Chapter 2

USFWS

Piping plover nest

Affected Environment

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Introduction

This chapter describes the physical, biological, and socioeconomic settings of the project area, Monomoy 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 Chatham, Massachusetts (maps 1.1 and 2.1). It is one of eight refuges in the Eastern Massachusetts NWR 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 7,921-acre refuge is composed primarily of North Monomoy Island and South Monomoy Island, 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 MLW 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 NWR'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, personal communication 2012). 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 1/2-acre lot, gently sloping from the road to a sandy shoreline on Stage Harbor. This lot is used for administrative purposes only, namely for refuge staff to use for boat access. The Service holds a right-of-way on privately owned roads to access this lot.

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 Island and Nauset/South Beach

South Monomoy Island 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 Island, 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 Island (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 Island, 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. The size of this part of Nauset/South Beach has changed since 2013 as the northern part near the break migrates to the west and sand continues to fill in the Southway. A June 2015 MOU between the Service and the Town administratively determined a management boundary at Nauset/South Beach. Lands west of this boundary are managed by the Service, but the majority of Nauset/South Beach lies to the east and is managed by the Town.

Minimoy Island

Minimoy Island, a small island located west of the northern tip of South Monomoy Island, 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 MA EOEEA, 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.

You may view this information at: *http://www.mass.gov/eea/waste-mgnt-recycling/water-resources/preserving-water-resources/mass-watersheds/cape-cod-watershed.html* (accessed February 2015).

On a larger scale, the Monomoy Islands are included in the Cape Cod and Islands watershed (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—North Atlantic Coast

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 ACJV 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.

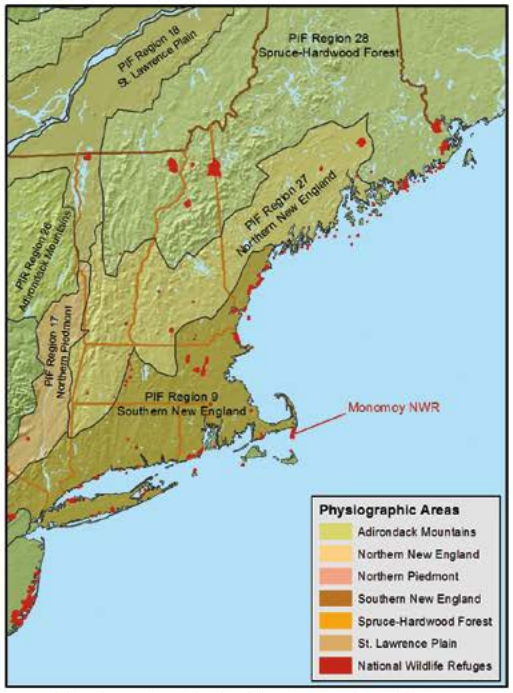
Strategic Habitat Conservation and Landscape Conservation Cooperatives

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 USFWS 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

Monomoy National Wildlife Refuge - Comprehensive Conservation Plan

Service and Partner Conservation Regions



Partners in Flight Physiographic Areas
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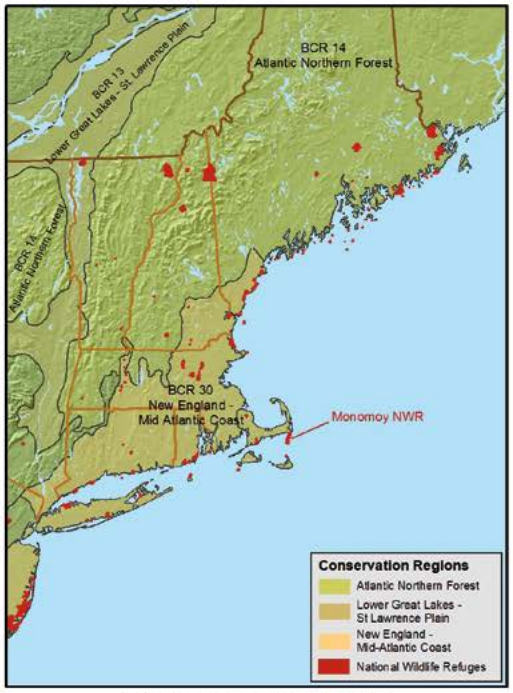

