Chapter 2

Piping plover nest

Affected Environment

- Introduction
- Physical Environment
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- Refuge Visitor Services Program
- Refuge Archaeological, Historical, and Cultural Resources
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- Refuge Administration

Introduction

This chapter describes the physical, biological, and socioeconomic settings of the project area, Monomoy National Wildlife Refuge (NWR) in Barnstable County, Massachusetts. We begin with the physical landscape description, including the cultural and historic settings and land use history, followed by current conditions, global climate change and sea level rise, air quality, and water quality.

Physical Environment

Monomoy NWR is located within the southern New England region (BCR 30 and PIF 9) off the elbow of Cape Cod in the Town of Chatham, Massachusetts (maps 1.1 and 2.1). It is one of eight refuges in the Eastern Massachusetts National Wildlife Refuge Complex. The refuge was established in 1944 and historically consisted of open water and shoals with eelgrass beds, intertidal flats, salt and freshwater marshes, dunes, freshwater ponds, and upland interdunal habitats. The 8,321-acre refuge is composed primarily of North Monomoy Island and South Monomoy, until recently a peninsula attached to the mainland via Nauset/South Beach. The refuge also includes Minimoy Island and property on Morris Island, and open waters within the Declaration of Taking. Nearly half (47 percent) of the refuge, and most (86 percent) of the land lying above mean low water is also congressionally designated wilderness. From the early 1900s to present day, resort and residential development and fishing operations, including shellfishing, have been the dominant land and water uses bordering the refuge.

The refuge's natural terrestrial habitats are dominated by intertidal sandflats, open sand, grassland-covered dunes, and salt marsh, interspersed with shrublands representative of coastal ecosystems. The majority (60 percent) of Monomoy's vegetation cover types are shaped by the dynamic tidal processes and shifting sands associated with barrier beach habitats. The remaining 40 percent is composed of upland shrubland and forest with woody shrubs and small trees. National Vegetation Cover Standards (NVCS) cover typing of the refuge has resulted in the delineation of 16 land cover types, including vegetation and water surface coverage (see appendix C).

Monomoy Refuge's beaches and salt marshes provide important spawning and nursery habitat for horseshoe crabs, and the refuge is one of the most important areas for horseshoe crabs in the State (USFWS 2002). The refuge provides habitat for large populations of gray and harbor seals and is the largest gray seal haulout site on the U.S. Atlantic seaboard. The most recent count (aerial photography conducted in March 2011) numbered 10,600 individual gray seals hauled out on the refuge (Waring 2012 personal communication). About 12 percent of the State's piping plover population nests on Monomoy NWR and Nauset/South Beach combined. The refuge has hosted one of the largest common tern colonies along the Atlantic seaboard in most years since 1999, and the largest laughing gull colony in Massachusetts in most years since 2001. Monomoy NWR also serves as an introduction site for the federally threatened northeastern beach tiger beetle. The refuge provides ideal habitat, and the project is significantly contributing to the recovery of this species (USFWS 1994, 2009b).

Morris Island/Stage Island

The Morris Island portion consists of 40 acres, connected to the mainland by a causeway, and is home to the refuge's headquarters and visitor contact station. This management unit includes beach, dunes, and salt marsh habitats that support a variety of flora and fauna, including migratory birds, horseshoe crabs, fish, mammals, reptiles, and amphibians. Four to 5 acres of intertidal salt marsh occur on the south end of the island, and American beach grass is the dominant dune vegetation. In addition, 12 upland acres are forested with woody shrubs and small trees, including northern bayberry, beach plum, pitch pine, scrub oak, and eastern red cedar.

The east side of Morris Island includes a slowly eroding coastal embankment rising close to 50 feet above a narrow beach. The narrow portion of the refuge beach extends southward until joining the more moderately sloping Morris Point, which encompasses intertidal flats, salt marsh, dunes, and beach. The Morris Island Interpretive Trail, popular with refuge visitors, follows this refuge beach corridor and loops through the different Morris Island habitats described above.

On the adjoining Stage Island, the refuge has a half-acre lot, gently sloping from the road to a sandy shoreline on Stage Harbor. This lot is used for vehicle storage and boat access. The Service holds a right-of-way on privately owned roads to access this lot, which is only accessible to the public through a refuge permit.

North Monomoy Island

North Monomoy Island is an estimated 1.3 miles long and 0.4 miles wide and consists of beach, dunes, intertidal salt marsh, and (sand and mud) flats. North Monomoy Island provides habitat for spawning horseshoe crabs, nesting habitat for salt marsh sparrows, and nesting and staging areas for shorebirds, terns, and wading birds.

South Monomoy and Nauset/South Beach

South Monomoy is roughly tear-shaped, about 6 miles long and 1.3 miles wide at the southern end and is characterized by sand and mudflats, sandy beaches, extensive dunes, salt marsh, and freshwater ponds and wetlands. Small salt marsh patches occur on the northwest and southwest sides, consisting primarily of salt marsh cordgrass, salt marsh hay, saltgrass, and black grass. The freshwater ponds and marshes, which cover more than 150 acres on South Monomoy, host cattail, pond lilies, and common reed (USFWS 1988).

As a result of ongoing, natural coastal beach migration processes typical of this area, adjacent Nauset/South Beach accreted sufficiently to connect to the northeast tip of South Monomoy (map 1.1) in 2006, creating a land bridge from the island to mainland Cape Cod. Sand is now accreting on the ocean side, widening the seaward side of the 2006 connection, while salt marsh forms on the interior side of the connection.

In early February 2013, a break in Nauset/South Beach occurred in areas that had been eroding for several years. The Nauset/South Beach “thumb” adhering to South Monomoy, while changing almost daily in size and shape, was estimated as 717 acres in June 2013. The winter storms that created the 2013 break also overwashed the majority of this residual “thumb.” That overwashing buried what had been dune and some salt marsh vegetation under sand, and lowered dunes while filling in the interdunal swales. The area is now generally lower and flatter than before the break, dominated by the bare sands of numerous overwash fans separated by patches of dune, some salt marsh vegetation abutting the intertidal flats of the old Southway channel, and approximately 3 miles of sandy beaches along the Atlantic Ocean.

Minimoy, a small island located west of the northern tip of South Monomoy, is also included in this management unit. This eroding island is currently estimated to be 0.25 miles long and 0.36 miles wide, and is also characterized by sandy beaches and dunes, as well as a growing salt marsh on the east side. This management unit provides habitat for thousands of nesting and migrating birds, including shorebirds and terns.

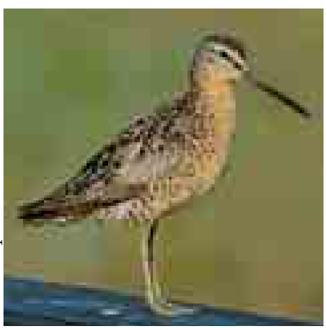
Cape Cod Watershed

Monomoy NWR is part of the Cape Cod watershed located in southeastern Massachusetts. Cape Cod was formed by glacial activity over 20,000 years ago. The Cape region is composed of glacial end moraines, which mark the approximate locations of the ice front, and outwash plains, formed by sediments deposited by streams of meltwater from the glaciers (Massachusetts Executive Office of Energy and Environmental Affairs [MA EOEEA] 2004). This created a series of connected, broad, sandy plains, and hilly terrain. The outwash deposits overlay bedrock at a depth of about 300 to 400 feet in the mid-Cape area. This contiguous and permeable sandy substrate forms the matrix of the Cape Cod Aquifer. The retreating glaciers left behind depressions that filled with water and are now known as kettle hole ponds. These ponds, along with freshwater wetlands, salt marshes, and estuaries, provide habitat for a variety of fish and wildlife (MA EOEEA 2004).

The Cape Cod Glacial Aquifer is a continuous, unconfined aquifer system underlying the Cape Cod peninsula. The peninsula extends into the Atlantic Ocean and is separated from the rest of Massachusetts by the Cape Cod Canal (Martin 2008). The aquifer consists primarily of highly permeable, glacial sediments, and is the principal source of drinking water for the peninsula.

The Cape Cod watershed, as designated by the Massachusetts Office of Energy and Environmental Affairs, extends 70 miles into the Atlantic Ocean and is surrounded by the salt waters of Buzzards Bay, Cape Cod Bay, the Atlantic Ocean, and Nantucket Sound. The watershed encompasses a drainage area of approximately 440 square miles and includes 559 miles of coastline, 145 public water supply wells, 8 State areas of critical environmental concern (ACEC), 116 square miles of protected open space, and numerous rare and endangered species. Watershed priorities set forth by the State of Massachusetts for the Cape Cod watershed are:

- Reduce or eliminate nonpoint source pollution through comprehensive water resources management planning.
- Ensure drinking water quality for the future by identifying potential new water supplies and protecting existing sources.
- Support community preservation efforts within the watershed, including planning for sustainable growth and protecting Cape Cod's critical habitats.
- Improve communication, outreach, and education between citizens and watershed partners.
- Monitor and assess fresh water ponds, coastal embayments, and threatened water bodies to protect water quality, habitat, and enhance recreational uses.


Bill Thompson/USFWS

Short-billed dowitcher

You may view this information at: *http://www.mass.gov/?pageID=eoeeaterminal&L=4&L0=Home&L1=Air%2c+Water+%26+Climate+Change&L2=Preserving+Water+Resources&L3=Massachusetts+Watersheds&sid=Eoeea&b=terminalcontent&f=eea_water_capecod&csid=Eoeea* (accessed August 2011).

On a larger scale, the Monomoy Islands are included in the Cape Cod and Islands watershed (U.S. Geological Survey [USGS] HUC 01090002), which encompasses Martha's Vineyard, Nantucket (including Muskeget and Tuckernuck Islands), and other small islands south of Cape Cod (U.S. EPA, *http://cfpub.epa.gov/surf/huc.cfm?huc_code=01090002*; accessed August 2011).

Geographical Setting and Landscape Context

Biophysical Ecoregion 2-3—North Atlantic Coast

The Nature Conservancy (TNC) has divided the continental United States into 63 ecoregions—large geographic areas that share similar geologic, topographic, ecological, and climatic characteristics. These ecoregions are modified from the U.S. Forest Service's "Bailey System" (Bailey 1995). TNC has developed ecoregional conservation plans that identify conservation targets and prioritize conservation actions.

Monomoy NWR is in the North Atlantic Coast ecoregion as described by TNC (map 2.1). This ecoregion extends from Pemaquid Point in Maine south to

Delaware Bay. Flat topography, low elevations (less than 600 feet), scattered moraines, large rivers draining into estuaries and bays, and a mild, humid climate characterize this region. Rocky coasts dominate the shorelands in the north, grading into salt marsh communities to the south. The once extensive forest graded from white pine-oak-hemlock forest, to dry oak-heath forests, to mesic coastal oak forests from north to south. Wetlands, beaver meadows, pine barrens, and heathlands were embedded in this forested landscape. Hundreds of years of land clearing, agriculture, and widespread development has fragmented the landscape and eliminated large areas of forest. Still, smaller ecological systems remain, including barrier beaches and dunes, salt marshes, and freshwater wetlands (TNC 2006). Current action sites for TNC exist on Martha's Vineyard and the Cape, where land protection and management activities are already occurring.

Atlantic Flyway
Monomoy NWR is within the Atlantic flyway. Flyways have been used for many years in North America as the unit for managing waterfowl populations because they allow land managers to link efforts to conserve migratory bird species and their habitats on breeding, migration, and wintering grounds. The Atlantic Coast Joint Venture area includes the entire U.S. Atlantic coast lying completely within the Atlantic flyway. In this large area, the ACJV partners work together to assess the status, trends, and needs of bird populations and their habitats. The partners then use this information to help guide the distribution of resources to the needs and issues of highest priority.

Strategic Habitat Conservation and Landscape Conservation Cooperatives
Strategic Habitat Conservation (SHC) is the conservation approach the USFWS is using to achieve its mission in the 21st century and represents a landscape approach that is strategic, science-driven, collaborative, adaptive, and understandable. "The purpose of SHC is to coordinate and link actions that various programs and partners perform at individual sites, so that their combined effect may be capable of achieving these outcomes at the larger landscape, regional, or continental scales. In this way, conservation actions can help recover and sustain species' populations as part of whole communities and systems, together with their ecological functions and processes.

"The SHC approach is built on five main components that compel the FWS to align expertise, capability, and operations across our programs in a unified effort to achieve mutually aspired biological outcomes: (1) *biological planning*—working with partners to establish shared conservation targets and measurable biological objectives (i.e., population) for these outcomes, and identify limiting factors affecting our shared conservation targets, (2) *conservation design*—creating tools that allow us to direct conservation actions to most effectively contribute to measurable biological outcomes, (3) *conservation delivery*—working collaboratively with a broad range of partners to create and carry out conservation strategies with value at multiple spatial scales, (4) *outcome-based monitoring*—evaluating the effectiveness of conservation actions in reaching biological outcomes and to adapt future planning and delivery, and (5) *assumption-driven research*—testing assumptions made during biological planning to refine future plans and actions. Both monitoring and research help us learn from our decisions and activities and improve them over time. SHC relies on an adaptive management framework to focus on a subset of shared conservation targets, set measurable biological objectives for them, and identify the information, decisions, delivery, and monitoring needed to achieve desired biological outcomes. SHC helps the Service, and the broader conservation community, effectively organize expertise and contributions across programs and partners, so our efforts to conserve landscapes—capable of supporting self-sustaining populations of fish, wildlife, and plants—are both successful and efficient.” For more information on SHC, go to: *http://www.fws.gov/landscape-conservation/shc.html* (accessed January 2013).

In cooperation with the USGS, the Service is promoting landscape conservation through a national geographic network of landscape conservation cooperatives (LCC). “LCCs are applied conservation science partnerships with two main functions. The first is to provide the science and technical expertise needed to support conservation planning at landscape scales—beyond the reach or resources of any one organization. Through the efforts of in-house staff and science-oriented partners, LCCs are generating the tools, methods, and data managers need to design and deliver conservation using the Strategic Habitat Conservation approach (see below for more details). The second function of LCCs is to promote collaboration among their members in defining shared conservation goals. With these goals in mind, partners can identify where and how they will take action, within their own authorities and organizational priorities, to best contribute to the larger conservation effort. LCCs don’t place limits on partners; rather, they help partners to see how their activities can “fit” with those of other partners to achieve a bigger and more lasting impact.” For more information on LCCs, go to: *http://www.fws.gov/landscape-conservation/lcc.html* (accessed January 2013).

Monomoy NWR is located in the North Atlantic LCC, which combines BCRs 14 (Northern Atlantic Forest) and 30 (New England/Mid-Atlantic coast), and contains 12 of 13 Northeast states as well as the District of Columbia (map 2.1). It includes a diverse array of ecosystems, from high elevation spruce-fir forests to coastal islands. Near Monomoy NWR, there exist many conserved lands along Cape Cod and the associated islands (map 2.1) with which the refuge can partner.

The North Atlantic LCC, “provides a partnership in which the private, state, tribal, and federal conservation community works together to address increasing land use pressures and widespread resource threats and uncertainties amplified by a rapidly changing climate. The partners and partnerships in the cooperative address these regional threats and uncertainties by agreeing on common goals for land, water, fish, wildlife, plant, and cultural resources and jointly developing the scientific information and tools needed to prioritize and guide more effective conservation actions by partners toward those goals.” For more information on the North Atlantic LCC, go to: *http://www.northatlanticlcc.org/* (accessed January 2013).

Western Hemisphere Shorebird Reserve Network

In 1995, Monomoy NWR was listed fourth among 96 sites meeting the Western Hemisphere Shorebird Reserve Network (WHSRN) shorebird staging site criteria. In March 1999, the refuge was designated as a WHSRN regional site. WHSRN is a voluntary, non-regulatory coalition of more than 160 private and public organizations in 7 countries working together to study and conserve shorebirds throughout their habitats. Membership in WHSRN provides the site with international recognition as a major host for shorebirds.

From maritime Canada to Virginia, the Western Hemisphere Shorebird Reserve Network has recognized six stopover sites that are especially important to migrating shorebirds: Bay of Fundy in New Brunswick and Nova Scotia, the Great Marsh in Massachusetts, Monomoy NWR, Edwin B. Forsythe NWR in New Jersey, Delaware Bay in New Jersey and Delaware, and Maryland—Virginia Barrier Islands in Maryland and Virginia (WHSRN 2006). The Bay of Fundy annually supports more than 30 species of southward migrating shorebirds with peak counts of the nine most common species totaling 800,000 to 1,400,000 annually (Hemispheric Importance; Hicklin 1987). The Great Marsh supports about 30 shorebird species with an estimated 67,000 shorebirds using

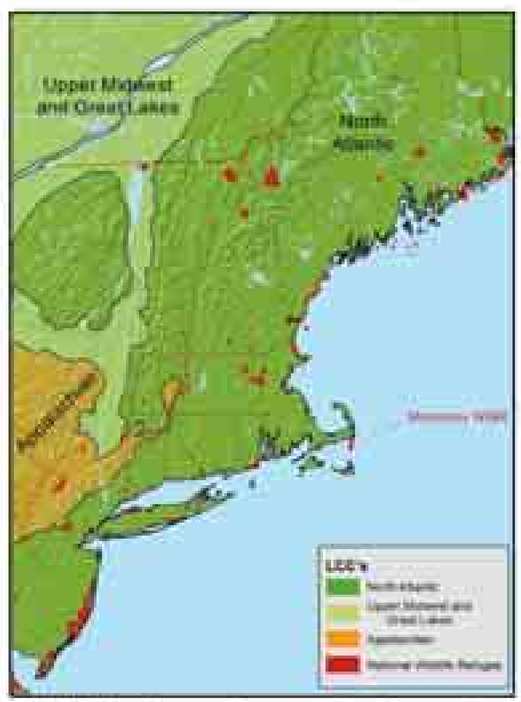
Monomoy National Wildlife Refuge - Comprehensive Conservation Plan

Service and Partner Conservation Regions

Partners in Flight Physiographic Areas

Bird Conservation Regions

The Nature Conservency Ecoregions



USFWS Landscape Conservation Cooperatives the site annually, particularly during southward migration (Regional Importance; WHSRN 2006). Edwin B. Forsythe Refuge supports 85,000 shorebirds annually during both migration periods combined (Harrington and Perry 1995). Maximum 1-day counts at Maryland–Virginia Barrier Islands have been over 54,000 birds during northward migration, and at Delaware Bay have exceeded 216,000 shorebirds (Clark et al. 1993), making this site the most important for northward migrating shorebirds in the eastern United States (Hemispheric Importance; Clark et al. 1993, Harrington et al. 1989).

Although no studies have estimated turnover rates and quantified the total number of shorebirds using Monomoy Refuge, at least 40 species have been documented since 1975 and thousands of migrants are estimated to use the refuge annually (International Shorebird Surveys unpublished data, Harrington and Perry 1995, Harrington et al. 1989, Koch and Paton 2009, Senner and Howe 1984, Veit and Petersen 1993). The designation of Monomoy Refuge as a WHRSN site is evidence of its value in hemispheric conservation of shorebirds. The criteria for being designated a regional site describe an area that hosts at least 20,000 shorebirds annually, or 5 percent of the species' flyway population based on peak species counts. Additional information about the WHSRN can be viewed online at: *http://www.whsrn.org/site-profile/monomoy-nwr* (accessed January 2013). More information regarding shorebird use of the refuge can be found in the Migrating Shorebirds section, under Migratory Birds.

Important Bird Area

Due to Monomoy NWR's relative importance to birds in Massachusetts, it was also designated an Important Bird Area (IBA) by the Massachusetts Audubon Society in 2000. The purpose of an IBA is to identify and protect sites that contain essential habitat for one or more species of breeding, wintering, or migrating birds. IBAs are designated as part of an international effort to protect bird habitat around the world. Information about the IBA program is available on the Massachusetts Audubon Society Web site and can be accessed at: *http://www.massaudubon.org/Birds_and_Birding/IBAs/ibaflashmapnew.php* (accessed January 2013).

