Discussion of overwash areas, thresholds for biota, deer density application, ditch density, natural dune growth, and shoreline rate of change metrics	NPS-ASIS: Brian Sturgis, Carl Zimmerman, Courtney Schupp, Jack Kumer, NPS-Other: Charles Roman, Cliff McCreedy, Eva DiDonato, Sara Stevens, UMCES-IAN: Bill Dennison, Tim Carruthers, Kris Beckert
11/17/2009	NPS I & M In-person at Univ. of RI	Additional I & M metrics added to the habitats for future assessments, finalization of metrics for each habitat	NPS-Other: Sara Stevens, Penelope Pooler, Dennis Skidds, Linda Arnold-Fabre, Charles Roman; UMCES-IAN: Bill Dennison, Tim Carruthers, Kris Beckert
4/27/2010	NPS and UMCES meeting at Park	Finalization of metrics, thresholds, diagrams, and discussion of implications and data gaps	Brian Sturgis, Jack Kumer, Courtney Schupp, Carl Zimmerman, UMCES-IAN: Kris Beckert, Tim Carruthers, Bill Dennison, Michael Williams

I&M-Inventory and Monitoring; MCBP-Maryland Coastal Bays Program; NPS-National Parks Service; UMCES-University of Maryland Center for Environmental Science; UMES-University of Maryland Eastern Shore; USGS-United States Geological Survey; VIMS-Virginia Institute of Marine Science.

Table A-2. Bacteria abundance from sites in the Atlantic Subtidal habitat. MPN is the bacteria count per 100 ml. SE is the standard error of the mean.

Year	# Days Sampled	Site	Mean MPN	SE	Max MPN	# Days > 104 MPN
2000	17	1-STB	6.8	3.2	55.0	0
2001	18	1-STB	1.2	0.4	5.0	0
2002	17	1-STB	2.6	0.8	16.0	0
2003	17	1-STB	11.8	1.0	20.0	0
2005	16	1-STB	11.3	1.3	31.0	0
2006	16	1-STB	9.8	0.7	20.0	0
2000	17	2-RST	9.3	3.3	49.0	0
2001	17	2-RST	1.6	0.5	7.0	0
2002	17	2-RST	2.5	1.0	16.0	0
2003	17	2-RST	10.0	0.0	10.0	0
2005	13	2-RST	10.0	0.0	10.0	0
2006	16	2-RST	9.2	0.1	10.0	0
2000	17	3-OCS	9.0	3.1	48.0	0
2001	17	3-OCS	1.6	0.5	8.0	0
2002	17	3-OCS	2.5	1.0	16.0	0
2003	16	3-OCS	10.6	0.6	20.0	0
2005	16	3-OCS	10.0	0.0	10.0	0
2006	16	3-OCS	13.3	2.4	42.0	0
2000	17	4-BH1	6.3	4.0	67.0	0
2001	17	4-BH1	1.7	0.5	7.0	0
2002	10	4-BH1	2.8	1.4	14.0	0
2000	17	5-BH2	6.8	4.8	83.0	0
2001	17	5-BH2	1.7	0.4	5.0	0
2002	10	5-BH2	2.6	1.5	16.0	0
2002	7	6-TCS	0.4	0.4	3.0	0
2003	17	6-TCS	11.2	0.8	20.0	0
2005	16	6-TCS	16.1	4.2	64.0	0
2006	16	6-TCS	9.1	0.1	10.0	0
2002	7	7-TCN	1.6	1.4	10.0	0
2003	17	7-TCN	16.9	4.0	64.0	0
2005	16	7-TCN	12.0	2.0	42.0	0
2006	16	7-TCN	9.1	0.1	10.0	0
2003	17	19-SBE	10.6	0.6	20.0	0
2005	16	19-SBE	11.9	1.4	31.0	0
2006	16	19-SBE	10.0	0.7	20.0	0

Table A-3. Bacteria abundance from sites in the Bay Subtidal habitat. MPN is the bacteria count per 100 ml. SE is the standard error of the mean.