Bird Conservation Regions
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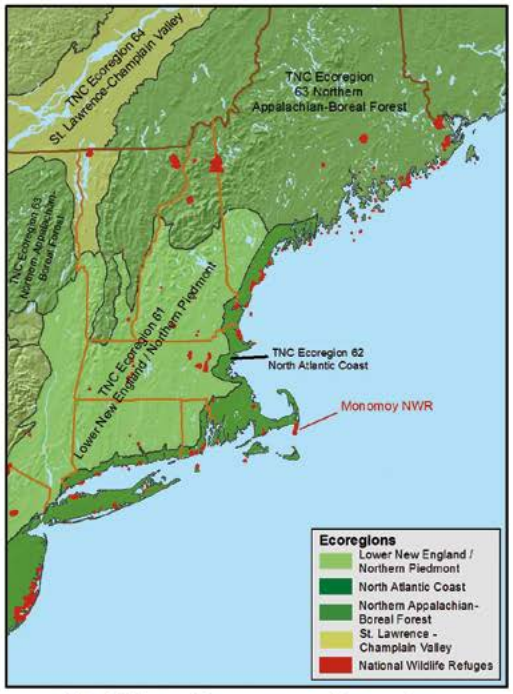

The Nature Conservancy Ecoregions
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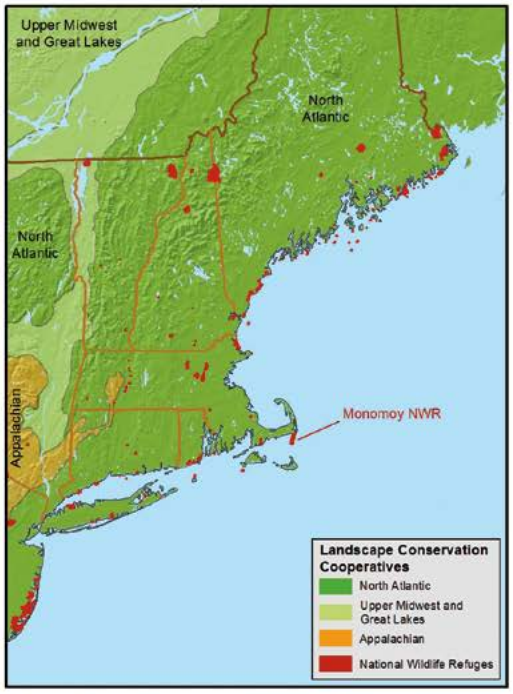

USFWS Landscape Conservation Cooperatives
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time. SHC relies on an adaptive management framework to focus on a subset of shared conservation targets, set measurable biological objectives for them, and identify the information, decisions, delivery, and 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 nationwide through a geographic network of LCC's. 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 SHC 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 do not 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 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 WHSRN 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 9 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 the site annually, particularly during southward migration (Regional Importance; WHSRN 2006). Edwin B. Forsythe NWR 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 NWR, 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 NWR 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 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 MPA as defined under EO 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).

EO 13547—Stewardship of the Ocean, Our Coasts, and the Great Lakes—established a national policy to 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 EO 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 (*https://www.cbd.int/sp/targets/*; accessed July 2013). Helping achieve this target is a global commitment on 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 Island is flanked by sandy beaches on the east and west, with north-south trending dunes between. The southern third of South Monomoy Island 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 (appendix I).

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 Islands 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 (appendix I). 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).

Bill Thompson/USFWS

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 Island 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 on the Massachusetts Ocean Resource Information System (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 MLW 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, Massachusetts to Chatham, Massachusetts, terminated just south of Morris Island, and was parallel and due east of the refuge.

In the late 1950s, a causeway was constructed between Stage and Morris Islands, and the channel separating the two islands was filled with sand. In 1965, 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 known locally as East Harding Beach. Although the channel continues to be dredged, sand is no longer deposited on this Town-owned portion.

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 Island, and the southern known as South Monomoy Island. 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 (appendix I). 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 Island.