Marine Protected Area

Monomoy NWR is also designated as a National Marine Protected Area (MPA) as defined under Executive Order 13158 of May 26, 2000 as, "…any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." The Monomoy NWR MPA's focus is on conserving natural and cultural heritage and sustainable production. The adjoining Cape Cod National Seashore is also a designated MPA along with the smaller, nearby Pendleton and Dixie Sword "Exempt Site" MPAs (*http://www.mpa.gov/dataanalysis/mpainventory/mpaviewer/*; accessed January 2013).

Executive Order 13547—Stewardship of the Ocean, Our Coasts, and the Great Lakes—established a national policy to, among other reasons, ensure the protection, maintenance, and restoration of the health of ocean, coastal, and Great Lake ecosystems and resources (*http://www.whitehouse.gov/the-press-office/executive-order-stewardship-ocean-our-coast-and-great-lakes*; accessed July 2013). The policies contained in this executive order formed the basis of the 2013 National Ocean Policy Implementation Plan. The plan was written by the National Ocean Council after extensive input from national, regional, and local stakeholders from all marine sectors; tribal, state, and local governments; the private sector; scientists; and the public (*http://www.whitehouse.gov/oceans*; accessed July 2013).

The International Convention on Biological Diversity adopted a revised and updated Strategic Plan for Biodiversity for the 2010 to 2020 period, which contains biodiversity targets, including Target 11: By 2020, at least…10 percent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative, and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes (*www.cbd.int/sp/targets*; accessed July 2013). Helping achieve this target is a global commitment on marine protected area (MPA) networks (Wenzel and Wahle 2013). Participation in the national MPA system does not constrain the management agency from changing its management of the MPA. The management agency retains the ability to add or reduce levels of protection, change the size of the MPA, or make other changes.

Geology and Topography

Geomorphic regions, or physiographic provinces, are broad-scale subdivisions based on terrain texture, rock type, and geologic structure and history. Monomoy NWR lies in the Sea Island Section of the Atlantic Coastal Plain delineated by the USGS *http://tapestry.usgs.gov/physiogr/physio.html*; accessed August 2011). Many of these islands off the Massachusetts coast mark the southern limit of the last glacial maximum (15,000 to 20,000 years ago), where terminal moraines of clay-rich, poorly sorted glacial materials were deposited. This had an influence on the subsequent development of beaches, offshore islands, and other landforms (*http://tapestry.usgs.gov/features/features.html*; accessed August 2011).

The Morris Island portion of the refuge is situated on outwash plain deposits (Oldale 1992). Ongoing erosion of the east side of the island, which rises up nearly 50 feet from a narrow beach to the refuge's headquarters site, has removed much of the beach. The southern portion of Morris Island slopes down moderately to mixed pine forest, dunes, intertidal salt marsh, and beach, and an adjoining dredge material "sand spit."

Traveling east to west on North Monomoy Island, one traverses a narrow beach, dunes, and intertidal salt marsh to reach a wide, intertidal sandflat. The northern two-thirds of South Monomoy is flanked by sandy beaches on the east and west, with north-south trending dunes between. The southern third of South Monomoy is typical of a dune-ridge island, with a high scarped dune line along the eroding eastern side and distinctive dune ridges running southwest in the direction of accretion. Although the littoral currents are the dominant force configuring the Monomoy Islands, dune vegetation, which traps sand moved by the prevailing winds, also plays an important role in dune formation and maintenance (Giese et al. 2010).

The Monomoy Islands and sand spits rest on a bed of glacial material left approximately 18,000 years ago in the wake of retreating glaciers (Oldale 1992). The islands themselves are estimated to be about 6,000 years old. The topography of the Monomoy Islands is highly dynamic and is continually being reshaped by wind and waves. Giese (1978) has traced the evolution of North and South Monomoy since the 1770s. The southern end has migrated to the south and west, while the northern end has alternately connected with and separated from the mainland of Cape Cod. Historically, the area's topography undergoes an estimated 150-year cycle, with land forms accreting, eroding, and overwashing, and islands being created and recreated to eventually form a peninsula (Giese et al. 2010). This is described in more detail in the History of Refuge Coastline Dynamics section. The future configuration of the Monomoy barrier complex largely depends on the rate of sea level rise, which is discussed under Global Climate Change and Sea Level Rise.

Coastal Geomorphology

Coastal geomorphology is the study of the processes that influence coastal landforms. These natural coastal processes include accretion and erosion, that is, the deposition and removal, of sand along shorelines. Sand eroded from one beach is transported or “down drifts,” and accretes on another. These processes are influenced by many factors, including ocean currents, tides, winds, sea floor bathymetry, and human modifications. The dynamic nature of these systems means that the same beach can both accrete and erode seasonally within a given year, and fluctuate between accretion and erosion over long periods of time (MA CZM 2011). These processes provide continually changing coastlines and habitats for many species of wildlife. The dynamic Cape Cod shorelines, including the Province Lands, as well as Nauset Spit and most of Great Island, were formed by the movement and relocation of sand as part of this process; both Provincetown and Monomoy Island are still growing by about 1 acre a year with sand eroded from the outer Cape beaches (*http://www.nps.gov/caco/naturescience/upload/geomorphology.pdf*; accessed October 2011).

According to the most recent shoreline analysis, 68 percent of the Massachusetts shoreline is in a long-term erosional trend, 30 percent is in a long-term accretional trend, and 2 percent shows no net change. Overall, results indicate that the Massachusetts shore is eroding at a long-term average annual rate of 0.58 to 0.75 feet (mid-1800s to 1994). This coincides with the 75 percent of U.S. coastline that is eroding (Woods Hole Oceanographic Institute [WHOI] 2003).

Snowy owl

For the shoreline along Chatham, the long-term average shoreline change rate over the same time period is a loss of 0.65 feet per year, but the short-term trend rates will vary by and within communities. These long-term annual averages take into account long-term erosion or accretion periods, potentially resulting in deceptively low change rates, when in fact the short-term change rates for a particular location can be much higher (WHOI 2003). South Monomoy has shifted to the south and west since the mid-1800s, with a long-term change rate of -15.6 feet per year (eroding) along the eastern edge, and +25 feet per year (accreting) on the southern tip (MORIS Shoreline Change Map; *http://maps.massgis.state.ma.us/map_ol/czm_shorelines.php*; accessed September 2011). This not only affects the overall size of the refuge, but also the available habitat for species that rely on coastal ecosystems, which are some of the major influences on the amount and quality of habitat for beach-nesting species (MA DFG 2006).

Tides and Currents

Monomoy NWR was formed by longshore, southbound, ocean currents that continuously transported sand from the Cape's eroding eastern shoreline north of the refuge. The barrier complex composing the refuge formed when the Nantucket Sound currents met these southerly flowing longshore currents and the entrained sand settled to form shoals and, eventually, islands (*http://www.capecodconnection.com/monomoy/monomoy.htm*; accessed September 2011).

Tides at Monomoy NWR are classified as semidiurnal (i.e., two high and two low tides every 24 hours). Data from the Nantucket National Water Level Observation Network (NWLON) station shows that from 1983 to 2001, the mean high water (MHW) was 6.24 feet, and mean low water was 3.20 feet (National Oceanographic and Atmospheric Administration [NOAA] 2009a)—a tidal difference of approximately 3 feet. At the refuge, the times of high and low tides are expected to coincide largely with those measured at Nantucket, although observed tides will fluctuate according to prevailing winds. Another NOAA station (buoy # 44018) located close to the refuge provides wind speed and direction, wave height, and other meteorological data. This information is available online at: *http://www.ndbc.noaa.gov/station_page.php?station=44018*; accessed June 2012.

History of Refuge Coastline Dynamics

The barrier islands and associated sand shoals at Monomoy NWR are constantly changing due to the complex nearshore geomorphology of the area, which includes storms, high winds, tide, and surf that change the terrain and shoreline. However, erosion and drift of sand from the outer beaches of Cape Cod are the foundation of the refuge's islands. The eroding sand from the north moved southward to reconnect Monomoy back to the mainland and form a peninsula for a short duration of time. A fixed boundary line (refuge Declaration of Taking) was established west of the Monomoy Islands, and the refuge's islands had room for migration and shift (U.S. District Court 1944).

In 1944, when Monomoy became a national wildlife refuge, the area was one contiguous landmass stretching from Morris Island approximately 8 miles south into Nantucket Sound. The southern end of Nauset Beach, commonly known as North Beach, which stretches from Orleans, MA to Chatham, MA, terminated just south of Morris Island, and was parallel and due east of the refuge.

At some point between 1944 and 1958, Stage Harbor was dredged for commercial fishing fleets, and sand was piled adjacent to the refuge lands at Morris Island. This new landmass is still recognizable today—the formation is a narrow finger of land heading west toward the Stage Harbor entrance. Although the channel continues to be dredged, sand is no longer deposited on this town-owned portion. During this same timeframe, a causeway was constructed between Stage and Morris Islands, and the channel separating the two islands was filled with sand. This was done to decrease the need for dredging in Stage Harbor, but also had the effect of increasing the land value of lands surrounding the refuge headquarters.

In 1958, a spring northeaster cut through the northern reaches of Monomoy, separating the island from mainland Chatham at Morris Island (figure 2.1, box 1). Monomoy Island was still accessible at low tide, and for a few years motor vehicles were able to access the island using a local ferry. Over time, however, the width of the channel between Monomoy and Morris Islands became very wide and ferrying motorized vehicles became infeasible. North Beach continued to slowly grow southward.

In 1978, a blizzard split Monomoy Island in two approximately one-third of the way down (figure 2.1, box 2); the northern island came to be known as North Monomoy, and the southern known as South Monomoy. Tidal flow through the 1978 inlet created a flood-tidal shoal near the western margin of the platform, which, due to the influence of the prevailing southwesterly wind waves, formed the islet known today as Minimoy Island (Giese et al. 2010). At the same time, the southern tip of North Beach had extended further south and was approximately due east from the mid-point of North Monomoy.

In 1987, a storm caused a break to form in front of the Chatham Lighthouse on Nauset Beach (figure 2.1, box 3); this break would continue to widen over the years. The new landmass (island) formed to the south, stretching from the Chatham Lighthouse south to North Monomoy, and became known as South Beach. Following this storm, the mainland was rip-rapped to protect the homes near the Chatham Lighthouse from scour and erosion.

In 1992, the Nauset/South Beach Island started to stretch westward and became attached to the mainland, in a landform known as a tombolo (figure 2.1, box 4).

In the winters of 1998 and 1999, a 975-foot rock revetment was installed between the Monomoy NWR beachfront and four adjacent landowners to the west on Morris Island. Following the revetment construction, beach renourishment took place with the addition of 1,300 cubic yards of sand. In 2005, the Service was approached by the Cape Cod Commission to determine if we wanted additional beach renourishment on Morris Island. With the information we had at that time, we determined that additional beach renourishment was not warranted. However, since then, the beach on the east side of Morris Island has experienced additional erosion, and we are now receptive to renourishment proposals.

From 1992 to 2006, Nauset/South Beach continued migrating southward, as sand eroded from the north and deposited on the south. These two parallel landmasses, the Monomoy Islands and Nauset/South Beach, were separated by a waterway known as the Southway. The southern tip formed a connection which could be crossed at low tide. During this time, sand from Nauset/South Beach was not transported south to re-nourish South Monomoy, but instead curled back into the Southway and moved between North and South Monomoy. The marshes on North Monomoy started to expand and the small cuts through the flats became difficult to navigate at low tide.

During this time, South Monomoy also started to erode on the east side, leaving its mid-point only 328 feet wide. The northern dunes on South Monomoy also eroded, losing half their elevation, and sand was pushed into Hospital Pond, a pond at the northern end of the island. While the intertidal connection probably occurred in 2005, a Thanksgiving Day northeaster in 2006 caused the southern tip of Nauset/South Beach to attach as dry sand to the northern tip of South Monomoy (figure 2.1, box 5). This attachment allowed a person to walk from the Chatham Lighthouse to Monomoy Point Lighthouse, something not possible since 1958.

Like South Monomoy, Nauset/South Beach has also changed in shape due to geomorphological processes, with some areas narrower than others. In February 2013, a break in Nauset/South Beach occurred through which small boats were able to pass at high tide. This break has remained as of this writing. This is discussed in greater detail in this chapter under Refuge Administration.

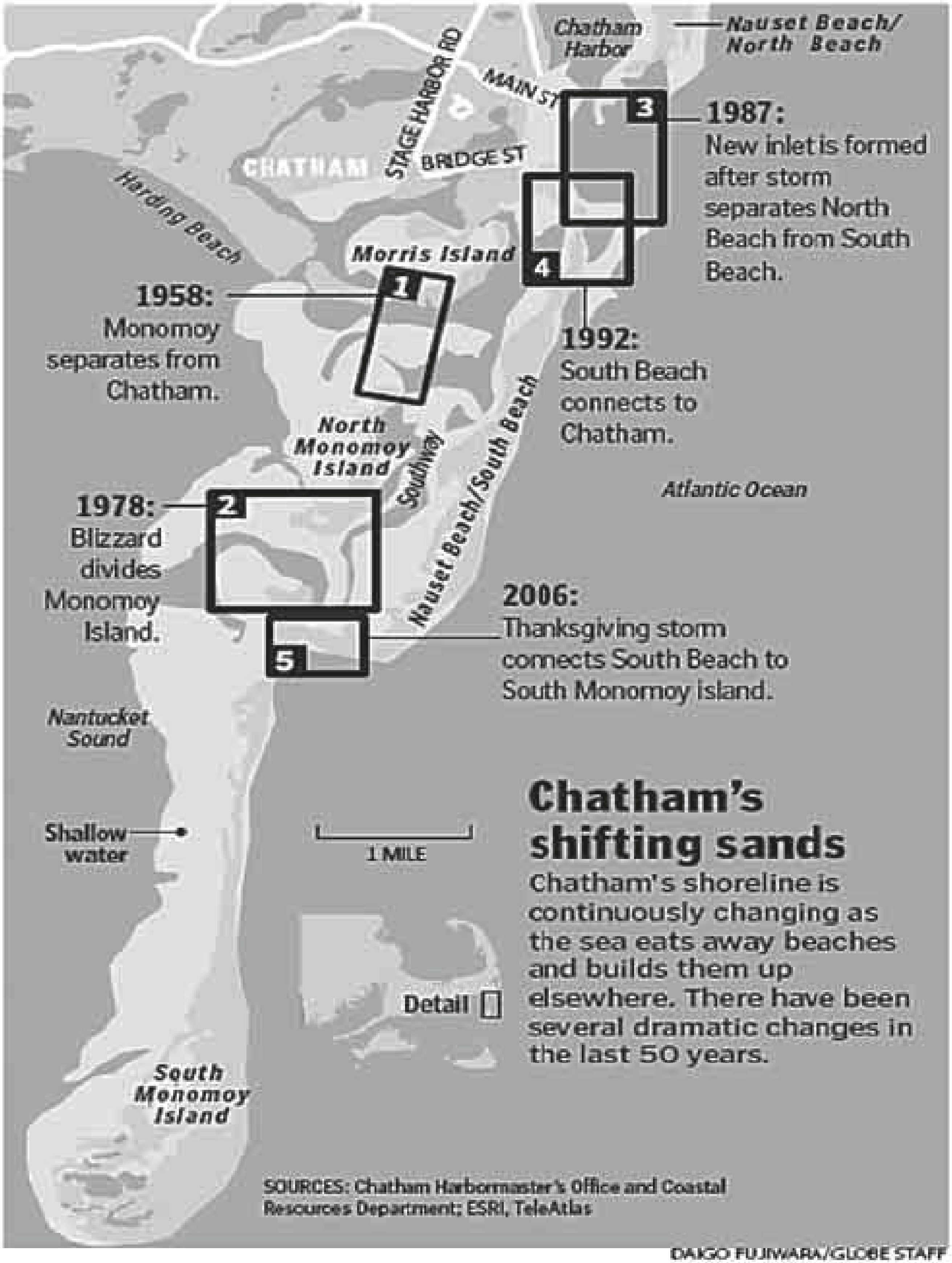


Figure 2.1. Landform Changes in Monomoy NWR and the Eastern Coastline of Cape Cod.

Major Historical Influences Shaping Landscape Vegetation

Understanding the historical distribution and composition of plant species can be useful in evaluating future management options for the Monomoy NWR (Foster et al. 2003). The Cape Cod area has undergone significant natural and anthropogenic changes, which have shaped the vegetation communities currently found on the refuge. The disturbance agents shaping the vegetation on Monomoy NWR include glaciation, other natural processes, and forms of human disturbance and land use. However, we have noted that ecologists caution against selecting one point in time, and instead recommend managing for a "historical range of variation" for each habitat type when considering the restoration of areas to native vegetation.

Understanding the history of the land, its biota, and its interactions, including the role of human beings, is the first task of restoration. For example, the study of the natural and cultural environment of coastal ecosystems increases our understanding of the ecological requirements needed to manage and conserve existing dune grasslands and maritime shrubland. A comprehensive overview of the influences on natural vegetation patterns across the Massachusetts landscape follows.

The Laurentide ice sheet covered Massachusetts and all of New England during the last glacial maximum, approximately 21,000 to 18,000 years before present (BP). The glacier reached its southernmost extent at the islands of Nantucket and Martha's Vineyard, marked by the deposition of terminal moraines on these islands. These terminal moraines are a build-up of the rock debris, or glacial till, embedded in the glacier that is sloughed off and deposited along the leading edge of the glacier. The sedimentation on these islands is consistent with this process (Motzkin and Foster 2002).

The advancing Laurentide ice sheet scoured the land and shallow-water areas, removing most plant and animal life, while retreating shorelines and exposed seabeds provided new areas for plant and invertebrate colonization (Oldale 2001). As the ice sheets retreated, sea levels gradually rose. In addition, the earth's crust slowly rebounded from the heavy weight of ice, but not as fast as sea levels were rising. By about 12,000 years BP, the coastline between the Bay of Fundy and Cape Cod was much as it is now (Pielou 1991). The indented coastline from Eastham southward to Chatham also owes its existence to the Laurentide ice sheet, and most likely represents the last remnant of an irregular coastline made up of headlands and embayments that marked the eastern limit of the glacial Cape. It also represents a western expansion of the South Channel lobe in the form of a sublobe, which, at its largest size, occupied the site of the Eastham outwash plain and limited the eastern extent of the Harwich outwash plain and the distribution of the Nauset Heights deposits (Oldale 2001).

As the ice age waned and the climate warmed, the glacier retreated, depositing till (Oldale 2001) and inundating low-lying coastal areas (Pielou 1991, Prentice et al. 1991). The exposed substrate was colonized by various plant communities, with tundra-like vegetation dominating the landscape at the southern terminus of the glacier (Jackson et al. 2000). For several thousand years, this tundra-like landscape was dominated by sedges and dwarf shrubs (Williams et al. 2004), but as the area continued to warm and trees were able to survive the shortening winters, forests became established. Initially, more cold-tolerant conifers dominated the landscape, with deciduous species reaching the area around 6,000 to 3,000 years BP (Foster et al. 2006). Most of Monomoy NWR consists of coastal wetlands and dunes; therefore, it is unlikely that extensive forest covered the local area. Dunes and intertidal areas would likely have only become an important component of the refuge area when sea levels rose to their current levels.

Contemporary Influences on Vegetation Patterns

Ecological processes and other natural disturbance regimes have also defined the current vegetation characteristics of the refuge. Of these, storms, salt spray, erosion/accretion, and fire have likely been the most important in limiting plant succession and maintaining a diversity of habitats. Through processes of erosion and accretion, winter storms and hurricanes have altered the size and position of dunes, marshes, and intertidal areas. As these areas changed in size and location, the suite of species that utilized them was altered concomitantly. For instance, expanding dune areas would have increased nesting opportunities for various seabirds. Storms might destroy some of the dune nesting sites, but would also remove or retard woody vegetation unsuitable for many nesting seabirds, allowing beneficial grasses to rapidly recolonize and dominate the newly formed dunes. Infrequent fires would also limit succession of woody shrubs and vegetation, thereby maintaining more sparsely vegetated areas for nesting. Likewise, storms and altered currents would change intertidal areas, affecting the abundance and composition of various shorebirds that use those sandflats.