Year	# Days Sampled	Site	Mean MPN	SE	Max MPN	# Days > 104 MPN
2006	144	BAS	14.00	3.60	64	0
2006	144	FLD	96.75	25.02	306	6
2006	144	LTC	20.19	4.23	64	0

Table A-4. Errors of beach shoreline rate of change calculations for Assateague Island. Calculations follow the methods outlined in Morton, R. A., and T.L. Miller. 2005. National assessment of shoreline change: Part 2: Historical shoreline changes and associated coastal land loss along the U.S. Southeast Atlantic Coast. U.S. Geological Survey Open-file Report 2005-1401.

Year Range	First year possible error (m)	Last year possible error (m)	Number of years	Measurement uncertainty (m/yr)[1,2]
1849-1908	11.36	11.36	49	0.33
1908-1933	11.36	11.36	25	0.64
1933-1942	11.36	11.36	9	1.78
1942-1962	11.36	11.36	20	0.80
1962-1980	11.36	11.36	18	0.89
1980-1997	11.36	1	17	0.67
1997-2008[3]	1	1	11	0.26

[1] These measurement uncertainties do not incorporate the uncertainty of the mapmaker's determination of the high water line, nor the uncertainty of whether the wet dry line was the same as the HWL on the day it was observed/mapped (or, for example, if wind pushed the water higher/lower on the beach).

[2] NOS T-sheet error is assumed to be 10.2 m map accuracy uncertainty and 5 m digitization uncertainty, as stated in Moore, L.J.,2000. Shoreline Mapping Techniques. J. Coastal Research 16(1) pp. 111-124.

[3] Shorelines mapped by ASIS (1997 - present) use post-processed GPS; results had submeter accuracy, so error is assumed to be 1 m.

Table A-5. Vegetation species that may be future indicators of horse and deer populations, as indicated by Sturm 2007.

Plant species	Effect of increased deer or horses	Primary species	Should this be a future indicator?	Comment
Acer rubrum (saplings)	negative abundance	deer	yes	
Agrostis stolonifera	negative abundance	unknown	inconclusive	Lower abundance at grazed sites, but does not grow back when grazing pressure is reduced
Ammophilia breviligulata	negative abundance	horse	yes	
Carex spp.	negative abundance	deer	yes	
Chasmanthium laxum	negative abundance	horse	yes	
Cirsium horridulum and *C. vulgare*	negative abundance	deer	yes	
Dicanthelium acuminatum	positive height	deer	yes	Not foraged, but outcompeted when pressure from deer is reduced
Eupatorium hyssopifolium	negative abundance	deer	yes	
Euphorbia tenuifolia	negative abundance	deer	yes	
Fimbristylis castanea	negative abundance	horse	inconclusive	Fluctuates highly in abundance
Hudsonia tomentosa	negative height	horse	yes	Suffers from trampling
Ilex opaca	negative abundance		no	
Lechea maritima	negative abundance	deer	yes	Infrequent species, increased when exposed to rest
Lechea maritima	unknown	unknown	inconclusive	
Morella spp.	positive mean height, negative lower cover	deer	yes	Removal of lower Morella vegetation increases mean height
P. taeda	positive abundance			ASIS maritime forests are now dominated by P. taeda because of herbivory of A. rubrum
Panicum amarum	negative abundance	deer	inconclusive	Localized areas have reduced abundance during summer due to grazing
Phragmites australis	positive abundance	deer	no	Compensatory grazing response
Rubus spp.	negative abundance	deer	yes	
Schoenoplectus pungens	positive abundance	both	yes	Horses affect in spring, deer affect in summer
Smilax rotundifolia	negative abundance	deer	unknown	Delayed response to reductions of herbivory intensity
Smilax rotundifolia	positive mean height	horse	yes	
Solidago sempervirens	negative abundance	deer	yes	
Solidago sempervirens	negative mean height	deer	inconclusive	Needs further investigation
Toxicodendron radicans	unknown	unknown	inconclusive	Needs further investigation
Vitis rotundifolia	negative abundance	deer	yes	

NPS 622/107814 , June 2011

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™