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) which formed to the south, stretching from the Chatham Lighthouse south to North Monomoy, 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 attached to the mainland, in a landform known as a tombolo (figure 2.1, box 4).

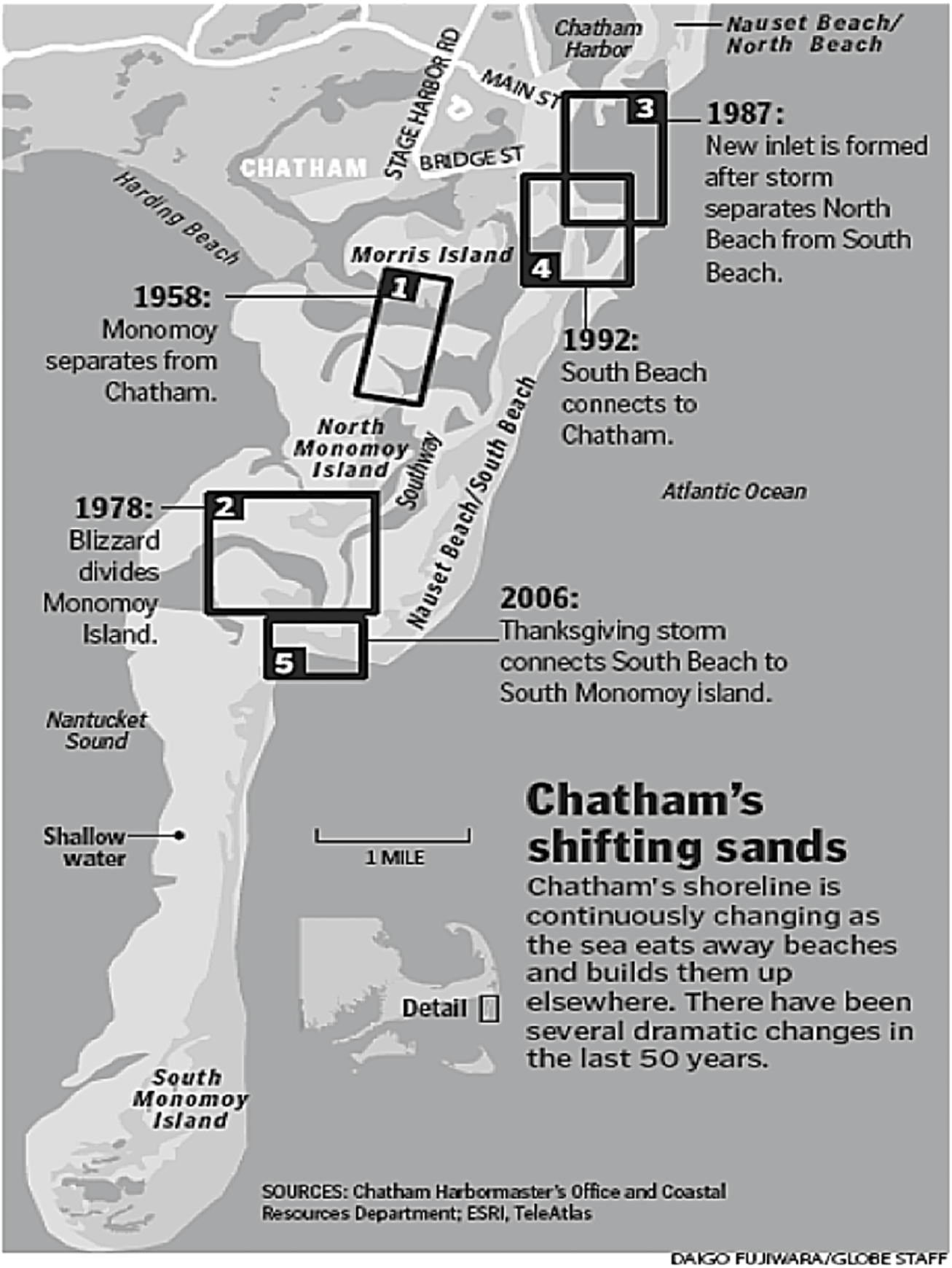
In the winters of 1998 and 1999, a 975-foot rock revetment was installed between the Monomoy NWR beachfront and four adjacent waterfront landowners to the west on Morris Island. Following the revetment construction, beach renourishment took place with the addition of 1,300 cubic yards of sand. In 2005, 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 Island, but instead curled back into the Southway and moved between North and South Monomoy Islands. The marshes on North Monomoy Island started to expand and the small cuts through the flats became difficult to navigate at low tide.