Fire

There is agreement in the literature that Native Americans did use fire as a tool to clear the mainland forest understory for ease of travel and hunting, to manage game populations, and possibly to create small openings around their seasonal camps (Day 1953, Russell 1983, Patterson and Sassaman 1988, Denevan 1992, Holmes et al. 1997, Williams 2000, Motzkin and Foster 2002, DeGraaf and Yamasaki 2001). The results of these land use practices have been described as creating a shifting mosaic of localized early successional, woody-dominated habitats, but likely did not result in broad-scale alterations to the landscape (Foster and Motzkin 2003). The Wamponoag people were known to inhabit areas now within Barnstable County, including Mystic Lake, Middle Pond, and Hamblin Pond, where they cleared small forest openings prior to colonial settlement

Donna Dewhurst/USFWS

Greater scaup pair

(Caljouw 2005). At the time of European settlement, mainland Cape Cod and the islands of Martha's Vineyard and Nantucket were a mosaic of pitch pine-oak forest, scrub oak and shrub heath openings (inhabited by the now extinct heath hen, Gross 1932, Bent 1932, Simberloff 1994, Johnsgard 2008), and small grasslands, with no large-scale occurrences of grasslands or other openings (Motzkin and Foster 2002, Foster et al. 2002). The more exposed coastal fringe barrier beaches and islands lying seaward of these interior woodlands were, however, dominated by grassland vegetation interspersed with small patches of bare sand or low-growing woody shrubs and scattered trees, and bordered by tidal *Spartina* marsh in more sheltered intertidal areas, much as they are today. Salt spray and aerosols (Boyce 1954), along with mechanical "sand blasting" from blowing sands and secondarily by periodic fires on these nutrient-poor sands, "pruned" woody plants to a low shrubby stature or even eliminated them (Motzkin and Foster 2002). However, fringe coastal dunelands have been largely excluded from the substantial studies of Cape Cod uplands (Motzkin et al. 2002) and therefore the role of fire is less certain.

In the (circa) 1,000 years before European settlement, fires were more common on Cape Cod uplands than in much of New England (Patterson and Sassaman 1988, Parshall et al. 2003). Fires were particularly important in pine woodlands on outwash soils on inner Cape Cod, and were less important on hardwood-dominated moraines; outer Cape Cod apparently experienced the lowest fire occurrence (Parshall et al. 2003). In the Cape Cod region, charcoal evidence from paleoecological studies indicates that the use of fire increased concurrently with the clearing of forests in the time of European settlement. Fire, in combination with other European practices such as logging, plowing, and grazing, transformed the landscape from one dominated by forests into one in which grasslands and coppice woods were prevalent. However, the palaeoecological record is not useful in determining the prehistoric occurrence and distribution of small grasslands or heathlands, or in clarifying the importance of upland shrublands versus woodlands. Fossil pollen of characteristic oak scrub species (e.g., bear oak) cannot be distinguished from that of tree oaks and associated characteristic ericaceous species that occur commonly in woodlands, shrublands, and heathlands (Motzkin and Foster 2002).

More recently, during the 61-year period from 1951 to 2012, there were six wildfires (unplanned, human-caused ignitions) in wildland fuels documented for Monomoy NWR, ranging in size from less than 0.1 to 6 acres. No natural (lightning) ignitions are documented during that same 61-year period. Wildfire causes included two ignited by signal flares from distressed boaters, one unattended campfire, one from arson, one grassfire during cabin disposal, and one undetermined cause. During the same 61-year period, at least 9 planned ignitions (prescribed fires) in wildland fuels are documented for Monomoy NWR, ranging up to 43 acres in size. Refuge personnel experimented with prescribed fire to provide green forage for fall and spring migrating waterfowl during the early 1950s. Burning for wildlife habitat was discontinued after the 1954 burns on a belief that the potential risk from erosion outweighed the intended forage benefits to migrating waterfowl and the logistical difficulties of applying fire in such remote, inaccessible areas during the few suitable weather windows available each year. The refuge resumed using fire as a tool for disposing of unoccupied and deteriorating camps during the late 1960s; this continued through the early 1980s. Fire remained absent as a habitat management tool at Monomoy until 2002 when two small vegetation management study plots were burned within the tern colony. During the period from 2002 to 2012, four prescribed burns were executed within the South Monomoy tern colony, the largest in October 2009 and 2012 when the same 35± acres of primarily beach grass was prescribed burned to improve tern nesting habitat each of those years.

Cultural Landscape Setting and Land Use History

Pre-Contact Period

The first human inhabitants of the Cape Cod region were the Paleoindians, who reached the eastern seaboard approximately 11,500 years ago. Organized in small bands, the Paleoindians were highly mobile and used a specialized toolkit that included distinctive scrapers and fluted spear points. The environment they knew was cool and dry; the landscape was vegetated in spruce-pine forest and was populated by temperate terrestrial species, including many animals still seen in the region today. Between the Cape and the areas that now encompass the islands of Martha's Vineyard and Nantucket, the ocean floor was exposed until about 8,500 years ago. Evidence of late Paleoindian settlements has been reported in Bass River, near Chatham; however, it is likely that numerous other habitation sites existed on the exposed continental shelf, since inundated by rising sea levels in the post-glacial period (Dunford and O'Brien 1997).

Early Native American Influences

The successors to the Paleoindians were Native Americans of the Early Archaic period, approximately 9,500 to 8,000 years ago. These people knew a climate that was increasingly warm and humid and a mainland environment in which woodlands were dominated by hemlock and beech, which had replaced open conifer-dominated parkland (Shuman et al. 2004). These changes in vegetation were accompanied by shifts in animal populations in the Cape Cod region. The Native Americans modified their technologies in response, adopting new forms of notched spear points, and may have used spear-throwing devices to launch projectiles over greater distances than was possible by hand. As forests of deciduous trees closed in over the landscape, previously barren zones offered attractive resources, such as hazelnuts, hickory nuts, butternuts, and some tuberous plants (Dent 1995).

The innovative subsistence strategies practiced by the people of the Early Archaic period led them to modify their settlement system, as they used longer-term occupations and took advantage of seasonally available resources found in a wider variety of locations. Sea level rise inundated the low-lying areas along Cape Cod, separating Martha's Vineyard and Nantucket from the mainland. People seasonally occupied centrally located residential camps from which hunting and collecting parties ventured. In the warmest months of the year, communities were established near estuaries and wetlands; during the colder months, camps were occupied in the more protected interior uplands of Cape Cod, near sources of fresh water (Dunford and O'Brien 1997).

During the Middle Archaic period (8,000 to 5,000 years ago), a climatic warming trend with moist and dry sub-episodes prevailed. Hickory, chestnut, and oak became the dominant tree species (Shuman et al. 2004) and, by the end of the period, mixed deciduous forests, similar in composition to those seen in the region today, prevailed. The fruit of these trees (i.e., mast, such as acorns and nuts) was a nutritious and easily stored food source for the Native Americans (Dent 1995).

Around 6,000 years ago, the shoreline of Cape Cod took the general form that is recognizable today. The formation of barrier beaches partially closed off small bays in the glacial landscape and formed lagoons protected from the ocean. Human populations appear to have grown as the Archaic period progressed. Evidence from archaeological sites suggests that people subsisted on a mix of hunting and gathering products obtained from maritime, estuarine, and inland sources that varied according to season. The coastal environment provided a concentrated, predictable, and highly productive set of resources for Middle Archaic people (Dunford 1999). The Native Americans of this period devised a variety of contracting-stem and side-notched projectile points that were suitable for hunting and fishing, and supplemented their tool kits with grinding and milling stones, ground-stone axes, drills, and wood-working tools such as adzes and celts.

Between 5,000 and 3,000 years ago, during the Late Archaic period, the Native American people of Cape Cod continued to hunt and gather over a large area, consuming greater volumes of shellfish. The time-honored settlement strategy continued; in the warmer months, communities lived near estuaries and wetlands, and during colder months, camps were occupied in protected inland locations (Dunford and O'Brien 1997). People burned forest underbrush to increase the productivity of certain plant species, establishing meadows and edge zones in the woodlands that attracted deer and other animals. Moister climatic conditions led to the dominance of hickory and chestnut on the mainland (Shuman et al. 2004), but the woodlands of Cape Cod were characterized by pine and oak.

By about 3,500 years ago, sea levels stabilized, and newly formed estuaries defined the coastline of Cape Cod. Currents running parallel to the shoreline carried sediment that eroded from marine scarps (i.e., sea cliffs); deposition of this sediment formed natural coastal barriers. The establishment of these barrier beaches created small, protected bays that enabled the formation of permanent estuary systems. For Native Americans, the estuaries and salt marshes that lay behind these beaches became the most productive environmental settings on Cape Cod (Dunford 1999).

Archaeologists define the Woodland period as the span of time between about 3,000 years ago and the era of initial contact with European explorers about 1500 A.D. (500 years BP). Native Americans of the Early Woodland period manufactured fired clay pottery, a development likely related to their adoption of horticultural techniques. Hunting, gathering, and fishing remained important subsistence activities, and people continued to reoccupy settlement sites that had been used during previous periods. The use of northern native plants, such as goosefoot and sunflowers, figured more centrally in subsistence during the Woodland period; however, archaeological evidence indicates a greater degree of sedentism in settlement practices, with village sites containing multiple storage pits and deep deposits suggestive of long-term habitations. The apparent definition of tribal territories was expressed through distinct decorative styles of pottery and other artifacts, such as bone combs associated with burials at village sites (Dunford 2000 personal communication).

The Late Woodland period, which began about 1,000 years ago and ended with the onset of the Contact period (circa A.D. 1500), was characterized by Native American cultivation of plants such as maize, beans, and squash, as well as Jerusalem artichokes and sunflowers. Shellfish and other marine resources supplemented this horticultural component of the diet. During the cold months, shellfish, tomcod, waterfowl, seals, and drift whales were utilized when other foods were not available. There is evidence that native people also manipulated herds of deer through the planned burning of forest underbrush and used domesticated dogs to drive deer from certain areas, such as croplands. Dogs were buried ritually in coastal shell heaps (also known as middens), and such burials occasionally were accompanied by grave goods and treated with ochre (Dincauze 2000 personal communication). In some cases, settlements were fortified in order to protect cropland. The presence of permanent villages evidently encouraged the development of complex sociopolitical structures within Native American groups and the emergence of the chiefdoms and sachemships, which the first Europeans encountered in the late sixteenth and early seventeenth centuries (Bragdon 1996). Based on the discovery of Late Woodland archaeological sites throughout Chatham, it is considered likely that the area (then called "Manomoyick") represented a local core of Native American settlement after A.D. 1500 (Steinitz and Loparto 1987).

Although Native Americans utilized much of the upland areas and cleared forests, the impacts of their land use patterns have been largely masked by subsequent alterations at the hands of early settlers and their descendants (Parshall and Foster 2002). In the mid-seventeenth century, accelerated clearing for settlement and agriculture reduced the extent of woodlands across Cape Cod and altered the composition and structure of remaining woodlands through repeated grazing, burning, harvesting, and other activities (Motzkin et al. 2002). Although these upland areas of the Cape have changed significantly through human use, the barrier islands and spits that make up the refuge have not been dramatically affected.

Contact Period

For southern New England, the years between A.D. 1500 and 1620 mark the Contact Period, when the Native American and European societies underwent an era of encounter and trade, prior to the establishment of the permanent English settlement at Plymouth. Populations of native peoples are also believed to have decreased dramatically during this period due in large part to disease pandemics (Carlson et al. 1992, Denevan 1992). As Wampanoag populations were decimated (especially from 1616 to 1619, possibly from leptospirosis), many settlements were abandoned and lands surrounding them went fallow. During this period, the Monomoyicks, a community of the Wampanoag tribe, occupied the vicinity of Chatham or "Manomoyick." The three islands in the refuge formed a peninsula at that time, which the Native Americans called "Monomoit" (Seufert-Barr 1995).

The explorer Giovanni da Verrazano made his voyage to the Northeast in 1524. In 1602, the English explorer Bartholomew Gosnold landed on the northern tip of Cape Cod, and named the locale for the abundance of fish he was able to catch. His records indicate that his men also made inland excursions on Cape Cod to gather resources. The ship's journals note that they sailed around the southeasterly tip of the Monomoy peninsula toward Chatham, and perhaps landed and interacted with Native Americans in Hyannis. In 1605, Samuel de Champlain led an exploration into Port Fortune (i.e., Stage Harbor) in Chatham, directly west of Monomoy (Bragdon 1996). Champlain's map of Port Fortune (circa 1605) shows the Monomoy peninsula, and illustrates the approximate locations and appearances of Native American villages near Chatham during the Contact period (figure 2.2). Settlements and planting areas were surrounded by palisades and featured wigwam-style dwellings. Champlain's map does not indicate any settlement on the Monomoy peninsula, although it is likely that the Monomoyicks visited the peninsula seasonally to procure fish, shellfish, and other estuarine products.

European Influences

After the account provided by Samuel de Champlain, there are no specific European references to Monomoy prior to the establishment of Plymouth Colony in 1620. However, the New England coast was visited by other explorers after Champlain's voyage, including Hudson (in 1609), Block (in 1613), and Smith (in 1614) (Holmes et al. 1998). Governor Bradford of Plymouth described how the riptides and heavy surf of the Pollock Rip off the eastern tip of the Monomoy peninsula turned the *Mayflower* back to the harbor at Provincetown and caused the Pilgrims to settle at Plymouth, instead of south beyond the Jersey coast, which had been their intended destination (Seufert-Barr 1995). The Pilgrims,"fell amongst dangerous shoals and roaring breakers and they were so far entangled therewith, as they conceived themselves in great danger…and thought themselves happy to get out of those dangers before night overtook them."

Bradford also noted that the Native American population of Cape Cod appeared to have been reduced significantly from the levels Champlain had previously described (Bradford 1994).

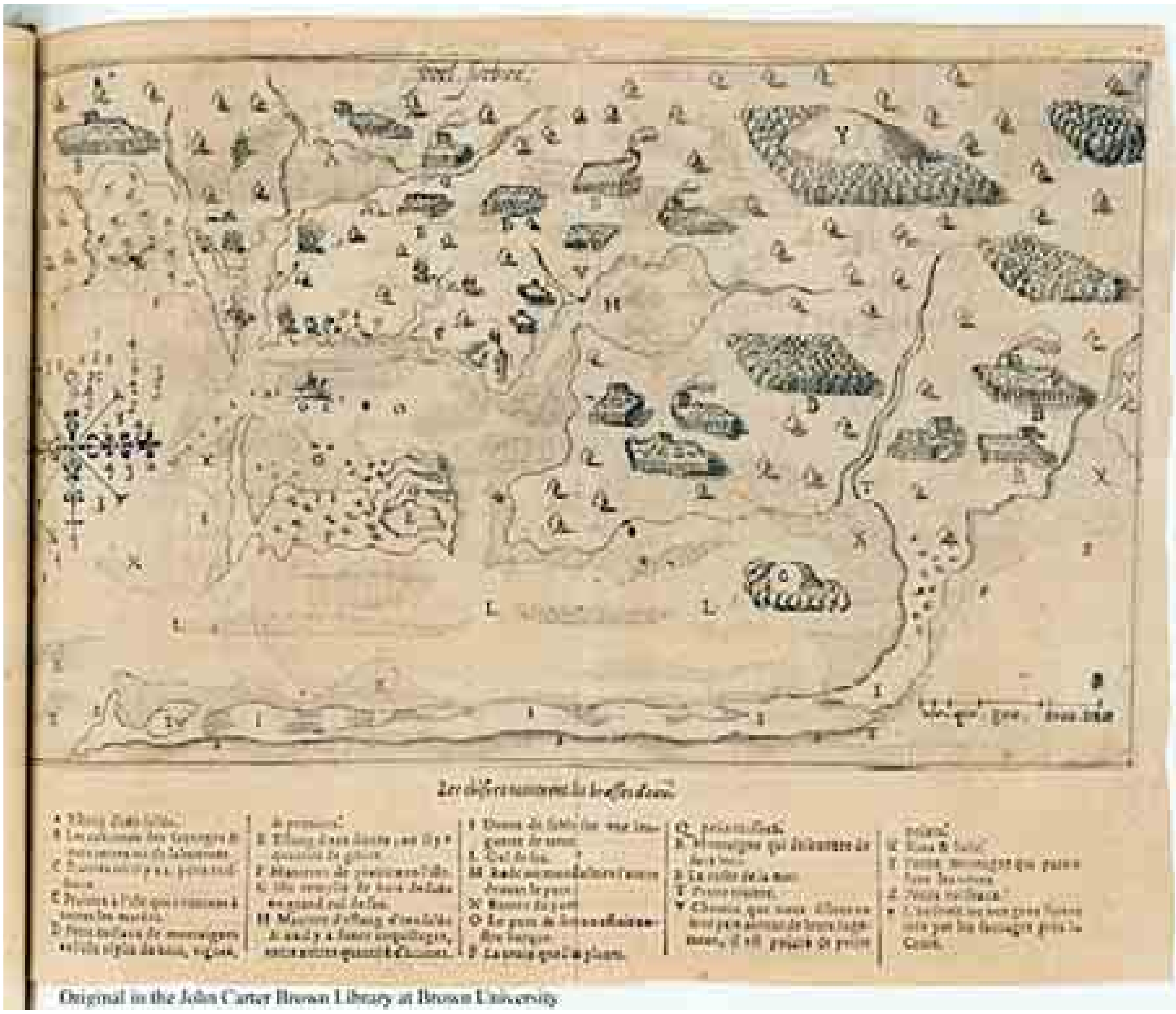


Figure 2.2. Champlain's Map of "Port Fortune" (Stage Harbor) in Chatham, Massachusetts, circa 1605 (Courtesy of the John Carter Brown Library, Brown University; also reproduced in Bragdon 1996). Note that the north arrow points to the right hand edge of the map; thus, the Monomoy peninsula is the narrow strip of land shown at the bottom of the map. *Translated legend: A. Salt water pond; B. Cabins of the savages and the fields in which they labor; C1. Meadows where there are 2 small streams; C2. Meadows covered at high tide (salt marsh); D. Little hillsides covered with woods, vines and plum trees; E. Fresh water pond, where there is much game; F. Different kinds of meadows on an island; G. Island covered with woods inside a large cul-de-sac; H. Salt water pond and where there are many shellfish, including large amounts of oysters; I. Sand dunes on a spit of land; L. Cul-de-sac; M. Roadstead where we anchored before the port; N. Port entry; O. The port and the place our bark was; P. The cross [we] planted; Q. Small streams; R. Far-away mountain; S. Sea coast; T. Small stream; V. Path we took in their country around their village, it is marked with small dots; X. Mud flats, tidal flats; Y. Small mountain seen from their territory; Z. Small streams. Place where our people were killed by the savages near the cross.* (Translated by Susan Danforth, John Carter Brown Library, Brown University).

Old World diseases introduced by the first Europeans had inflicted a mortality rate as high as 75 percent on the Native American communities of Cape Cod by circa 1616, leading to the abandonment of entire Native American villages and settlement areas (Denevan 1992). The first colonial settlements on Cape Cod occurred in Sandwich in 1638, followed by Barnstable and Yarmouth in 1639 (Holmes et al. 1998). Prior to the establishment of those communities, settlers in Plymouth had conducted trade with the surviving Native American groups of the lower Cape. They were assisted in this by Tisquantum ("Squanto"), a Native American who had befriended the Pilgrims shortly after their arrival. Tisquantum served as an interpreter and guide, providing instruction on planting and fishing techniques, and establishing relations between Plymouth and the Native American community at Monomoy (Forbes 1921). In 1641, Monomoy was mentioned in the court records of Plymouth, when Edward Holman was called to account for the removal of items from a shipwreck on the Monomoy shore (Shurtleff and Pulsifer 1856).