During this time, South Monomoy Island also started to erode on the east side, leaving its mid-point only 328 feet wide. The northern dunes on South Monomoy Island 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 noreaster in 2006 caused the southern tip of Nauset/South Beach to attach as dry sand to the northern tip of South Monomoy Island (figure 2.1, box 5) above the high tide mark. This attachment allowed a person to walk from the Chatham Lighthouse to Monomoy Point Lighthouse, something not possible since 1958.

Like South Monomoy Island, 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 remains, and the waters to the west of the break are getting shallower as sand fills in the Southway.

Figure 2.1. Landform Changes in Monomoy NWR and the Eastern Coastline of Cape Cod prior to 2006.



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. 1998, 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 Wampanoag 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 (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, 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 paleoecological 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 nine 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

Monomoy shoreline

Claire Revekant 2014

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 After Death (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, personal communication 2000).

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, personal communication 2000). 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-17th 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).

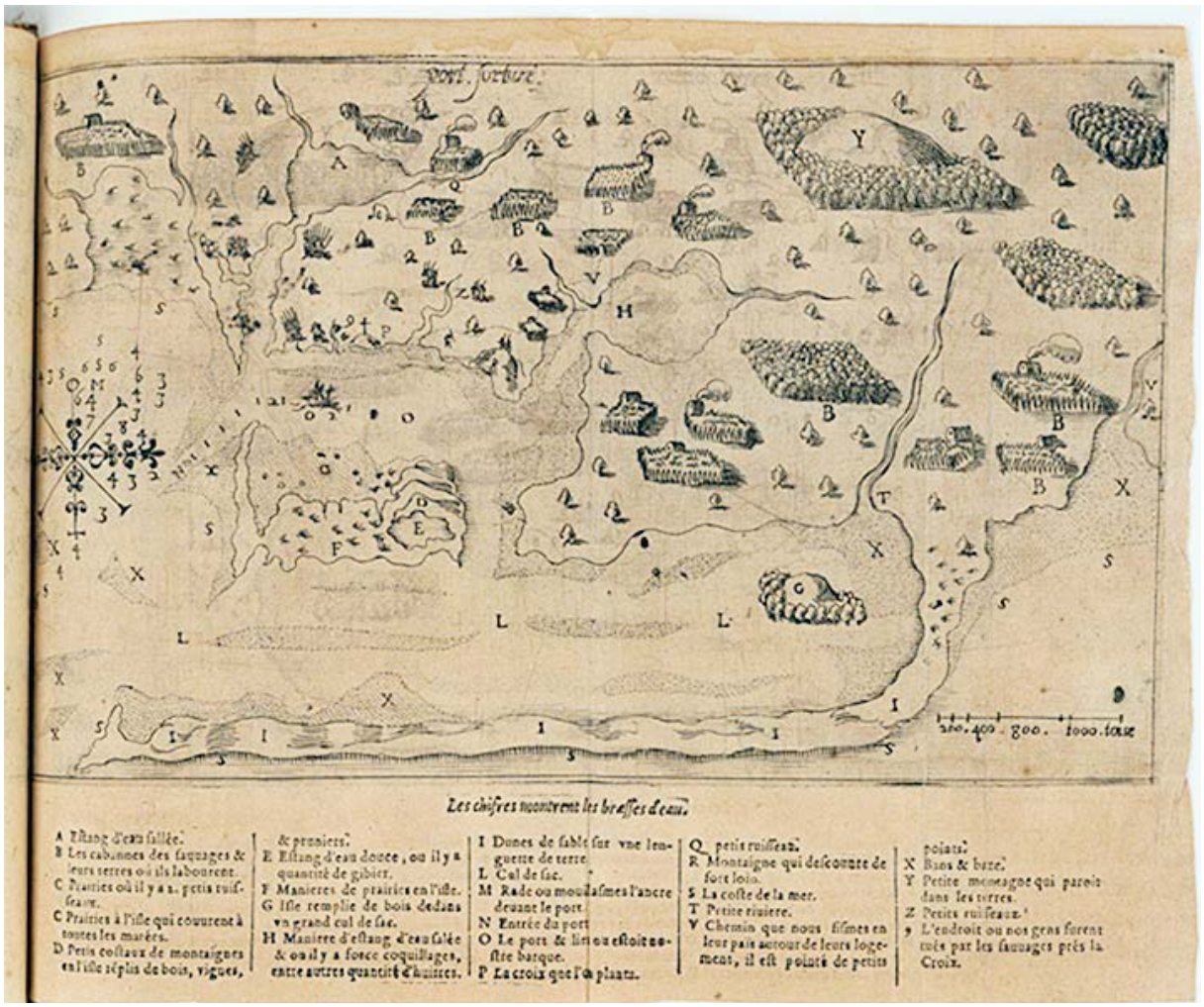


Figure 2.2. Champlain's Map of "Port Fortune" (Stage Harbor) in Chatham, Massachusetts, circa 1605 (Courtesy of the John Carter Brown Library, Brown University; also reproduced in Bragdon 1996). Note that the north arrow points to the right hand edge of the map; thus, the Monomoy peninsula is the narrow 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 two 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).

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 18th 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 20th 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 20th 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 (U.S. Coast Guard (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 SUP's 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 Island (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 USACE (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 Explosive Ordinance Disposal (EOD), and there were no MEC finds during the 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 IPCC 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 nor'easters, 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.

USFWS

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 Island 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, Environmental Protection Agency (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 20th 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 NWLOW, 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 six 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 final CCP/EIS, we focused our sea level rise discussion to a report specifically prepared for Monomoy NWR, (appendix I).

The report found in Appendix I shows that, at the current rate of sea level rise, sediment supply from Nauset/South Beach to Monomoy would be capable of maintaining the barrier complex, as well as supporting ongoing accretion along the southern tip of South Monomoy Island. Based on relative sea level rise in southern New England and global rates, the following general patterns are predicted 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 Island, and a reduced sediment load possibly deepening Monomoy Flats (appendix I)