In 1651, the colonial settlement of Eastham, north of Monomoy, was established in lands formerly occupied by the Nauset Native American community. The Nauset population had been reduced by disease, enslavement, and emigration to Mashpee on the upper Cape, although a sachemship still existed in the Monomoy area (Holmes et al. 1998). In 1656, without the authorization of the Plymouth Colony, Captain William Nickerson entered into an agreement with Mattaquason, the sachem of the Monomoyicks, about the acquisition of lands, which included the current Monomoy, Morris, and Stage Islands; this transaction was authorized by the court in 1672 (Forbes 1921, Chatham Public Documents 2010). The missionary Daniel Gookin reported in 1674 that Manamoyick, which contained 71 members at the time, was one of three Christian Native American communities occupying lower Cape Cod (Gookin 1966). In 1686, Captain James Forster purchased Morris Island, then known as Quitnesset, located at the northern end of the Monomoy peninsula (Forbes 1921). The local colonial economy during this time was centered on farming and maritime activities. Farmers raised grain crops, but soils became depleted, leading to an increase in animal husbandry and sheep farming by 1700. Whaling supplied oil, while mackerel and cod fishing provided food, and shellfish procurement provided bait to the cod industry (Holmes et al. 1998).

The Town of Chatham was designated as the "constablewick of Monomoy" in 1696, and was incorporated with its current name in 1712 (Chatham Public Documents 2010). At that time, the Monomoy peninsula was used as pasture for sheep and cattle. The spit at the end of the peninsula was notorious for shipwrecks, and led to a new form of local industry—salvaging materials from shipwrecks. In 1711, Stewart's Tavern was opened on the south part of the Monomoy peninsula. It served passing sailors, and its presence suggests that a small fishing community (later known as Whitewash Village) had already been established on the peninsula by the early eighteenth century. In 1802, the Massachusetts Humane Society placed one of its first shelters for seafarers near the southern tip of Monomoy peninsula (i.e., Monomoy Point) to provide shelter for shipwrecked crews who managed to make it to shore (Seufert-Barr 1995).

During the early 1800s, a deep natural harbor, known as Powder Hole, attracted a sizeable settlement at Whitewash Village. As many as 50 families maintained homes there and the village featured trading stores and a pair of shipyards that served ships of the booming coastal trade. The community suffered a setback after the harbor was eroded away by a hurricane in 1860, hindering access to the fish population that had sustained the local economy. Nonetheless, settlement continued on the southern Monomoy peninsula into the early twentieth century. At its height, Whitewash Village housed about 200 residents and featured a public school and an inn called the Monomoit House. The local economy focused on fishing for cod and mackerel, which were dried and packed for markets in Boston and New York (Seufert-Barr 1995). In the mid-twentieth century, the village featured approximately two dozen seasonal cottages and associated outbuildings.

The first Monomoy Point Lighthouse was constructed in 1823. It was the fifth lighthouse commissioned on Cape Cod and was intended to aid vessels traveling around the treacherous point at Pollock Rip. In 1849, after the elements had damaged the first lighthouse, the existing Monomoy Point Lighthouse was constructed. An important and significant example of cast-iron lighthouse construction, the tower is 40 feet high. When it was active, the light could be seen for 12 nautical miles out to sea. The lighthouse, which is accompanied by an attached keeper's house and detached oil house, was decommissioned in 1923 (Oak Point Associates 2009). The historic lighthouse, keeper's house, and oil house are the only structures that still stand on the Monomoy peninsula.

The U.S. Lifesaving Service built the Chatham Life Saving Station (USLSS 13) near Morris Island on the Monomoy peninsula in 1872. Two years later, a second lifesaving station (Monomoy, USLSS 14) was built approximately 4 miles further south on the peninsula. Finally, a third station, the Monomoy Point Lifesaving Station (USCG 44), was built in 1902 near Whitewash Village serving as the southernmost component of a series of 13 such stations between Chatham and Provincetown (Seufert-Barr 1995, *http://www.uscg.mil/history/*; accessed October 2011). At the mid-point between each of these three lifesaving stations “half-way houses” were built.

Human Influences over the Past 100 Years

By the early 1900s, the Monomoy peninsula was a popular holiday destination, where families built summer camps and duck hunters visited during the fall and winter. The elite Monomoy Brant Club brought sportsmen to the remote beach for duck hunting from 1862 to 1932. Brant were attracted each spring during northward migration to the extensive, dense eelgrass beds near the Inward Point and Romp Hole areas hunted by the club. In addition to the cottages at Whitewash Village, several seasonal dwellings were distributed throughout the Monomoy Point area and northward along the peninsula. More than two dozen cottages and outbuildings were located at Hammonds Bend in the central part of the peninsula. In 1932, the Monomoy peninsula was taken over by the U.S. military and used for aerial strafing and bombing training during World War II (Seufert-Barr 1995).

After the refuge was established in 1944, the owners of summer camps were able to obtain special use permits for seasonal use of the refuge up until 2000, when the last cabin was removed. In 1958, winter storms breached the Monomoy peninsula at its northern end, turning it into an island; storms during the winter of 1978 further divided the island, creating the geographically distinct North Monomoy Island and South Monomoy (figure 2.1, box 1 and 2, respectively).

The refuge includes an area previously known as the Monomoy Island Gunnery Range. This formerly used defense site (FUDS) was utilized for practice bombing from 1944 through 1950. In 2010, a site inspection report was completed by the U.S. Army Corps of Engineers (USACE 2010) to determine the potential for any risks to people or the environment associated with the Monomoy Island FUDS. Based on the study, only practice bombs, signals, and spotting charges were likely used. No confirmed munitions or explosives of concern (MEC) have been found historically or during the 2009 to 2010 study. Subsurface and surface soil samples were collected and presented with one or more of the following metals: aluminum, iron, zinc, antimony, copper, and nickel; however, levels did not exceed human health risk or ecological risk and these “subsurface anomalies [are] likely attributed to cultural debris.” The study’s conclusions indicate there is a “low risk” to human and ecological receptors from potential MEC from remnant sources (suspected 5-pound practice bombs were discovered and blown in place by Fort Devens EOD, and there were no MEC finds during 2009 field investigation); site characteristics (limited access to the area, which is only accessible by boat); walking [more than 5 miles]; or special vehicle permit [extremely rare]). The potential for human interaction was deemed limited. During the military use of the FUDS, the center of the bombing target was located on land, but due to dynamic coastal processes, is now located offshore in the Atlantic Ocean. It is therefore assumed that “no known or suspected hazards” are present in the land portion of bombing range or air-to-ground gunnery range. Although the FUDS is open to the public during daylight hours, there are posted signs indicating closed areas where the public is not allowed.

Current Climate

Monomoy NWR is bounded by Nantucket Sound to the west and the Atlantic Ocean to the east, resulting in a maritime-influenced climate characterized by warmer temperatures in the winter and cooler temperatures in the summer compared to mainland locations. Approximately 38.9 inches of precipitation falls annually (NOAA 2002). Winter and summer temperatures are more moderate than nearby inland areas, with average temperatures of 31 degrees Fahrenheit (°F) in January and 71 °F in July (NOAA 2002). Many storms are accompanied by heavy winds and high seas that erode beaches and contribute to the dynamic coastline that surrounds the refuge.

Global Climate Change and Sea Level Rise

The global climate has been relatively stable over the last 10,000 years; however, it is now known that human activities, such as burning fossil fuels and deforesting large areas of land, are having a profound influence on the Earth’s climate. Climate warming is unequivocal, as evidenced by observations of increased global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (International Panel on Climate Change [IPCC] 2007). In its 2007 assessment report on climate change, the International Panel on Climate Change stated that it had “very high confidence that the global average net effect of human activities since 1750 has been one of warming” (IPCC 2007). The U.S. Climate Change Science Program (CCSP) published findings in agreement with the IPCC report, stating that “studies to detect climate change and attribute its causes using patterns of observed temperature change in space and time show clear evidence of human influences on the climate system (due to changes in greenhouse gases, aerosols, and stratospheric ozone)” (CCSP 2008a).

Climate change is of serious concern to the Service and to our partners in the conservation community. Scientists are predicting dramatic changes in temperature, precipitation, soil moisture, sea level, frequency and magnitude of storm-surge flooding, and coastal erosion—all of which could adversely affect the function of ecological systems and modify vegetation and wildlife distributions (CCSP 2009). We expect that species’ ranges will continue to shift northward or to higher elevations as temperatures rise; however, responses would likely be species-specific and vary according to local changes in precipitation and temperature. Under rapidly changing conditions, migration, not evolution, would determine which species are able to survive (USFWS 2006a). Species that cannot migrate or otherwise disperse at a sufficient rate to keep pace with shifting climate zones, such as many plants and a variety of less motile wildlife, will suffer the most.

Climate change impacts in coastal regions include a higher frequency of intense hurricanes and storms, more severe impacts of lesser intensity storms, including northeasters, warming ocean waters, and rising sea levels (Frumhoff et al. 2007). Sea level rise is one of the most potentially serious consequences of climate change for coastal ecosystems like Monomoy NWR. According to the USGS, sea levels have been steadily rising 1 to 2 millimeters (0.04 to 0.08 inches) per year since the 19th century (*http://geochange.er.usgs.gov/poster/sealevel.html*; accessed August 2011). This is a result of a reduction of ice caps, ice fields, and mountain glaciers, in combination with the thermal expansion of ocean waters. If sea level continues to rise, this could have serious impacts on coastal barriers and islands like Monomoy and Nauset/South Beach.

Horseshoe crab shell on the beach

Local impacts would be determined by whether the land is subsiding (lowering in elevation due to underground changes, e.g., ground water pumping) or uplifting; other determinants include topography and the presence of sea walls and other anthropogenic factors (Galbraith et al. 2002). In the Northeast, sea level rise is higher than the global average because of land subsidence, and parts of South Monomoy have been classified as areas of high vulnerability to sea level rise by the USGS. Coastal communities in Massachusetts, such as Gloucester and Marshfield, are predicted to lose more than 5 percent of their land area due to rising ocean waters by 2100 (TNC 2006). By the mid-1990s, Boston had already seen an increase in mean sea level since 1950 by 5 to 6 inches, and was predicted to see another increase of 22 inches by 2100 (TNC 2006, EPA 1997). These losses in coastal land area include intertidal, salt marsh, and drier coastal upland habitat, resulting in a decrease in feeding, resting, and breeding habitat for many coastal fish and wildlife species. Potentially impacted species include many marine and coastal bird species, lobsters and clams, and commercial fish including menhaden, alewife, and herring, among other species (Frumhoff et al. 2007).

Global mean sea level continues to rise due to thermal expansion of the oceans (IPCC 2007) and the loss of mass from glaciers, ice caps, and the Greenland and Antarctic ice sheets (Church et al. 2001, Bindoff et al. 2007). There is high confidence that the rate of sea level rise has increased between the mid-19th and the mid-20th centuries (Bindoff et al. 2007). Church et al. (2004) estimated a rate of 1.8±0.3 mm per year sea level change along the global coastline during 1950 to 2000, and Church and White (2006) determined a change of 1.7±0.3 mm per year for the twentieth century. However, satellite observations available since the early 1990s provide more accurate sea level data, with nearly global coverage. This decade-long satellite altimetry data shows that sea level has been rising at a rate of around 2 mm per year since 1993 (figure 2.2). This is significantly higher than the average during the previous half century (Bindoff et al. 2007).

In figure 2.3, the red curve shows reconstructed sea level fields since 1870 (updated from Church and White 2006), the blue curve shows coastal tide gauge measurements since 1950 (from Holgate and Woodworth 2004), and the black curve is based on satellite altimetry (Leuliette et al. 2004). The red and blue curves deviate from their averages from 1961 to 1990, and the black curve deviates from the average of the red curve for the period from 1993 to 2001. It is important to note that the change in sea level is highly non-uniform spatially; in some regions rates are up to several times the global mean rise, while in other regions sea level is falling.

Several recent studies are predicting higher rates of sea level rise than what has been reported by IPCC (2007). The projected increase in rate of sea level rise has been attributed to a greater contribution by melting glaciers and increased ice-sheet flow. According to Meier et al. (2007), global sea level is likely to rise at rates ranging between 3.1±0.7 mm per year.

The National Water Level Observation Network, operated by the NOAA, comprises approximately 175 long-term, continuously operating stations located along the U.S. coast. There are reliable data from some of these stations going back over 150 years (NOAA 2009a). The NWLON station nearest to Monomoy NWR is located at Nantucket Island, Massachusetts (station #8449130). Based on monthly mean sea level data from 1965 to 2006, the mean sea level rise trend at this location is 2.95±0.46 mm/year (figure 2.4 equivalent to a rise of 0.97 feet in 100 years (NOAA 2009a). Within a 150-mile radius of the refuge, there are 6 NWLON stations with sea levels ranging between 1.95 and 2.7 mm/year (average 2.46 mm/year), with an average error of ±0.27 mm/year (NOAA 2009a).

The Service is addressing the potential for significant changes that will be felt by all coastal refuges due to climate change and sea level rise. In recognition of this, Monomoy NWR is one of several coastal refuges in the Northeast for which a sea level affecting marshes model (SLAMM) analysis was completed in 2009; however, for the purposes of this draft CCP/EIS, we focused our sea level rise discussion to a report specifically prepared for Monomoy NWR by Giese et al. (2010).

Giese et al. (2010) reported changes as a result of current rates of sea level rise. Their report showed that, at the current rate of sea level rise, sediment supply from Nauset Beach to Monomoy would be capable of maintaining the barrier complex, as well as supporting ongoing accretion along the southern tip of South Monomoy. Based on relative sea level rise in southern New England and global rates, Giese et al. (2010) predict the following general patterns to occur:

> Between 2010 and 2030, Nauset/South Beach overwashes would create washover fans along the inner (western) side; Nauset/South Beach sediment would move southward along the South Monomoy outer shore; and Monomoy Point would grow south/southwestward. Between 2030 and 2050, washover shoals would reach Morris Island and end Outermost Harbor navigation; a re-curved spit would develop on the southwestern side of Monomoy Point that sweeps northward. In the third quarter of the century (2050 to 2075), shoals from Nauset/South Beach would end all "inside" navigation and connect Morris Island to South Monomoy and the Monomoy Point hook would join the western shore of South Monomoy. During the final quarter (2075 to 2100), Monomoy would exist as a peninsula for a majority of the period, but eventually thins south of Morris Island; Monomoy Point would extend southwestward onto a nearby portion of Handkerchief Shoal; and an enclosed pond would form on the western shore of South Monomoy inside the re-curved spit.

Increased rates of sea level rise would dramatically alter the current configuration of the area, with increased erosion of Morris Island, the connection of Morris Island to South Monomoy, and a reduced sediment load possibly deepening Monomoy Flats (Giese et al. 2010).

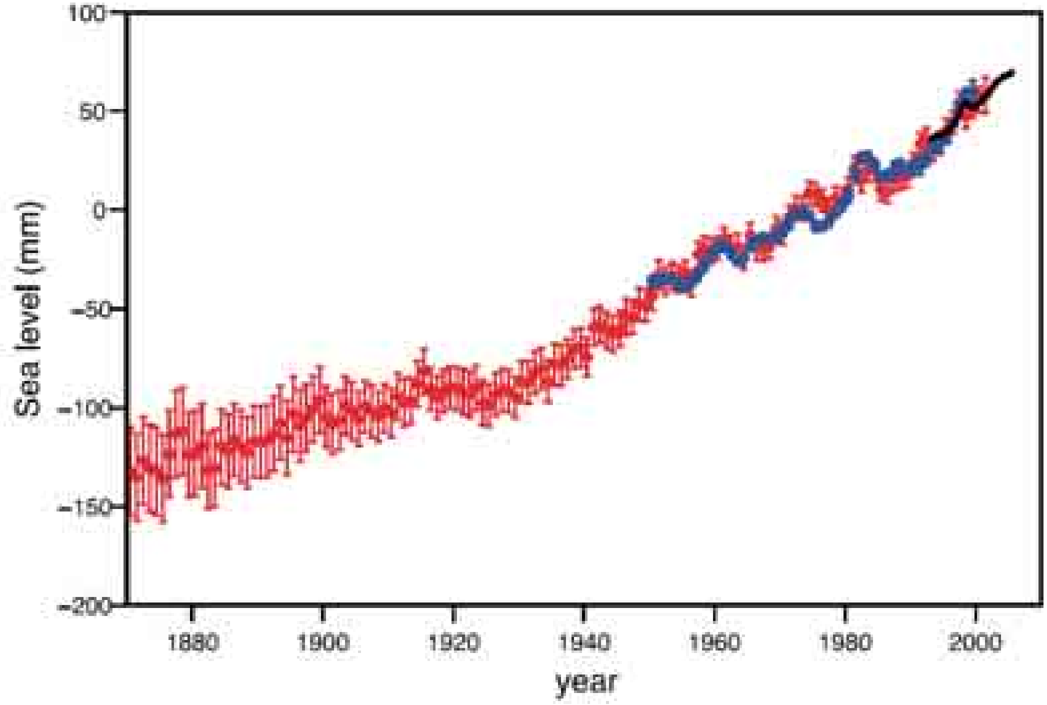


Figure 2.3. Annual Averages of the Global Mean Sea Level in Millimeters. (Error bars show 90 percent confidence intervals (Source: IPCC 2007). Dataset includes reconstructed sea level fields (red), coastal tide gauge measurements (blue), and satellite altimetry (black) data.)

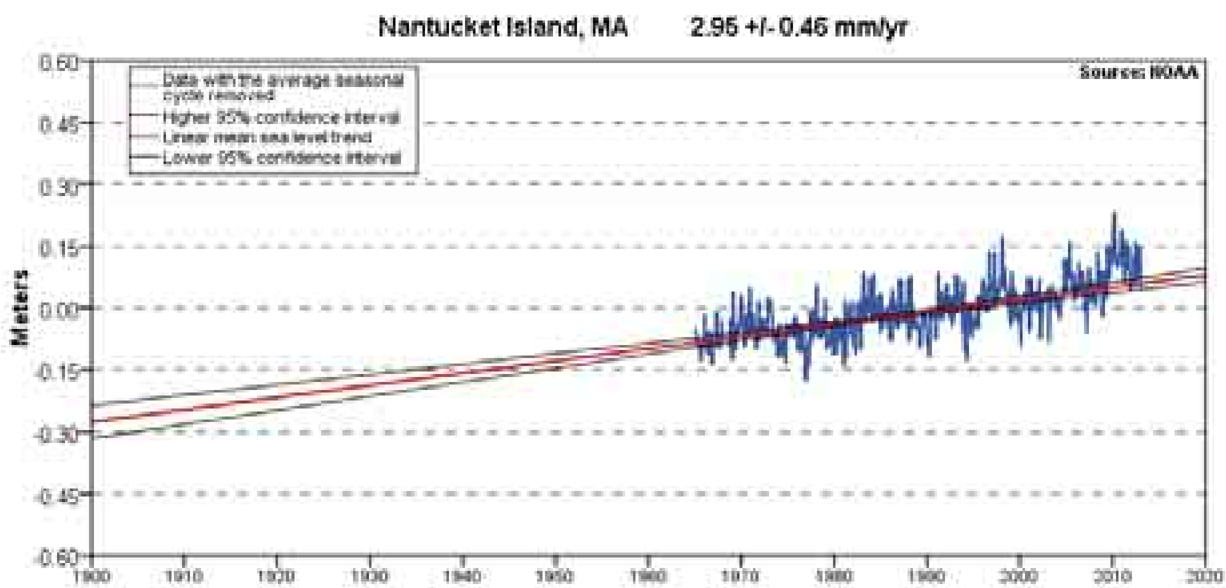


Figure 2.4. Mean Sea Level Trend at Nantucket Island, MA (Source: NOAA 2009a).