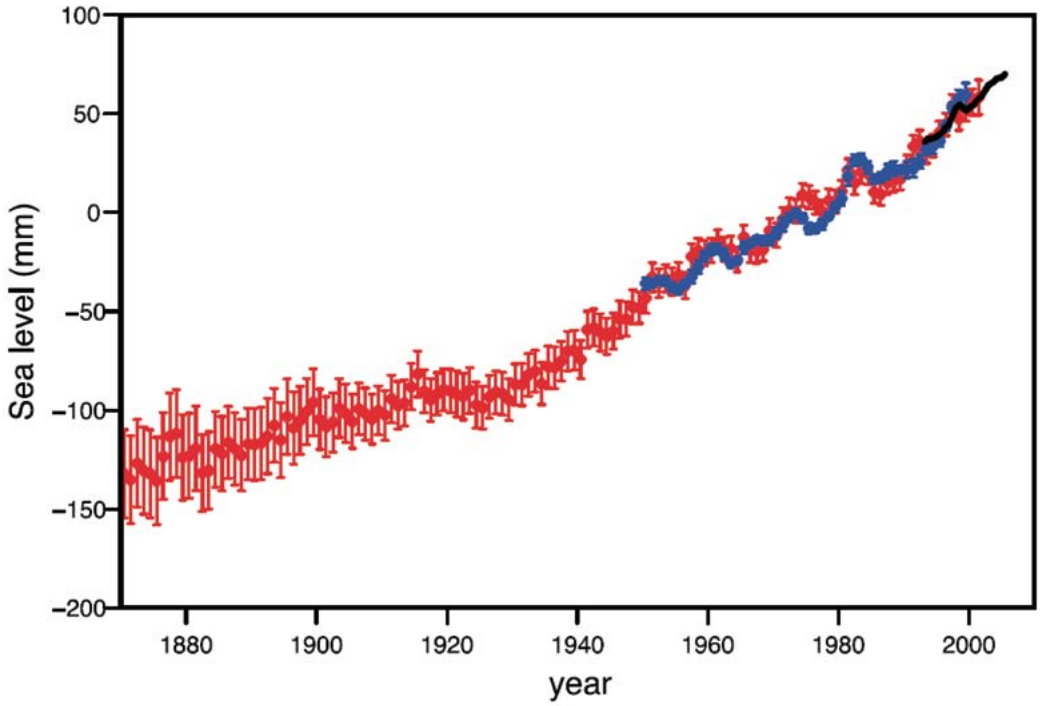


Figure 2.3. Annual Averages of the Global Mean Sea Level in Millimeters. (Error bars show 90 percent confidence intervals (Source: IPCC 2007). Dataset includes reconstructed sea level fields (red), coastal tide gauge measurements (blue), and satellite altimetry (black) data.)

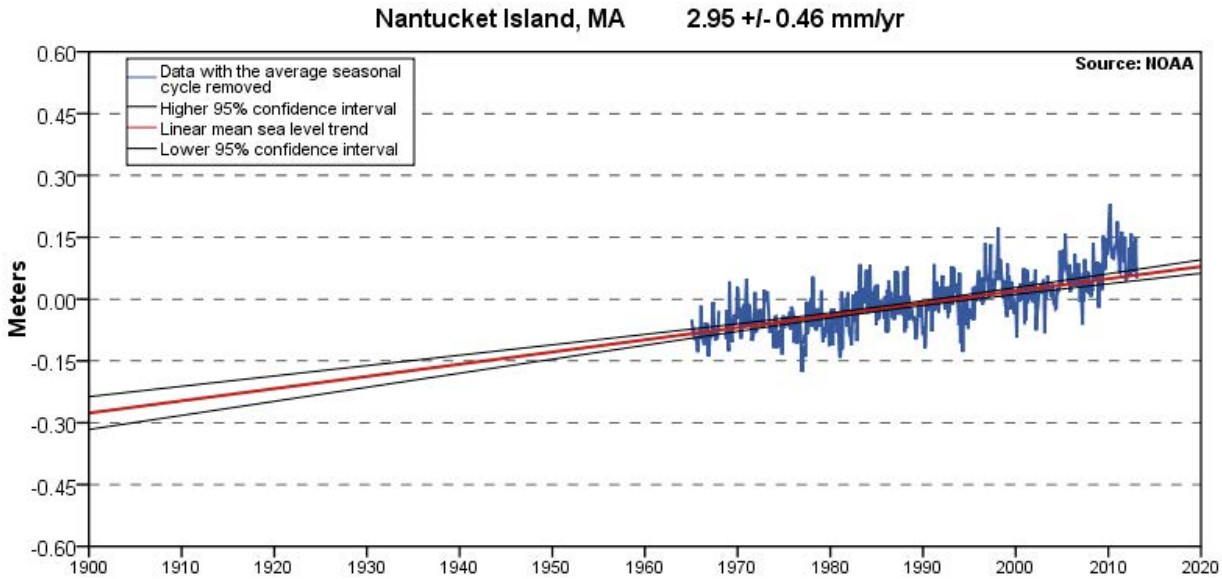


Figure 2.4. Mean Sea Level Trend at Nantucket Island, MA (Source: NOAA 2009a).

Air Quality

Under the Clean Air Act of 1990 (CAA), the 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 parts per million(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 1,050 acres of barrier beach and dune habitat. It contains very little fresh water (Station Ponds on South Monomoy Island), 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 MLW) 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 Code of Massachusetts Regulations(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, Dissolved Oxygen(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 MA 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 MA CZM 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 Island, 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 Island. 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 Island. 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 (MA DPH) 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 MA DPH 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, personal communication 2012).

State-Reported Impaired Waters
In 2010, the MA 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 MA DEP compiled those reports and submitted them to the EPA and Congress to satisfy the Federal reporting requirements under section 305(b) of the CWA.

Much of the data in this MA 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, Quality Assurance/Quality Control(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 Hydrologic Unit Code(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(FAA) 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 (United States Department of Agriculture(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 MA CZM 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 fall 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 NVCS, which is the Federal standard. This system classifies vegetation on a national scale for the United States and is linked to international vegetation classifications. 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 for 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 (see appendix C). 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

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.