Air Quality

Under the Clean Air Act of 1990 (CAA), the Environmental Protection Agency (EPA) regulates six criteria pollutants—ozone, carbon monoxide, nitrogen dioxide, particulate matter, sulfur dioxide, and lead, and hazardous and other toxic air pollutants, including mercury, under the CAA Amendments of 1990. For each criteria pollutant, EPA has established a maximum concentration above which adverse effects on human health may occur; these threshold concentrations are called National Ambient Air Quality Standards (NAAQS). Areas of the country where air pollution levels persistently exceed the NAAQS may be designated “nonattainment.” When an area does not meet the air quality standard for one of the criteria pollutants, it may be subject to the formal rule-making process to designate it as “nonattainment.” The CAA further classifies nonattainment areas based on the magnitude of an area’s problem. These nonattainment classifications may be used to specify what air pollution reduction measures an area must adopt, and when the area must reach attainment (40 CFR 81).

The Massachusetts Department of Environmental Protection (MA DEP) monitors levels of ozone and particle pollution from several stations in Massachusetts for attainment or exceedance of the NAAQS. These standards are reviewed every 5 years by the EPA and may be changed based on new scientific information. It is incumbent upon each state to ensure these standards are met and maintained. In the case of an exceedance of these standards, pollution control strategies are implemented, and once the standards are attained, a plan is developed to maintain that standard in such a way that incorporates future economic and emissions growth.

Over the last decade, the State has made progress in reducing the number and severity of ozone exceedances, and in January 2008 submitted a state implementation plan to the EPA that describes strategies to attain the 8-hour ozone standard by 2010 (MA DEP 2008). In 2010, Massachusetts was in attainment of the air quality standards for all pollutants except ozone. Ozone at ground level is a respiratory irritant that can reduce the overall function of the lungs, cause asthma attacks, and aggravate chronic lung diseases. It also inhibits vegetation growth, and is often found in higher concentrations far downwind from the origin of the precursors that react to form it (MA DEP 2011).

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Lichen (Ramalina *spp.*)

At one time, the NAAQS for ozone was based on the maximum 1-hour ozone concentration that occurred each day during the ozone monitoring season. In 1997, EPA set a new 8-hour ozone standard that was designed to be more representative of exposure over time, rather than just a maximum concentration. Massachusetts is designated as nonattainment of this standard. However, ozone monitors currently show that the State is meeting the 1997 0.08 ppm standard (MA DEP 2011). The 8-hour standard was revised in 2008 to 0.075 ppm. In March 2009, Massachusetts recommended to EPA that the entire state be designated as nonattainment with the 2008 standard. In January 2010, EPA proposed to revise the primary 8-hour ozone standard to a level with a range of 0.06 to 0.07 ppm. EPA postponed the new ozone standards in September 2011.

There are in total 15 continuous ozone monitoring stations across the State. Based on information collected from these sites, there were 14 days when the 8-hour ozone standard of 0.075 ppm was exceeded by at least one monitoring station in 2010. There were 36 exceedances during those 14 days (i.e., multiple monitors exceeded the standard on the same day) (MA DEP 2011). The closest two monitoring stations to the refuge are included in those that registered exceedances: Fairhaven (5 days) and Truro (4 days). Exceedances at a station averaged over 3 years can lead to a violation of NAAQS. Based on data from 2008 to 2010, both of these stations indicated violation of the 8-hour ozone standard (MA DEP 2011).

Water Quality

Water quality must be addressed for compliance with the Federal Water Pollution Control Act of 1977, also known as the Clean Water Act (CWA). The CWA provides EPA with the authority to establish water quality standards (or states to establish standards equal to or more stringent than EPA standards); control discharges into surface and subsurface waters; develop waste treatment management plans and practices; and issue permits for dredging, filling, or discharging to a water body. The CWA requires states to monitor and classify water bodies, establish water quality goals, and publish lists of monitoring and classification results; it also gives states the authority and responsibility to publish water quality standards (U.S. Code, Title 33, Chapter 26).

Summary of the General Condition of Monomoy

Monomoy NWR contains freshwater and saltwater wetland habitats including salt marsh, intertidal flats, and ponds. The only source of fresh water is from precipitation and infiltration. The EPA designated the Cape Cod Aquifer as a sole source aquifer in 1982 because it supplies at least 50 percent of the drinking water consumed in the area above it (MA EOEEA 2004). This designation provides limited Federal protection of groundwater resources that serve as drinking water supplies and means that Federal funding will not be available for any project the EPA determines poses a threat to the water quality of the aquifer through recharge. The benefit of such a designation is increased public awareness that there is only one source of drinking water for the entire community; therefore, the community may be more willing to protect it locally. Groundwater recharge is through precipitation events. Cape Cod receives an annual average of 45 inches of rainfall, almost half of which recharges the aquifer system (MA EOEEA 2004).

The refuge consists of approximately 1,970 acres of barrier beach and dune habitat. It contains very little fresh water (Station Ponds on South Monomoy), and is not affiliated with any public well fields. Monomoy is surrounded by saline water.

Long-Term Trends and Status of Water Quality for Monomoy

In Massachusetts, certain surface waters with exceptional socioeconomic, recreational, ecological, or aesthetic values are designated outstanding resource waters (ORWs) and require additional protection under State water quality regulations. The waters of Monomoy NWR, including waters in and adjacent (i.e., within 1,000 feet seaward of mean low water) to the Cape Cod National Seashore (all ORWs), are classified as marine waters Class SA[1] or freshwaters Class B[2] (MA DEP 2002).

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[1] *Class SA waters* are designated for primary and secondary contact recreational activities and as excellent fish and wildlife habitat. Class SA waters also have excellent aesthetic value. Specific Class SA waters may be designated for shellfish harvesting in 314 CMR 4.00. Any desalination plant making withdrawals from Class SA water must protect the existing and designated uses of the water. This is the most stringent coastal water classification and includes strict standards for bacteria, DO, and other characteristics to protect the designated uses of the water and human health.

[2] *Class B waters* are designated for primary and secondary contact recreational activities and for fish and wildlife habitat. Class B waters also have consistently good aesthetic value. Class B waters are suitable for compatible industrial processes, cooling, irrigation, and other agricultural uses; some Class B waters are designated as suitable for public water supply with appropriate treatment.

According to MA DEP (1993), water quality impairment in the Cape Cod watershed was due primarily to the presence of pathogens (as measured by fecal coliform bacteria) in many areas and organic enrichment/low dissolved oxygen. Sources of these contaminants, when known, included urban runoff, onsite wastewater systems, highway maintenance and runoff, and recreational activities.

Within coastal waters, the Massachusetts Office of Coastal Zone Management (CZM) states that nonpoint source pollution is the number one source of pollution problems. Contaminants include soil sediments, nutrients from fertilizers and sewage, and chemicals from pesticide use and other sources, such as fuel, cleaning chemicals, paint, and oil from marinas and boats. These pollutants are picked up as the contaminated stormwater runoff or snowmelt flows directly into a surface water body (such as the ocean) or seeps through the soil into a surface water body. The Massachusetts Office of Coastal Zone Management is working with several groups on a coastal nonpoint pollution control program to restore and protect coastal waters; additional information about this program is available online at: *http://www.mass.gov/czm/cwq.htm* (accessed October 2011).

Big and Little Station Ponds are 32-acre and 11-acre freshwater ponds, respectively, on South Monomoy, originally formed when a bay was closed off by the growth of a re-curved spit. Other small freshwater ponds and wetlands are present on South Monomoy. Most are natural, but a few lie in depressions excavated by the Service in the early 1950s in an effort to increase waterfowl habitat. Almost 25 acres of salt marsh surround the 5-acre estuarine Hospital Pond at the northern end of South Monomoy. Powder Hole, which in the mid-1800s was a deep and extensive harbor, is now a shallow estuarine water body on the southwest end of the refuge.

In 2001, the Massachusetts Department of Public Health received Federal funding to begin monitoring marine beaches throughout the State. Any public or semi-public beaches are tested daily or weekly for enterococci as an indicator organism for water quality throughout the swimming season. In the 2009 bathing season, 16 beaches in Chatham were part of the marine beaches testing program. Three of these beaches recorded single sample exceedances of the standard (MA DPH 2010).

The Massachusetts Department of Public Health analyzed water quality data from 89 sites at public beaches throughout the Cape Cod region, including Chatham. The water samples, collected between 2003 and 2012, were used to measure levels of the fecal indicator bacteria (FIB) enterococci, a group of bacterial species typically found in human and animal intestines and feces (WHOI 2012). In marine waters, the accepted level of enterococci for a single water samples is 104 colony-forming units per 100 milliliters (cfu/100 ml). The analysis found that beaches near seal haulout sites showed a decreasing trend in yearly FIB exceedance events over the last decade, while beaches away from these haulout sites demonstrated an increasing trend (WHOI 2012).

The waters immediately west of Monomoy in Nantucket Sound are designated as a no discharge area (NDA), meaning that no boats may discharge any sewage, treated or otherwise, in these waters immediately adjacent to Monomoy NWR. This designation is applied when a community or the State determines that an area is ecologically or recreationally important enough to warrant additional protection. Influxes of sewage from boats, even when treated, can discharge nutrients, chemicals, and pathogens into the water, increasing public health concerns as well as overall concern for water quality. Increased levels of nitrogen, a component of sewage, can have wide-ranging effects on water bodies, including encouraging algal blooms, decreasing dissolved oxygen content, and increasing turbidity (poor water clarity), which all can impact the species reliant upon these coastal waters.

Water quality measures during 2011 from eight sampling sites throughout Nantucket Sound indicate a generally good condition for nitrogen (average of 0.58 uM), water clarity (using Secchi disk, 2.0 to 7.3 meters), and chlorophyll-a (0.45 to 4.32 micrograms/liter) (Costa 2012 personal communication).

State-Reported Impaired Waters

In 2010, the DEP released the 305(b)/303(d) Integrated List of Waters (report; MA DEP 2010). It combines both the 305(b) Water Quality Assessment and the 303(d) Report on Impaired Waters for each river basin. The DEP compiled those reports and submitted them to the EPA and Congress to satisfy the Federal reporting requirements under section 305(b) of the Clean Water Act.

Much of the data in this DEP report comes from a number of different third-party sources including Federal, State, and nongovernmental agencies, as well as projects with State, local, or Federal funding that submit individual watershed reports. Though the sources of data are varied, they must all have a quality assurance project plan, use of a State certified lab, QA/QC for data management, and documentation in a citable report. This ensures they are all subject to the same documentation and validation procedures.

The report on impaired waters in the State describes segments of streams, lakes, and estuaries that exhibit violations of water quality standards, and details the pollutant responsible for the violation(s) and the cause and source of the pollutant, if known. There were 102 impaired waters in the Cape Cod (USGS HUC 0109002) watershed (MA DEP 2010); of these, 84 are Category 4a, 3 are Category 4c, and 15 are Category 5 waters. Pathogens were the primary cause for impairment, but other impairments included nutrients, organic enrichment/low dissolved oxygen, other habitat alterations, turbidity, and noxious aquatic plants. Within the Cape Cod watershed, 49 pathogen-impaired segments are prioritized based on proximity to sensitive areas or designated uses that require higher quality standards, such as swimming areas, or shellfishing areas.

Noise

Surf and wind are the dominant noises on Monomoy NWR and tend to drown out many other sounds. An agreement between the Federal Aviation Administration and the Service provides a requested minimum altitude of 2,000 feet for all aircraft over the refuge, but numerous intrusions (i.e., low flying aircraft) cause disturbance to wildlife and visitors, which is a refuge violation (50 CFR 27.34). Boat motors are also audible.

Biological Environment

Soils

Most soils on the refuge are classified as beaches and sandy soils stabilized by vegetation, but deposited so recently that there is no soil development (USDA 1993). Exceptions include Ipswich mucky peat found in the estuarine marshes and Freetown muck located in freshwater potholes and depressions; both of these soil types are poorly drained soils formed in organic deposits. Ten soil types were identified for the refuge using the most recent data available according to the Web Soil Survey (table 2.1; *http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm*; accessed September 2011).

Intertidal and subtidal bottom sediments occurring within the refuge Declaration of Taking boundary are predominantly classified as lithogenous, neritic marine deposits. These deposits consist of soil and rock, especially mineral quartz (SiO_2) particles, eroded and washed from continental land masses into the shallow seas along the inner continental shelf margins, and then sorted and transported by ocean waves currents. The Massachusetts Office of Coastal Zone Management maps show that the "generally sand" map unit predominates, with several smaller areas with finer texture mapped as "generally mud" within the Monomoy boundary (*http://maps.massgis.state.ma.us/map_ol/moris.php*; accessed March 2013).

Ocean energy, especially wave energy, repeatedly sorts and redistributes bottom sediments in shallow, nearshore areas; larger or coarser particle sizes are deposited closest to shore where the wave energy or water velocity is highest, while smaller or fine particle sizes are deposited farther from shore or shoreline areas protected from wave energy. "Sand" that typifies the Generally Sand CZM map unit has greater than 50 percent (by dry weight) of the particles falling in the 0.0625 to 2.00 mm size range using the modified Shepard ternary classification (Shepard 1954, Wentworth 1922) standard used by the USGS Sediment Lab at the Woods Hole Field Center (Poppe et al. 2000). "Mud" typifying the generally mud map unit has at least 50 percent (dry weight) of the particles falling below 0.0625 mm in size. Of 66 bottom sediment sample points in or around Monomoy included in the CZM data set, 85 percent (56) were classed as sand, 11 percent (7) as mud or clay, and 4 percent (3) as gravel deposits.

Table 2.1. Monomoy NWR Soil Types.

Soil Type	Percent Slope	Drainage Class	Parent Material	Landform
Berryland mucky loamy coarse sand	0 to 2	Very poorly drained	Loose sandy glaciofluvial deposits	Terraces
Carver coarse sand	3 to 8	Excessively drained	Sandy glaciofluvial deposits; loose sandy glaciofluvial deposits	Outwash plains
Carver coarse sand	8 to 15	Excessively drained	Sandy glaciofluvial deposits; loose sandy glaciofluvial deposits	Ice-contact slopes
Carver coarse sand	15 to 35	Excessively drained	Sandy glaciofluvial deposits; loose sandy glaciofluvial deposits	Ice-contact slopes
Freetown mucky peat	0 to 1	Very poorly drained	Highly decomposed herbaceous organic material	Bogs
Beaches			Reworked sandy and gravelly glaciofluvial deposits and/or reworked sandy and silty marine deposits	Not available
Hooksan sand, rolling		Excessively drained	Loose sandy eolian deposits	Barrier beaches
Hooksan sand, hilly		Excessively drained	Loose sandy eolian deposits	Barrier beaches
Udipsamments, smoothed		Not available	Sandy excavated or filled land	Not available
Ipswich, Pawcatuck, and Matunuck peats	0 to 1	Very poorly drained	Marine, partly-decomposed herbaceous organic material	Marshes

The sandflats of Monomoy are variably dynamic intertidal areas consisting of unconsolidated sediments primarily in the range of medium sand to fine sand with a small amount of silt and clay (Leavitt and Peters 2005). Grain sizes for sediment particles found in fine and medium sand generally falls within the range of 0.063 to 0.05 mm (Wentworth 1922). The flats are subjected to a moderate hydrodynamic flow regime, which results in a homogenous matrix of sand with minimal vertical stratigraphy (Leavitt and Peters 2005).

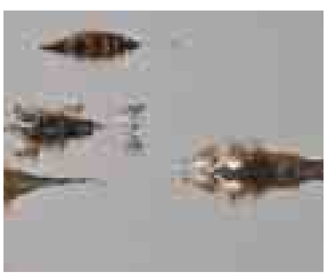
Refuge Vegetation

In the summer of 2010, NatureServe and the Sewall Company mapped vegetation communities on the refuge according to the National Vegetation Classification System (NVCS), which is the Federal standard. This system classifies vegetation on a national scale for the United States and is linked to the international vegetation classification. The NVCS provides a uniform name and description of vegetation communities found throughout the country and helps determine relative rarity. Based on their work in 2010, the NatureServe group generated a report summarizing a subset of the international classification standard covers of vegetation associations attributed to Monomoy NWR. Their report includes vegetation community element descriptions, element distributions along the North Atlantic coast and Northeast, and global rarity rankings of refuge communities (NatureServe 2010). Vegetation communities were described using a combination of 2010 aerial photography and ground-truthing by NatureServe, the Sewall Company, and refuge staff. Map 2.2 illustrates the distribution of different habitat cover types within the refuge and appendix C describes the type of habitats found on Monomoy NWR.

Submerged Aquatic Vegetation (SAV)

Submerged aquatic vegetation (SAV) is a critically important component of the aquatic environment in shallow coastal ecosystems, and its presence and robustness are indicators of good water quality. As far back as the 16th and 17th centuries, eelgrass was recognized for its value in sustaining waterfowl, providing habitat for fisheries and substrate for shellfish, and as a crucial component of sediment and shoreline stabilization. Humans harvested eelgrass for use as insulation, filler materials in bedding, and as compost for agriculture. Concern for the loss of these valuable services was magnified in the 1930s when a wasting disease decimated a large portion of the North Atlantic populations of eelgrass, including populations in Massachusetts (*http://www.mass.gov/dep/water/resources/eelpaper.htm;* accessed January 2013). Hotchkiss and Ekvall reported in 1929 that dense, extensive eelgrass beds were present north and west of Inward Point on the Common Flats, but the 1938 Griffith report described eelgrass beds in this same area as small and widely scattered.

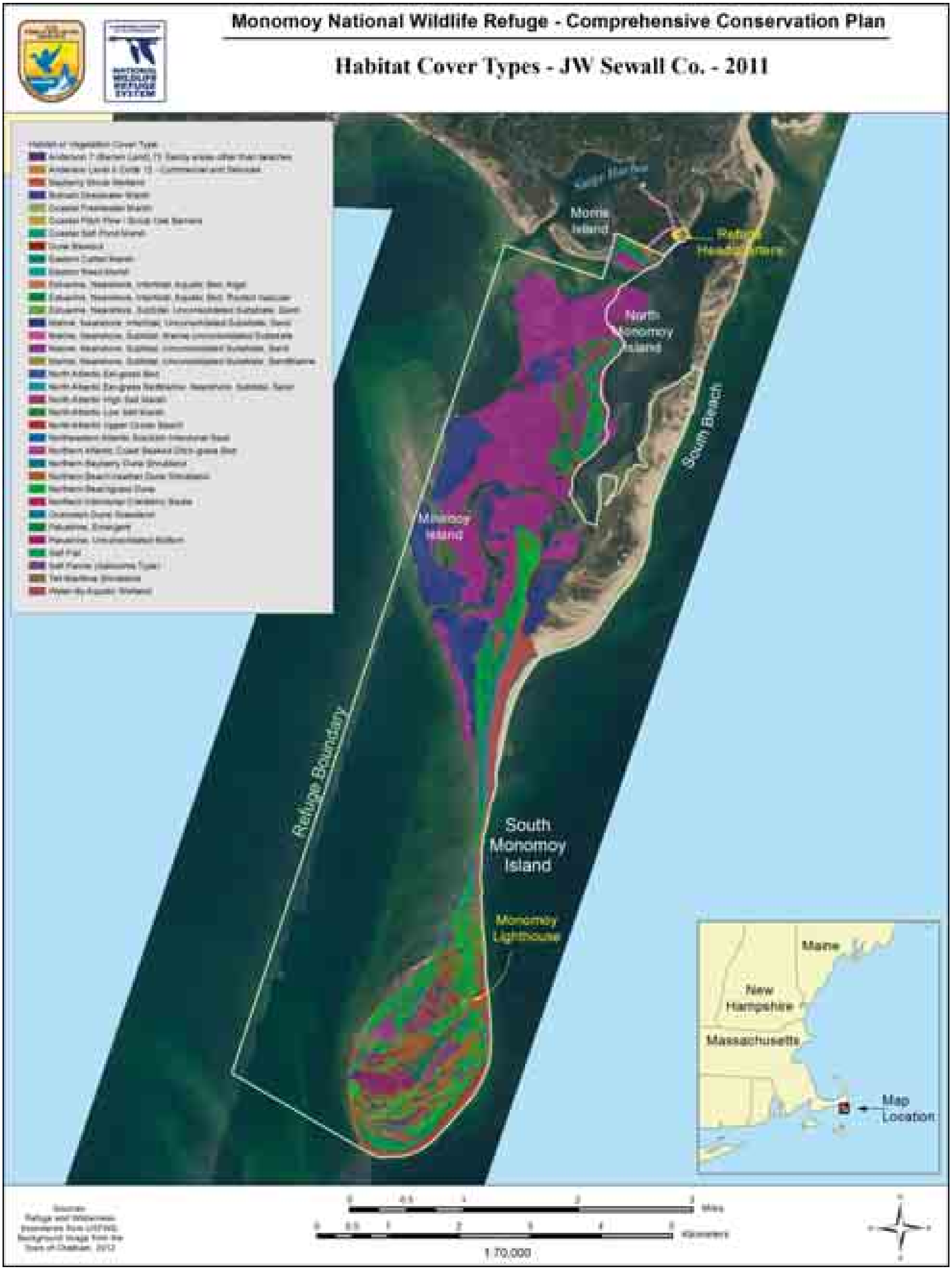
Results from Massachusetts studies and several related national and international research programs all point to the detrimental effects of nutrient enrichment and eutrophication in coastal waters, including large-scale declines of seagrass meadows. These studies suggested that seagrasses can potentially serve as sentinels of coastal environmental change associated with natural and anthropogenic disturbances. Appropriate monitoring of environmental quality and mapping the changes in seagrass distribution and abundance can provide scientists and managers with a sensitive tool for detecting and diagnosing environmental conditions responsible for the loss or gain of seagrasses.


Matt Poole/USFWS

Sandpipers

SAV can only thrive in shallow depths where light reaches the benthic zone. The rooted aquatic beds provide shelter and food for numerous aquatic invertebrates. SAV also recycles nutrients, helps to stabilize sediment, and oxygenates the water (Costello and Kenworthy 2011).

SAV composition varies with salinity. In Massachusetts, eelgrass along the coastline is the most common species. The MA DEP began a program in 1995 to track and monitor changes in existing eelgrass beds to provide an indicator of water quality. Eelgrass is an ideal species because it is sensitive to nitrogen loading and physical disturbance, and can be documented using aerial photos. Widgeon grass also forms beds in shallow sandy subtidal substrates in association with eelgrass and, like eelgrass, currently occurs less commonly than reported just prior to refuge establishment in 1944 (Hotchkiss and Ekvall 1929, Salyer 1938, Griffith 1938). The MA DEP SAV mapping effort and data set includes widgeon grass and other seagrasses detected in the "eelgrass" category.



Monomoy National Wildlife Refuge - Comprehensive Conservation Plan
Habitat Cover Types - JW Sewall Co. - 2011
Morris Island
Refuge Headquarters
North Monomoy Island
South Beach
Monomoy Island
Refuge Boundary
South Monomoy Island
Monomoy Lighthouse
Maine
New Hampshire
Massachusetts
Map Location
1:70,000

Morris Island and Stage Harbor embayments were two of the 46 embayments used by the MA DEP Eelgrass Mapping Project. Nantucket Sound open waters had the largest 1994 to 1996 baseline SAV area (4,201.56 of the Statewide 14,323.63 hectares) of the seven open water areas mapped. Open water seagrass beds such as those at Monomoy occur as mosaics of many small (less than 1 to 5 m^2) and large (greater than 5 to 10 m^2) patches due to their exposure to wave energy and currents, and were prone to underestimation. One of the most important services that open water SAV beds provide is a source of new propagules from their flowers and seeds. These become the new recruits critical for coastal embayment SAV bed recovery such as in Morris Island and Stage Harbor (Costello and Kenworthy 2011). Even deeper water SAV beds are vulnerable to damage from channel maintenance, beach renourishment, or fishing trawls or dredges.

Measurements were taken during three timeframes: 1994 to 1996 (Period 1), 2000 to 2002 (Period 2), and 2006 to 2007 (Period 3). It is our understanding that some areas within the Declaration of Taking and to the southway were mapped in 1995 and 2001. The Morris Island embayment site showed a net 8.8 percent decrease in SAV area, from 69.15 hectares (ha) down to 63.04, yielding a net -0.84 percent/year rate of decline over the entire analysis period. All of this decrease occurred between Periods 1 and 2, when the rate of decline was -3.02 percent/year. But this trend reversed to a +1.78 percent/year increase between Periods 2 and 3. The Stage Harbor embayment showed a 40.3 percent decrease in acreage, from 105.62 ha down to 63.10 ha, for a net -4.68 percent/year rate of decline for the entire analysis period. As with the Morris Island embayment, most the Stage Harbor embayment SAV area decline occurred during Periods 1 and 2 when the rate of decline was a sharp -8 percent/year, before slowing (improving) to -0.71 percent/year between Periods 2 and 3 (Costello and Kenworthy 2011). The median rate of decline for the South Shore Cape Cod embayments region was -3.39 percent/year (-7.73 percent/year between Periods 1 and 2, slowing to -1.21 percent/year between Periods 2 and 3), which is slightly less than the -3.7 percent/year recently reported global rate of decline for seagrasses (Waycott et al. 2009).

Conservation measures implemented for the region appear to have slowed the rate of seagrass loss, and may even be reversing an alarming regional and Statewide decline in SAV bed area for the embayments nearest to Monomoy NWR open waters, but for which SAV data are currently limited. We are stepping up our efforts to monitor seagrass loss and plan to undertake restoration projects with our partners.

Federally Listed Endangered or Threatened Species

Three federally listed species are known to breed on Monomoy NWR: piping plover (threatened), roseate tern (endangered), and northeastern beach tiger beetle (threatened). The following paragraphs describe the presence of these three species on Monomoy NWR. A total of 39 species known to use the refuge are on the Massachusetts State list of endangered and threatened wildlife. See appendix A for a complete list of State-listed and federally listed species present on the refuge.

Piping Plover

On January 10, 1986, the Service listed the piping plover as endangered (Great Lakes population) and threatened (Atlantic coast and Great Plains populations) under the ESA. Management and protection of piping plovers is one of the priority programs for the refuge. Many other avian species benefit from piping plover management, especially the least tern and the American oystercatcher.

Early documentation of piping plover on the refuge are scattered, but the species was nesting on the refuge prior to listing. A former refuge manager, Edwin Chandler, documented in his annual narratives seeing plover chicks as early as 1953, even putting a plover chick photo in his May to August 1954 narrative.

Griscom and Snyder (1955) reported 15 pairs of piping plovers on Monomoy NWR in 1955. Beginning in 1983, piping plovers were counted and monitored annually on Monomoy NWR. In February 1988, a master plan (USFWS 1988) was completed for Monomoy NWR, which stipulated that all piping plover nesting sites be closed seasonally to the public. Starting that year, these nesting sites were closed to the public from April through August to help protect the birds, their nests, and their habitat on the refuge, and that effort has continued to the present time. In recent years, the refuge has had a low of four nesting pairs of piping plover in 1993, with recorded numbers greatly expanding after the initiation of the avian diversity program in 1996 (although part of this increase may represent increased monitoring efforts). While plovers successfully nest on Monomoy NWR, current numbers (39 pairs in 2012) are generally lower than the potential capacity estimated for Monomoy NWR (94 pairs; USFWS 1996b; see map 2.3). Table 2.2 shows the number of nesting piping plover pairs and productivity tabulated over the last 16 years (1996 to 2012).

Table 2.2. Piping Plover Nesting and Productivity at Monomoy NWR (1996 to 2012).

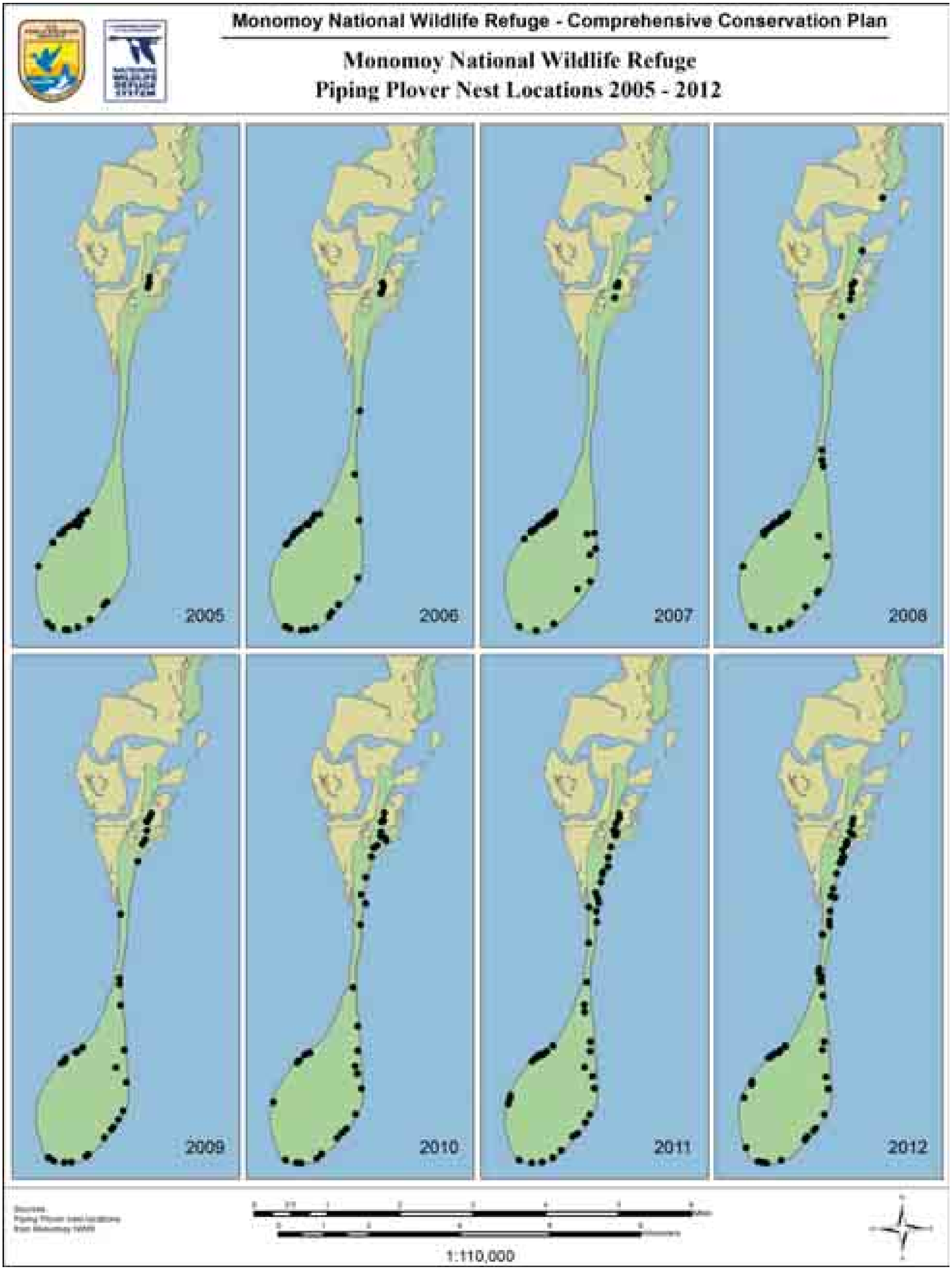
Year	Number of Nesting Pairs*; Productivity (p)**				Overall Productivity
	North Monomoy Island	South Monomoy	Minimoy Island	Total	
1996	1; p = 0.00	19; p = 2.21	N/A***	20	2.10
1997****	1	25	N/A	26	1.65
1998	1; p = 4.00	26; p = 0.69	N/A	27	0.81
1999	1; p = 0.75	26; p = 1.35	N/A	27	1.41
2000	2; p = 1.50	28; p = 1.32	N/A	31	1.33
2001	2; p = 2.00	27; p = 1.89	N/A	29	1.90
2002	2; p = 2.00	32; p = 0.94	N/A	34	1.00
2003	2; p = 2.50	31; p = 1.42	1; p = 1.00	34	1.47
2004	1; p = 3.00	24; p = 1.29	2; p = 0.00	27	1.26
2005	1; p = 0.00	18; p = 0.72	0; p = 0.00	19	0.68
2006	1; p = 4.00	24; p = 0.88	0; p = 0.00	25	1.00
2007	1; p = 3.00	19; p = 0.74	0; p = 0.00	20	0.85
2008	1; p = 0.00	26; p = 1.04	0; p = 0.00	27	1.00
2009	1; p = 0.00	31; p = 0.74	1; p = 0.00	33	0.70
2010	0; p = 0.00	33; p = 2.33	0; p = 0.00	33	2.33
2011	0; p = 0.00	41; p = 1.12	0; p = 0.00	41	1.12
2012	0; p = 0.00	39; p = 1.38	0; p = 0.00	39	1.38

**Pair numbers reflect the minimum total count for each year, and may not be the same as the index count reported to the State annually. The index count only reflects pairs present during the census window.*

***Productivity and overall productivity represent the minimum number of chicks fledged per nesting pair on the refuge.*

****The landform referred to as Minimoy Island may have existed as early as 2001 but was not surveyed until 2003 (Koch 2011 personal comment).*

*****Productivity by island is unknown for this year, but overall productivity is given as reported in Megyesi 1998.*


Monomoy National Wildlife Refuge - Comprehensive Conservation Plan
Monomoy National Wildlife Refuge
Piping Plover Nest Locations 2005 - 2012
2005
2006
2007
2008
2009
2010
2011
2012
1:110,000

Piping plover recovery efforts on the refuge have corresponded closely to management actions recommended in the Piping Plover Recovery Plan (USFWS 1996a) and revisions (USFWS 2009a). Refuge staff install symbolic fencing (sign posts with "area closed" and "beach closed" informational signs; refer to glossary) around nest sites to limit access to the area. While there are many miles of nesting habitat, the refuge is currently supporting fewer pairs of plovers than it might sustain based on habitat availability. Seasonal closures for piping plovers are based on the level of disturbance in a given area and the location of active nesting and foraging sites. Closures currently do not include all available habitat, though the refuge is moving toward increasing closures to incorporate all available high quality nesting habitat as staff time allows. If the refuge were to see an increase in public use and human disturbance, all available nesting, foraging, and staging habitat would be closed to ensure that valuable habitat was preserved. At current levels of public use, this is not a concern. The purpose of symbolic closures is to keep visitors away from nesting sites and limit disturbance to incubating adults. Predator exclosures are also placed around nests, when appropriate, to help prevent avian and mammalian predation. The staff conducts annual censuses of breeding piping plovers and monitors their productivity to determine the number of chicks fledged per pair. Reducing predation, including removal of predators, is an important action identified in the Piping Plover Recovery Plan. Predator management is an integral part of piping plover recovery efforts on the refuge and will continue into the future. Avian predators (e.g., herring and great black-backed gulls) and mammalian predators (e.g., coyote, opossum, skunk, raccoon) have been documented as responsible for nest loss.

Roseate Tern

On November 2, 1987, the Service listed the northeastern breeding population of the roseate tern as endangered. Monomoy NWR is an important nesting site for this species.

Massachusetts tern populations, including roseate and common terns, were abundant during the mid-nineteenth century, with hundreds of thousands of pairs reportedly nesting on Muskeget Island alone and several smaller colonies located on the mainland of Cape Cod that included colonies in Chatham and Wellfleet (Nisbet 1973). By the late 1800s, due to a combination of shooting and egging for food and bait, and feather collection for the millinery trade, numbers of terns nesting on Cape Cod and the islands had dramatically declined to estimates of between 5 and 10 thousand pairs. Conservation legislation in the early 1900s provided enhanced protection from human persecution and Massachusetts tern numbers rose to between 20 and 40 thousand in the State (Nisbet 1973). Beginning in the 1930s, gull populations began to expand and their populations rapidly increased in part due to the accessibility of food from open garbage dumps and discarded items from the fishing industry (MDFW 2013). Expanding gull populations soon caused tern numbers to again decrease significantly by gulls taking over nesting sites and causing intense predation on existing tern colonies. By 1977, loss of available habitat and predation brought tern numbers in Massachusetts to their lowest on record. Since 1977, cooperative efforts by Federal, State, and private conservation partners have reversed this decline for common terns, which have seen substantial population growth in recent decades. Roseate terns, however, have not had the same success. Initially, pair numbers in the State of Massachusetts increased from the 1977 low, but by 1979 began to decrease. The population experienced a series of increases and decreases over the last three decades, but is currently once again approaching the low population levels of the mid-1970s (Mostello 2012).

The first 20th century report of common and roseate terns nesting on Monomoy NWR occurred in 1961 (Nisbet 1980). The tern colony increased rapidly to 2,000 pairs by 1963, and from 1963 to 1984, Monomoy supported one of the largest tern colonies in the Northeast. Several hundred pairs of roseate terns were found nesting on Monomoy NWR during these years. In 1978, concern heightened when tern reproductive success began to decline on the refuge. The numbers of nesting roseate terns began decreasing in the early 1980s and eventually declined to 1 nesting pair in 1988, down from 400 nesting pairs in 1980.

The roseate tern was listed as an endangered species because of the significant reduction in nesting sites: 30 major colonies were abandoned or experienced substantial declines between 1920 and 1979. By 1997, Cape Cod, Nantucket, and Martha's Vineyard had only 20 nesting pairs—significantly low numbers when compared to the 105 pairs in 1999. Due to inconsistent tern surveys and monitoring protocols prior to 1987, it is unclear whether the population is now stable or declining (USFWS 1998a). In 2002, Monomoy NWR, though considered a minor site, was one of only three sites in Massachusetts supporting nesting roseate terns. One of the recovery criteria in the Roseate Tern Recovery Plan calls for a "minimum of six large colonies (greater than or equal to 200 pairs) with high productivity (greater than or equal to within the tern's current geographic distribution) (USFWS 1989, USFWS 1998a).

The potential for a large roseate tern colony at Monomoy NWR is great, given the large common tern colony, which has similar nesting requirements. In general, common terns prefer slightly less dense vegetation, approximately 30 percent vegetation with 70 percent open sand, than do roseate terns. Roseate terns tend to prefer the opposite configuration, with about 70 percent vegetation to 30 percent open (Koch 2013 personal comment). Monomoy NWR has the potential to support a large nesting site again if we can control predation and are able to successfully provide the optimal habitat. All roseate terns in the Northeast nest in close association with large, productive common tern colonies; one of the largest of these is on the refuge (USFWS 1998a).

As a baseline for setting future population goals, the Roseate Tern Recovery Plan sets the productivity level for roseate tern at one fledged chick per nesting pair (USFWS 1998a). Roseate terns use the refuge during the breeding and post-breeding seasons. In 1998 and 1999, more than 20 pairs of roseate terns nested on South Monomoy with good to average productivity, but in 2000 nesting numbers declined dramatically. The decline in numbers observed in 2000 may have been due to predator presence; a great horned owl was present in the colony early in the season. As a result, the tern colony was abandoned every night from May 11 to June 14; for a total of 3 weeks there was full abandonment, with partial abandonment for 1 to 2 weeks thereafter. Roseate terns are generally more skittish than common terns, and may have had a hard time establishing territories due to the already existing common tern territories in this same area. Another possible explanation for the decline may be the loss of traditional nesting areas. It's possible these birds nested on Minimoy Island in 2002, but this site was not surveyed until 2003.