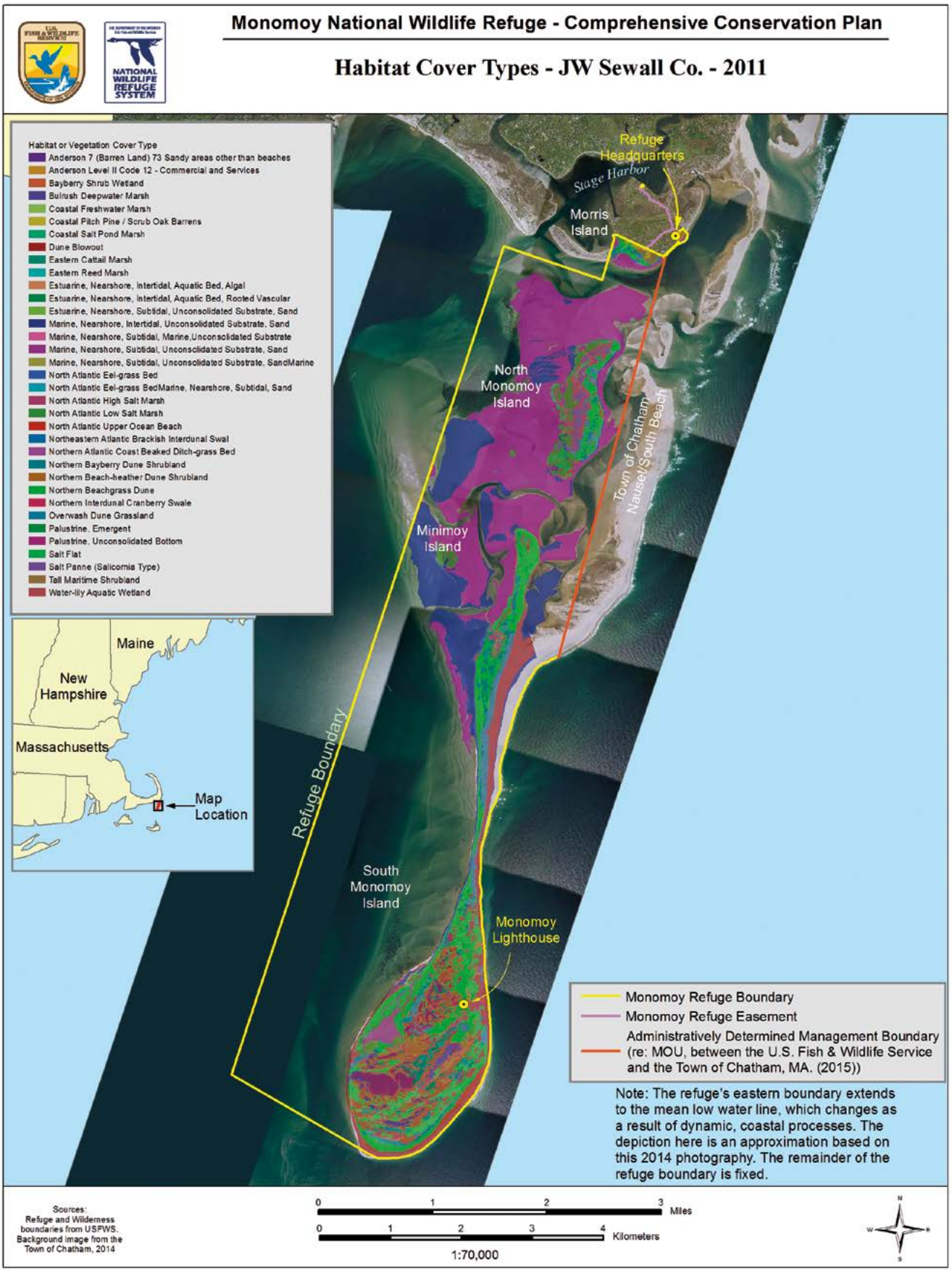
Results from Massachusetts studies and several related national and international research programs all point to the detrimental effects of nutrient enrichment and eutrophication in coastal waters, including large-scale declines of seagrass meadows. These studies suggested that seagrasses can potentially 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.