From 2003 to 2008, Minimoy Island hosted between 10 and 43 pairs of roseate terns. Erosion of the western side of Minimoy Island in recent years resulted in decreased habitat for roseate terns, until virtually no suitable habitat was available by 2009. Beginning in 2009, refuge staff attempted to attract roseate terns back to the main common tern nesting colony on South Monomoy by placing nesting structures, decoys, and a sound system in suitable habitat. In 2009, no roseate terns nested on the refuge, but in 2010, roseate terns returned to the nesting area on South Monomoy. Refuge staff conduct annual censuses of roseate terns, as well as productivity monitoring (to determine number of chicks fledged per nest), banding of adults and juveniles, post-breeding staging counts, and habitat enhancement (e.g., use of nesting structures). Table 2.3 shows the number of nesting pairs and productivity of roseate terns at the refuge over the last 15 years (1996 to 2012).

Predator management is an important part of the roseate and common tern restoration efforts on South Monomoy. The presence of a single mammalian predator (e.g., coyote, skunk, and raccoon) or avian predator (e.g., great horned owl, black-crowned night-heron) in a tern colony can decrease productivity or cause the terns to abandon the site entirely. Predation can limit the distribution and abundance of breeding terns and their reproductive success (Kress and Hall 2004, USFWS 2010a). Habitat management to benefit nesting seabirds and shorebirds currently includes vegetation management based on prescribed burns to remove grasses and duff.

Table 2.3. Roseate Tern Nesting and Productivity at Monomoy NWR (1996 to 2012).

	Number of Nesting Pairs; Productivity (p)						
	South Monomoy			Minimoy Island**			Refugewide Total Count
	A Count	B Count*	Total Count	A Count	B Count	Total Count	
1996	6; p = 0.00	0; p = 0.00	6	N/A	N/A	N/A	6
1997	0; p = 0.00	1; p = 0.00	1	N/A	N/A	N/A	1
1998	22; p = 0.38–0.97	17-20; p = 0.46-0.93	39-42	N/A	N/A	N/A	39-42
1999	27; p = 0.90	5-14; p = 0.57-0.29	32-41	N/A	N/A	N/A	32-41
2000	3; p = 1.00	0; p = 0.00	3	N/A	N/A	N/A	3
2001	6; p = 0.33	0; p = 0.00	6	N/A	N/A	N/A	6
2002	3; p = 1.00	0; p = 0.00	3	N/A	N/A	N/A	3
2003	3; p = 1.33	0; p = 0.00	3	10; p = 1.50	5; p = 0.40	15	18
2004	1; p = 1.00	0; p = 0.00	1	24; p = 1.13	2; p = 0.50	26	27
2005	1; p = 0	0; p = 0.00	1	22; p = 1.23	1; p = 1.00	23	24
2006	2; p = 0.50	0; p = 0.00	2	24; p = 1.00	3; p = 0.67	27	29
2007	2; p = 1.00	0; p = 0.00	2	43; = 1.00	13; p = 0.13	56	58
2008	0; p = 0.00	0; p = 0.00	0	30; p = 1.00	7; p = 0.00	37	37
2008	0; p = 0.00	0; p = 0.00	0	30; p = 1.00	7; p = 0.00	37	37
2009	0; p = 0.00	0; p = 0.00	0	0; p = 0.00	0; p = 0.00	0	0
2010	7; p = 1.14	0; p = 0.00	7	1; p = 2.00	0; p = 0.00	1	9
2011	7; p = 0.29	0; p = 0.00	7	3; p = 1.67	2; p = 0.00	5	12
2012	1; p = 2.00	1; p = 0.00	2	6; p = 0.50	0; p = 0.00	6	8

**Pairs identified during the B Count may have nested during the A Count at other sites. Since not all roseate terns are banded, we can never be certain that B nests are new pairs.*

***The landform referred to as Minimoy Island may have existed as early as 2001 but was not surveyed until 2003 (Koch 2011 personal comment).*

Northeastern Beach Tiger Beetle

In August of 1990, the Service listed the northeastern beach tiger beetle as threatened. This tiger beetle occurred historically "in great swarms" on beaches along the Atlantic coast from Cape Cod to central New Jersey, and along Chesapeake Bay beaches in Maryland and Virginia. In 1994, only two small populations remained on the Atlantic coast.

Currently northeastern beach tiger beetles can be found at two sites north of the Chesapeake Bay in Massachusetts: one on the south shore of Martha's

Vineyard and one on South Monomoy and Nauset/South Beach in Chatham, MA. The successful establishment of a northeastern beach tiger beetle population is believed to require a long stretch of relatively wide beach with no ORVs and relatively light recreational impacts. It is difficult to find these characteristics along the Massachusetts coast.

On beaches where they occur, adult northeastern beach tiger beetles are most active on warm, sunny days along the water's edge, where they are commonly seen feeding, mating, or basking (thermoregulation). The number of adult beetles active on rainy or cool, cloudy days is very low, probably because the beetles need to maintain high body temperatures for maximal predatory activity. Adults tend to be concentrated in wider sections of beach, and occur in smaller numbers or may even be absent from nearby areas of narrow beach (USFWS 1994).

Larvae occur in a relatively narrow band of the upper intertidal to high drift zone, but may relocate their burrows throughout their development to adapt to environmental and seasonal changes in the beach ecosystem (USFWS 1994). The larval stage of this beetle lasts approximately 2 years and each population consists of two cohorts: adults that emerge in odd years and adults that emerge in even years. Given that there are two distinct cohorts at each site, it is common that the population size varies from year to year, as does the exact location of spawning adult beetles. Cohort success may also depend on annual variation in weather and the ability of the larvae to survive winter storms and other natural and tidal fluctuations.

Searches on Monomoy NWR in the 1980s failed to locate the northeastern beach tiger beetle, but the structure of the habitat seemed favorable. Federal ownership, the occurrence of historic collection records labeled "Chatham" (the town in which the refuge is located), and the desire of State wildlife officials to retain Massachusetts beetles within the State all combined to make Monomoy the leading candidate as an introduction site. Meetings held in the winter of 1997 discussed translocation of beetles, though, for a variety of reasons, this was not feasible in 1998. Translocations were attempted in 1999, but weather was not favorable and larvae could not be found at the donor site (Nothnagle 2000). The first larval beetle transplant occurred in May 2000, when 23 third instar tiger beetle larvae were moved from Martha's Vineyard to the refuge. Adult beetles generally emerge from their sandy burrows in July and August, and that year, five adult tiger beetles emerged and were found on the refuge. Introduction continued to occur from 2001 through 2003 with 34, 33, and 23 larvae transplanted, respectively. In 2001, approximately 24 adults were found; in 2002, 27 adults were found; and in 2003, 19 adults were found. Table 2.4 shows the number of northeastern beach tiger beetle larvae translocated and the number of adults captured and marked on the refuge between 2000 and 2012.

Since 2004, tiger beetle larvae have not been transferred to Monomoy NWR due to logistical challenges and habitat loss on the source beach at Martha's Vineyard. However, through continued adult tiger beetle monitoring, the annual presence of tiger beetles has been documented on the refuge. Annual monitoring confirms successful survival and production of tiger beetles through all stages of life, and gives a firm indication of a new self-sustaining population at Monomoy NWR. In addition to monitoring of adult tiger beetles, tiger beetle distribution has been mapped and larval habitat surveys have been conducted from 2008 through 2012 (map 2.4). The November 2006 land bridge joining Nauset/South Beach and Monomoy NWR developed at the center of the northeastern beach tiger beetle habitat. Currently, adults and larvae occupy an area that spans several miles on the refuge and Nauset/South Beach. The Town of Chatham has been supportive of the refuge staff's work concerning the beetles.


Monomoy National Wildlife Refuge - Comprehensive Conservation Plan
Northeastern Beach Tiger Beetle Distribution
Morris Island
Refuge Headquarters
North Monomoy Island
Minimoy Island
South Beach
Refuge Boundary
South Monomoy Island
Monomoy Lighthouse
2000 Larval Reintroduction
2012 Outliers
2011 Outliers
Tiger Beetle Main Habitat
1:70,000

Table 2.4. Northeastern Beach Tiger Beetle Translocated and Marked at Monomoy NWR (2000 to 2012).

Year	Number of Larvae (Translocated)	Number of Beetles Marked	High Count
2000	23	6	6
2001	34	24	24
2002	33	27	27
2003	23	19	19
2004	0	26	26
2005	0	16	16
2006	0	65	75
2007	0	19	19
2008	0	179	180
2009	0	102	102
2010*	0	90	571**
2011*	0	100	375**
2012*	0	40	1228**

**Tiger beetle populations on the refuge became too large to capture all adults for marking and instead a subset was marked to approximate the population and high counts were taken on most survey days.*

***Population estimate is approximately 30 to 40 percent of the highest or peak count in a given year. This was determined using program Mark (Kapitulik 2011 personal comment).*

Birds

This section describes migratory bird species, including waterfowl, shorebirds, seabirds, other colonial nesting waterbirds, raptors, and other birds of conservation concern that are found on the refuge.

Migratory Birds

Refer to appendix A for a complete list of birds present on the refuge.

Red Knot

The red knot is a candidate for Federal protection under the Endangered Species Act. These birds undertake one of the longest migrations known, traveling from their furthest wintering ground at the tip of South America to their Arctic breeding grounds and back again each year, an estimated 16,000-mile round trip. Their migration also includes some of the longest non-stop flights in the bird world, an estimated 5,000 miles over a 6-day period (Niles et al. 2010). Protection of breeding, migration, and wintering habitat is critical to this species' recovery (Niles et al. 2008). Delaware Bay, arguably the most important stopover in the Western Hemisphere, supporting thousands of red knots especially during the northward migration, has been the focus of much research in the last two decades.

Southeastern Massachusetts, and Monomoy Refuge in particular, are likely to provide one of the most important sites for adult and juvenile red knots during their southward migration (Koch and Paton 2009, Harrington et al. 2010a, Harrington et al. 2010b). Research has shown that this region supports red knots bound for different winter destinations. North American wintering birds exhibit different migration chronology, flight feather molt, and even foraging habits than South American wintering birds (Harrington et al. 2010b). In 2009, refuge staff began partnering with the Conserve Wildlife Foundation of New Jersey and others to cannon-net shorebirds on Monomoy Refuge during southward migration. Refuge staff were interested in capturing shorebirds to test for avian influenza (see the shorebird section for more details), but through the partnership were also able to start deploying geolocators on red knots to learn more about migration, stopover, and wintering sites. Geolocators are global location sensors that record changes in ambient light levels. This information can then be used to estimate sunrise and sunset, allowing for an estimated calculation of latitude and longitude (Nisbet et al. 2011). In 2009 and 2010, more than 50 data loggers were deployed on adult and sub-adult red knots passing through Monomoy Refuge and surrounding beaches. During this time, geolocators were also deployed at Delaware Bay and other sites. Preliminary results from geolocators retrieved from North American wintering red knots (recovered at Monomoy refuge and other participating sites) have confirmed the importance of Monomoy Refuge as a stopover site; North American wintering red knots spent 58 to 75 days here before migrating south in November. This work has also confirmed the importance of Florida as a wintering site, and has raised the awareness of occupied sites in North and South Carolina, Haiti, Columbia, and Cuba (Burger et al. 2012).

While we are beginning to learn more about migration, stopover, and wintering sites of adults, currently there is little information on migration routes, and no information on wintering sites of juvenile red knots. Survival of juveniles during their first winter could be a key factor in population dynamics. Knowledge of migration and wintering sites would allow researchers to assess habitat condition, work toward minimizing disturbance and other limiting factors, and better understand first-year survival. As a result, we have continued working with partners and began placing geolocators on juvenile red knots (54) migrating through Chatham in 2011. We continued this work in 2012, but very few juveniles were observed in the area in 2012 (likely due to a poor breeding season) and only 11 juvenile red knots were captured and outfitted with geolocators.

While only a subset of captured red knots at Monomoy Refuge are outfitted with geolocators, all red knots receive a unique 3-digit alpha-numeric lime green flag, which can be read from a distance by researchers, bird watchers, and the general public. Resightings of banded birds are incorporated into a collaborative resighting database, (available online at: *http://www.bandedbirds.org*), which allows all partners to benefit from this information. The compilation of banding and resighting data in one central place, collected from participants throughout the flyway, increases the power of these data and allows for a greater understanding of this species' migration paths and habitat use. Refuge staff have supported and participated in intensive resighting surveys of red knots in the Chatham area since 2009 (resighting surveys were also occurring in previous years without USWFS support). From 2009 to 2012, more than 8,500 red knots with unique alpha-numeric flags, or flag and color band combinations, have been observed for inclusion in the *www.bandedbirds.org* database.

Waterfowl and Waterbirds

Established for the protection and perpetuation of migratory waterfowl (Bureau of Biological Survey 1938), Monomoy NWR is one of the sites in Massachusetts with the largest diversity of breeding waterfowl species. Brood surveys done sporadically over the years have found the following waterfowl species breeding on the refuge: mallard, Canada goose, American black duck, gadwall, green-winged teal, American wigeon, northern pintail, northern shoveler, blue-winged teal, and ruddy duck (USFWS unpublished data). Many of these species nest in other locations in Massachusetts; however, South Monomoy's freshwater ponds and marshes provide important migratory stopover and wintering habitat for waterfowl. Redhead, bufflehead, common goldeneye, hooded merganser, lesser scaup, greater scaup, ring-necked duck, canvasback, pied-billed grebe, and American coot have also been found to use Monomoy's freshwater ponds and marshes as migratory stopovers (Nikula 2011 personal communication).

The shellfish-rich waters around Monomoy NWR attract thousands of migrating and wintering scoter, common eider, long-tailed duck, and red-breasted merganser. Extensive eelgrass and sea lettuce beds in the nearshore waters of Monomoy Refuge provide winter food for wintering and migrating Atlantic brant. Midwinter waterfowl surveys are conducted annually coast-wide and include waters surrounding Monomoy Refuge. Table 2.5 below includes counts of waterfowl (except mute swans) from 2005 to 2012 for waters surrounding Monomoy NWR, as well as all of coastal Massachusetts and offshore islands (in parentheses).

Table 2.5. Midwinter Waterfowl Surveys (January) for Waters Surrounding Monomoy NWR and Coastwide (in parentheses) (2005 to 2012).*

Year	American Black Duck	Atlantic Brant	Bufflehead	Canada Goose	Common Eider	Goldeneye	Long-tailed Duck	Mallard	Merganser	Scaup	Scoter
2005	414	0	52	78	1033	1	31	0	8	0	19
2006	683	52	64	293	1746	67	67	2	40	0	0
2007	497 (20280)	0 (1417)	133 (7663)	120 (11144)	25859 (37831)	0 (1585)	0 (168)	0 (5324)	61 (8125)	0 (1161)	623 (8707)
2008	795 (18346)	0 (2272)	18 (6116)	433 (10316)	578 (78856)	16 (4659)	0 (273)	0 (4629)	51 (3676)	0 (3741)	8 (21654)
2009	103 (18877)	32 (1908)	28 (9312)	32 (11105)	6584 (65676)	0 (1037)	21 (1437)	0 (3288)	52 (4316)	18 (3524)	1 (12337)
2010	522 (18599)	0 (1572)	70 (5790)	126 (8229)	108 (46097)	0 (1092)	0 (239)	2 (2452)	14 (8940)	0 (4273)	2 (5450)
2011	245 (16589)	0 (1213)	2 (2032)	211 (11299)	25014 (46198)	0 (835)	0 (148)	0 (1808)	4 (4643)	0 (2382)	26 (4817)
2012	906 (30591)	40 (1550)	0 (3860)	580 (16579)	603 (41076)	5 (5587)	5 (698)	0 (3153)	51 (15025)	0 (4534)	333 (7111)

Source: Klimstra 2012

* *Species that were not recorded at Monomoy NWR during any year from 2005 to 2012, but were recorded elsewhere in Massachusetts, are not included in this table. Data obtained from midwinter waterfowl survey records, USFWS. Information about these surveys can be found at: https://migbirdapps.fws.gov/mbdc/databases/mwi/aboutmwi_allflyways.htm*; accessed January 2013.

Migrating Shorebirds

A 1984 report of the International Shorebird Survey cites Monomoy NWR among the five most important of 454 autumn shorebird stopover areas studied east of the Rocky Mountains (Harrington 1984 as cited in USFWS 1988). In March 1999, the refuge was designated as a WHSRN regional site based on a maximum one-day count of approximately 21,000 shorebirds (WHSRN 2006; see

USFWS

Service employee holding a tern

WHSRN section for details). In particular, the refuge provides habitat for significant numbers of species that are listed as highly imperiled or high concern by the U.S. Shorebird Conservation Plan (Brown et al. 2001), as highest or high priority within Bird Conservation Region 30 (ACJV 2005; *http://www.acjv.org/bird_conservation_regions.htm*; accessed January 2013), New England/Mid Atlantic coast, and as birds of conservation concern in Region 5 (Maine to Virginia; USFWS 2008a) by the U.S. Fish and Wildlife Service.

Monomoy NWR is a favored stopover site for southward migrating shorebirds because of its location in the landscape and critical foraging habitats (Koch and Paton 2009). During northward migration, many shorebirds traveling north along the east coast of the United States stop at Delaware Bay and then migrate nonstop to sites in Canada, thus bypassing New England completely. However, during southward migration, many shorebirds use more easterly migratory routes back to their non-breeding areas, thus traveling through more northerly areas of the Atlantic coast (Morrison 1984, Myers et al. 1987). The Cape Cod region of Massachusetts protrudes into the Atlantic Ocean, attracting southbound shorebirds following a more easterly path. Habitats at Monomoy Refuge are dynamic, with tides and storms continually moving and depositing sediments. The combination of invertebrate-rich intertidal mudflats and bordering salt marsh and upper beach provides foraging and roosting habitats (Koch and Paton 2009).

Most migratory shorebirds that use the refuge as a stopover site forage during low tides on the expansive flats and salt marsh habitat surrounding the islands, and move to other areas such as Nauset/South Beach to roost at high tides. Shorebirds that remain on the refuge during high tides in recent years have roosted in the higher elevations of salt marsh and beach berm/dunes on the northeast and south sides of Minimoy Island, the western side of North Monomoy Island, and on and around the land connection between Nauset/South Beach and South Monomoy (Koch and Paton, in prep). Most salt marsh habitat on the refuge is closed to public access from April through at least July, and sometimes through August, to protect nesting shorebirds and waterbirds. The majority of flats where shorebirds forage and beach areas where shorebirds roost are mostly open to public access. However, because most of the habitats used by shorebirds are not easily reached without a boat, human disturbance is relatively low compared to other sites in Massachusetts (Koch and Paton 2009).

Standardized shorebird surveys were conducted on one-hectare (1-ha) plots throughout the majority of the intertidal habitat on Monomoy NWR from April to October (2006) and November (2007) to characterize seasonal species diversity and abundance. Table 2.6 summarizes relative abundance of all documented shorebird species during 2006 and 2007, using shorebird-use-days; one shorebird-use-day equals one individual shorebird detected within a 1-ha plot during a survey. We detected 22 shorebird species during surveys (21 in 2006 and 20 in 2007) and eight additional species outside of our surveys. Semipalmated sandpipers, sanderlings, black-bellied plovers, dunlin, and short-billed dowitchers combined accounted for more than 75 percent of all shorebirds counted. Nine species had a combined 2-year total of 1,000 shorebird-use-days or more (Koch and Paton 2009).

Table 2.6. Conservation Priority and Abundance of all Shorebird Species Observed in Survey Plots at Monomoy NWR in 2006 and 2007.

Species	Conservation priority[a]	Total shorebird-use-days[b]	High count ha^{-1} [c]	Mean (SE) shorebird-use-days ha^{-1} [c]
Black-bellied plover	H, M	10,798	146	2.7 (0.1)
American golden-plover	H	2	1	< 0.1 (0.0)
Semipalmated plover	M	6,369	200	1.6 (0.1)
Piping plover	HH	90	13	< 0.1 (0.0)
American oystercatcher	HH, BCC	354	15	0.1 (0.0)
Greater yellowlegs	H	661	70	0.2 (0.0)
Lesser yellowlegs	BCC	209	37	0.1 (0.0)
Willet	H	696	9	0.2 (0.0)
Whimbrel	HH, BCC, M	15	4	< 0.1 (0.0)
Hudsonian godwit	BCC, H	141	16	< 0.1 (0.0)
Marbled godwit	BCC, H	10	4	< 0.1 (0.0)
Ruddy turnstone	HH, M	1,392	122	0.3 (0.0)
Red knot	HH, BCC, M	3,164	137	0.8 (0.1)
Sanderling	HH, M	14,896	450	3.7 (0.2)
Semipalmated sandpiper	H, BCC, M	19,365	512	4.9 (0.4)
Western sandpiper		6	3	< 0.1 (0.0)
Least sandpiper		2,684	97	0.7 (0.1)
White-rumped sandpiper	H, M	424	61	0.1 (0.0)
Pectoral sandpiper		12	7	< 0.1 (0.0)
Dunlin	H, M	8,106	138	2.0 (0.2)
Short-billed dowitcher	H, BCC, M	7,499	277	1.9 (0.1)
Long-billed dowitcher		8	2	< 0.1
TOTAL		**76,901**	**579**	**19.3 (0.7)**

[a] *Additional shorebird species detected outside of plots include: killdeer, solitary sandpiper, spotted sandpiper, upland sandpiper, curlew sandpiper, stilt sandpiper, buff-breasted sandpiper, and red-necked phalarope.*

[b] *Species prioritized as Highest Priority (HH) and High Priority (H) for BCR 30 (ACJV 2005), species listed as a Bird of Conservation Concern (BCC) for U.S. Fish and Wildlife Service Region 5 (Maine to Virginia; USFWS 2008) or species that occur in high concentrations on the northern Atlantic U.S. Coast and for which this area has been identified as extremely important during migration (M) relative to other areas by the U.S. Shorebird Conservation Plan (Brown et al. 2001).*

[c] *Cumulative total of birds counted; does not account for individual birds that may have been counted on multiple days. Both years combined.*

Figure 2.5 shows migration chronology of shorebirds on Monomoy NWR. Seasonal variation in species-richness was similar between years and was higher during southward migration (especially during 15 July to 31 August) compared to northward migration, and was lowest during June in both years (Koch and Paton 2009).

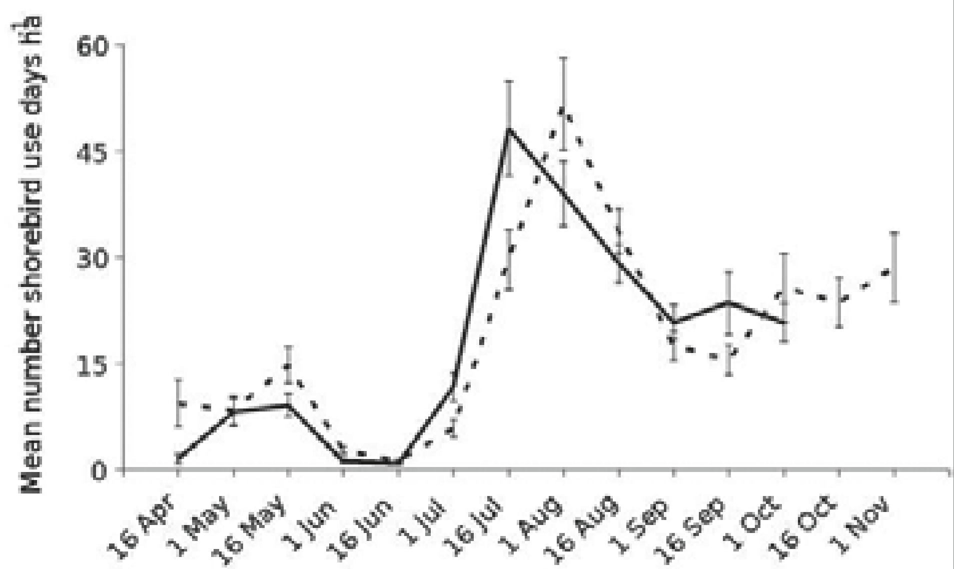


Figure 2.5. Seasonal Variation in Mean (+ or – 1SE) Shorebird-use-days for all Shorebirds Based on Semi-monthly Time Intervals at Monomoy NWR. Solid line represents 2006 and dashed line represents 2007.

All species, except ruddy turnstone, were more common during southward migration compared to northward migration (figure 2.6). Of the eight species that were more common during southward migration, we observed two different patterns of migration. During southward migration, semipalmated plover, semipalmated sandpiper, least sandpiper, and short-billed dowitcher exhibited rather short, distinct windows of migration and little annual variation in migration chronology (except for semipalmated sandpiper). These species were also completely absent or rare during northward migration. In contrast, black-bellied plover, red knot, sanderling, and dunlin had a more protracted southward migration, and these species (except for red knot) were also present in substantial numbers during northward migration. The observed increase in shorebird-use-days during southward migration may be partially attributed to an influx of juveniles, but is more likely explained by differences in species-specific northward and southward migration pathways. Many species of New World shorebirds exhibit an elliptical migration, travelling along more easterly pathways during southward migration (Morrison 1984, Myers et al. 1987, Gratto-Trevor and Dickson 1994). For example, Myers et al. (1990) found sanderlings primarily used central and Pacific migration corridors during northward migration through North America, but shifted to the Atlantic coast during southward migration, especially using Monomoy NWR and sites along some Atlantic states. Lower shorebird abundance on the northeast Atlantic coast during the northward migration may be partly a result of climate and lower food availability (Morrison 1984).

In 2009, refuge staff began partnering with the Conserve Wildlife Foundation of New Jersey and others to cannon-net shorebirds on Monomoy Refuge during southward migration. Refuge staff were interested in capturing shorebirds to test for highly pathogenic avian influenza (HPAI).

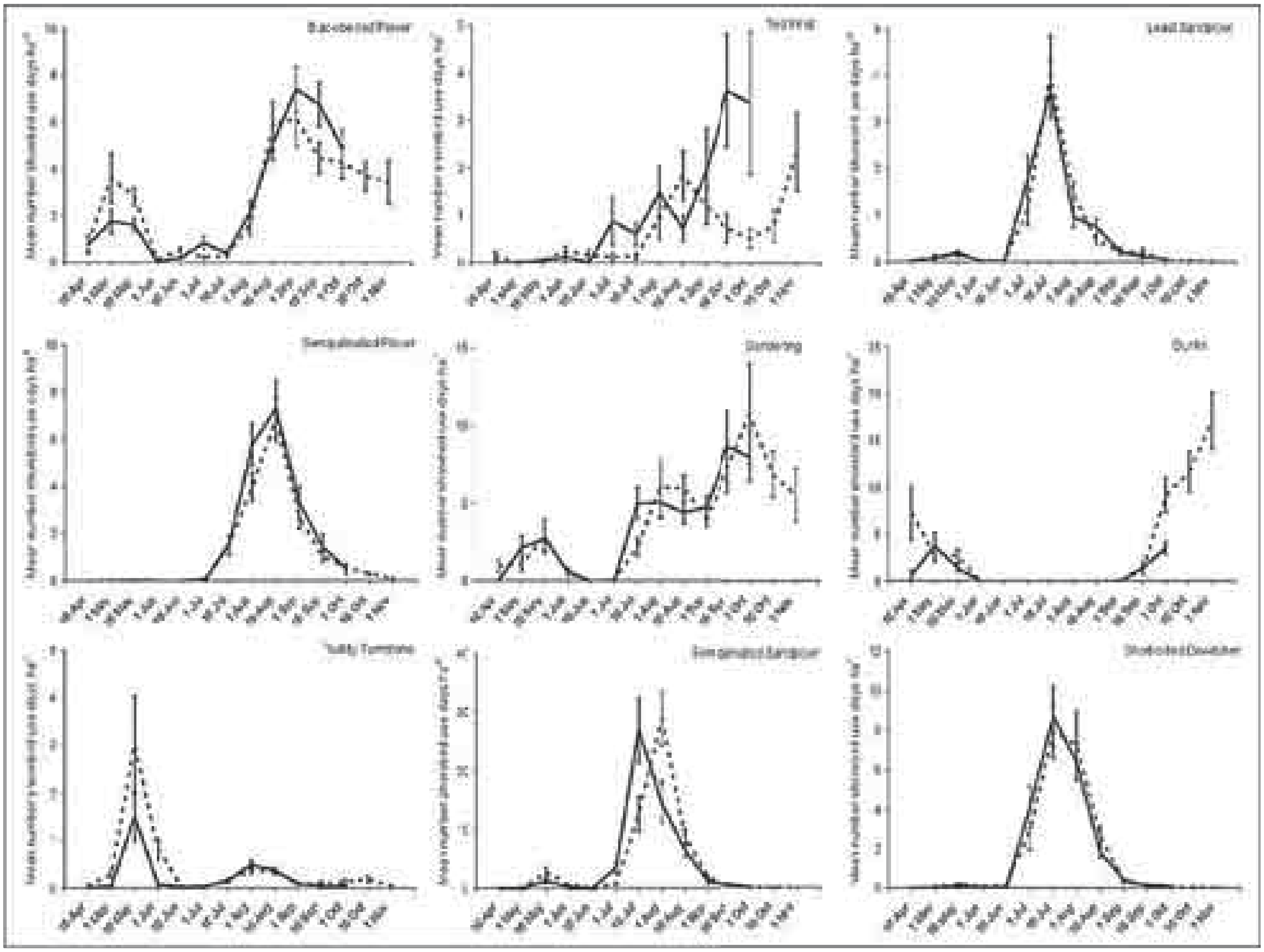


Figure 2.6. Seasonal Variation in Mean (+ or – 1SE) Shorebird-use-days for Nine Shorebird Species Based on Semi-monthly Time Intervals at Monomoy NWR. Solid lines represent 2006 and dashed lines represent 2007.

Tens of thousands of shorebirds, representing more than 20 species, rely on the refuge during spring and fall migration. Many of these species have been identified as high priority for live bird sampling in the Atlantic flyway (Atlantic Flyway Migratory Bird Technical Section 2006). Because of the abundance and diversity of birds present on the refuge during spring, summer, and fall, Monomoy NWR is of particular interest with respect to HPAI surveillance. In 2009, staff collected cloacal and pharyngeal swabs from 1 semipalmated plover, 16 black-bellied plovers, 30 sanderlings, and 103 red knots. Staff continued monitoring for HPAI in 2010 collecting swabs from 2 semipalmated sandpipers, 3 black-bellied plovers, 11 sanderlings, and 90 red knots. All swabs from 2009 and 2010 tested negative for HPAI.

Through this partnership and cannon-netting effort, we have also been placing metal Bird Band Laboratory-issued bands on all shorebirds, and unique 3-digit alpha-numeric lime green flags that can be read from a distance by researchers, bird watchers, and the general public on red knots (see the Red Knot section for details on this species), short-billed dowitchers, and sanderlings. Resightings of banded birds are incorporated into a collaborative resighting database, bandedbirds.org, which allows all partners to benefit from this information. The compilation into one database of banding and resighting data collected from participants flyway-wide increases the power of these data and allows for a greater understanding of migration paths and habitat use of this species.

Nesting Shorebirds

In addition to hosting tens of thousands of shorebirds during migration, the refuge's specialized habitat supports nesting shorebirds of conservation concern, including piping plovers, American oystercatchers, and willets. Piping plovers' nesting history on Monomoy NWR is described above. American oystercatchers and willets have expanded their breeding ranges to include coastal Massachusetts and have established themselves as nesters on Monomoy Refuge within the last 30 years. Numbers of nesting American oystercatchers in the past 16 years is included in table 2.7, but pair numbers prior to 2002 are likely underestimates due to the low level of monitoring done in these years. Good estimates of productivity are difficult to obtain because of the secretive nature of American oystercatcher chicks, but annual productivity is generally between 0.25 and 0.50 chicks/pair. Willet nests are only counted opportunistically, but it is likely that 25 to 50 pairs of willets nest on the refuge each year. Predation of eggs and chicks by coyotes and gulls and nest overwash continue to limit reproductive success of this species. Monomoy NWR remains one of the most important nesting sites in Massachusetts for American oystercatchers, and in some years has been one of the more important staging sites for oystercatchers prior to the onset of migration. Very little is currently known about staging site selection for this species, but it is likely that disturbance is an important limiting factor. In some years, high counts of staging American oystercatchers on the refuge in September have exceeded 200 individuals, but usage varies widely between years (Koch 2011 personal communication).

Table 2.7. American Oystercatcher Nesting and Productivity at Monomoy NWR (1996 to 2012).

Year	Number of Nesting Pairs; Productivity (p)			
	North Monomoy Island	South Monomoy	Minimoy Island	Refugewide
1996*	N/A	8 nests found	N/A	8 nests found
1997*	N/A	6 pairs	N/A	6 pairs
1998*	8 pairs	6 pairs	N/A	14 pairs
1999*	7 pairs	10 pairs	N/A	17 pairs
2000*	3 pairs	12 pairs	N/A	15 pairs
2001*	5 pairs	14-15 pairs	N/A	19-20 pairs
2002	9; p = 0.33	17; p = 0.65	N/A	26; p = 0.54
2003	12; p = 0.08	17; p = 0.35	4; p = 1.25	33; p = 0.36
2004	10; p = 0.30	15; p = 0.27	9; p = 0.78	34; p = 0.41
2005	11; p = 0.00	11; p = 0.09	7; p = 0.00	29; p = 0.03
2006	8; p = 0.63	13; p = 0.38	8; p = 0.63	29; p = 0.52
2007	13; p = 0.62	13; p = 0.62	8; p = 0.13	34; p = 0.50
2008	14; p = 0.57	11; p = 0.09	6; p = 0.17	31; p = 0.32
2009	8; p = 0.00	8; p = 0.38	6; p = 0.17	22; p = 0.18
2010	10; p = 0.20	8; p = 0.88	6; p = 1.67	24; p = 0.79
2011	8; p = 0.50	9; p = 0.00	6; p = 0.67	23; p = 0.35
2012	9; p = 0.00	11; p = 0.27	6; p = 0.33	26; p = 0.19

**Oystercatcher productivity was not quantified in these years.*

Seabirds
The following is a description of tern and gull species that occur on the refuge.

Common Terns
For most of the late 19th century and first half of the 20th century, Monomoy was a continuation of either Nauset Beach or Morris Island and was not particularly remote or inaccessible. During the 1920s and 1930s, terns established large colonies at nearby Tern Island and North Beach, but apparently not on Monomoy. A few least terns and arctic terns reportedly nested on Monomoy as early as 1921 and at other times through the 1950s (Erwin 1979a).

In 1958, a storm separated Monomoy from the mainland, and the first 20th century report of common terns and roseate terns nesting on Monomoy was recorded in 1961 (Nisbet 1980). The colony increased rapidly to at least 2,000 pairs by 1963. The rapid growth was probably due to recruitment from the nearby colonies at Tern Island and North Beach, and possibly Muskeget Island. During most of the 1960s, tern colonies were located at both the north and south ends of the refuge, but in 1971, the expanding herring gull colony usurped the tern sites at the south end, and the terns formed a single large colony on what is now North Monomoy Island (USFWS 1988). From 1963 to 1984, Monomoy NWR supported one of the largest tern colonies in the Northeast. Until 1979, nesting populations ranged from 2,000 to 4,000 pairs. Most of these were common terns, but several hundred pairs of roseate terns were also present. Arctic terns on the southern edge of their range never numbered more than three or four dozen pairs on Monomoy.

By the late 1970s, common, roseate, and arctic terns were restricted to the north end of North Monomoy Island, with a laughing gull colony nearby. Concern heightened in 1978 when tern reproductive success began to decline. In addition to pressure from the gulls to the south, the tern and laughing gull colonies were becoming constricted from the north due to erosion of the island. After a February 1978 storm, the erosion rate accelerated and in the summer of 1979 was estimated to be 16 to 33 feet per month (USFWS 1988).

Common and roseate tern numbers declined steadily throughout the 1980s and 1990s. In 1996, an avian diversity project was initiated by the Service to create more nesting space for terns. Despite the public opposition, this first year of gull control was extremely successful and tern numbers increased dramatically at the restoration site; numbers continued to increase annually through 2003, reached a plateau for a few years, and then started to decline slightly in 2007, reaching an ultimate recent low in 2009 (figure 2.7).

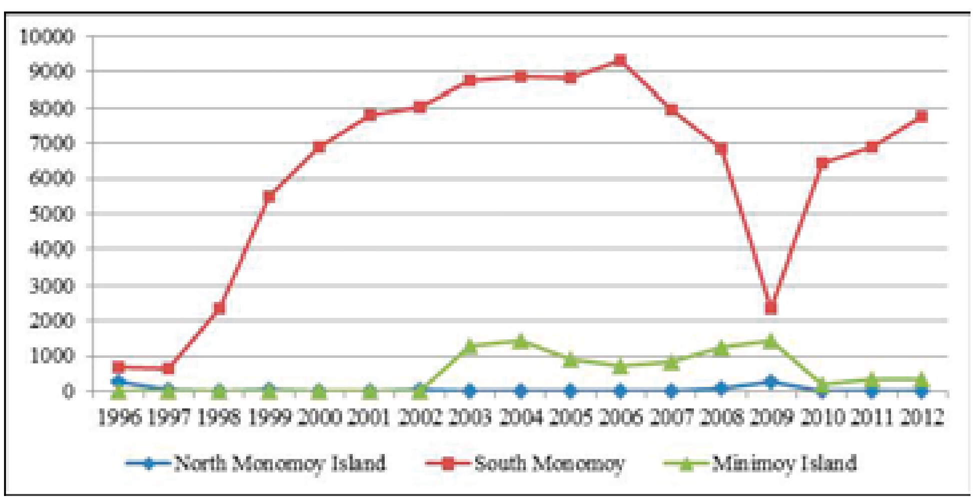


Figure 2.7. Nesting Common Terns on Monomoy NWR (1996 to 2012).

At its height, Monomoy NWR boasted the largest common tern colony in Massachusetts—approximately 43 percent of the population in the State, and it has been the largest tern colony on the Atlantic seaboard. Reproductive success was generally great to excellent in most years for the first 10 years following restoration, but in more recent years, productivity has often been reduced by heavy predation from gulls, coyotes, and black-crowned night-herons, storms and inclement weather, and a combination of marginal habitat and disease outbreaks (table 2.8). Additionally, the number of nesting common terns on Monomoy NWR is inversely related to the number of nesting common terns at Plymouth Beach in Plymouth, MA, and the quality of that nesting site. The increase of nesting common terns in the first few years following the start of the project was concomitant with a decline in the nesting common terns at Plymouth Beach. Birds nesting at Plymouth Beach had been subject to predator pressures prior to abandoning that site and moving to Monomoy Refuge. Similarly, in recent years when nesting numbers at Monomoy refuge have declined, numbers at Plymouth Beach have increased. Band resighting data confirmed that birds from Plymouth Beach were disproportionately represented and much more likely to be at Monomoy NWR than birds from warm-water sites in Buzzards Bay.

Table 2.8. Common Tern Productivity (1996 to 2012).

Year	Common Tern Productivity (SMNY A-period)
1996	1.50
1997	1.70
1998	1.83
1999	1.61
2000	1.85
2001	1.2
2002	0.70
2003	1.26
2004	1.59
2005	1.41
2006	0.96
2007	0.70
2008	1.12
2009	0.35
2010	1.25
2011	1.28
2012	1.26

To maintain tern populations, refuge staff have employed a variety of techniques to improve nesting habitat and increase tern productivity. Techniques such as vegetation manipulation, including application of herbicide and controlled burning, as well as the use of artificial nesting structures have been employed. The two main objectives for controlling vegetation, primarily American beach grass on South Monomoy, have been to reestablish suitable nesting habitat for roseate and common terns in historic nesting areas, and to decrease optimal nesting habitat for an encroaching population of laughing gulls. In 2001, one 30×30 meter control plot and two 15×30 meter adjacent experimental plots