Eelgrass in the Southway

Holly Bayley 2013

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


Monomoy National Wildlife Refuge - Comprehensive Conservation Plan
Habitat Cover Types - JW Sewall Co. - 2011
Habitat or Vegetation Cover Type
Anderson 7 (Barren Land) 73 Sandy areas other than beaches
Anderson Level II Code 12 - Commercial and Services
Bayberry Shrub Wetland
Bulrush Deepwater Marsh
Coastal Freshwater Marsh
Coastal Pitch Pine / Scrub Oak Barrens
Coastal Salt Pond Marsh
Dune Blowout
Eastern Cattail Marsh
Eastern Reed Marsh
Estuarine, Nearshore, Intertidal, Aquatic Bed, Algal
Estuarine, Nearshore, Intertidal, Aquatic Bed, Rooted Vascular
Estuarine, Nearshore, Subtidal, Unconsolidated Substrate, Sand
Marine, Nearshore, Intertidal, Unconsolidated Substrate, Sand
Marine, Nearshore, Subtidal, Marine,Unconsolidated Substrate
Marine, Nearshore, Subtidal, Unconsolidated Substrate, Sand
Marine, Nearshore, Subtidal, Unconsolidated Substrate, SandMarine
North Atlantic Eel-grass Bed
North Atlantic Eel-grass BedMarine, Nearshore, Subtidal, Sand
North Atlantic High Salt Marsh
North Atlantic Low Salt Marsh
North Atlantic Upper Ocean Beach
Northeastern Atlantic Brackish Interdunal Swal
Northern Atlantic Coast Beaked Ditch-grass Bed
Northern Bayberry Dune Shrubland
Northern Beach-heather Dune Shrubland
Northern Beachgrass Dune
Northern Interdunal Cranberry Swale
Overwash Dune Grassland
Palustrine, Emergent
Palustrine, Unconsolidated Bottom
Salt Flat
Salt Panne (Salicornia Type)
Tall Maritime Shrubland
Water-lily Aquatic Wetland
Refuge Headquarters
Stage Harbor
Morris Island
North Monomoy Island
Town of Chatham Nauset/South Beach
Minimoy Island
Refuge Boundary
South Monomoy Island
Monomoy Lighthouse
Maine
New Hampshire
Massachusetts
Map Location
Monomoy Refuge Boundary
Monomoy Refuge Easement
Administratively Determined Management Boundary (re: MOU, between the U.S. Fish & Wildlife Service and the Town of Chatham, MA. (2015))
Note: The refuge's eastern boundary extends to the mean low water line, which changes as a result of dynamic, coastal processes. The depiction here is an approximation based on this 2014 photography. The remainder of the refuge boundary is fixed.
Sources: Refuge and Wilderness boundaries from USFWS. Background image from the Town of Chatham, 2014
0 1 2 3 Miles
0 1 2 3 4 Kilometers
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N
W
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S

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.

Morris Island and Stage Harbor embayments were 2 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(ha)) 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 (Outermost Harbor and the Southway) and Stage Harbor (Costello and Kenworthy 2011).

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 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 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 of the Stage Harbor embayment SAV area decline occurred between 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). The Massachusetts Division of Marine Fisheries "review of Google Earth images suggests there is a wide area of losses south of Inward Point which occurred gradually between 2003 and 2008 and has since remained essentially stable" (MA DFG 2014). They indicated the water depths in the area make "the use of large vessels and heavy fishing gear infeasible, and there is no evidence of scarring from trawls or boats, and finally that fish weirs are all located outside of the extent of the eelgrass meadow. There is evidence in the photos of shifting shoals" (MA DFG 2014).

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). A fourth federally listed species, the red knot (threatened) uses Monomoy NWR during their long-distance migration, particularly when

staging during the fall southbound migration. The following paragraphs describe the presence of these four species on Monomoy NWR. Over 35 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, recent numbers (44 pairs in 2014) 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 18 years (1996 to 2014).

Piping plover

Amanda Boyd/USFWS

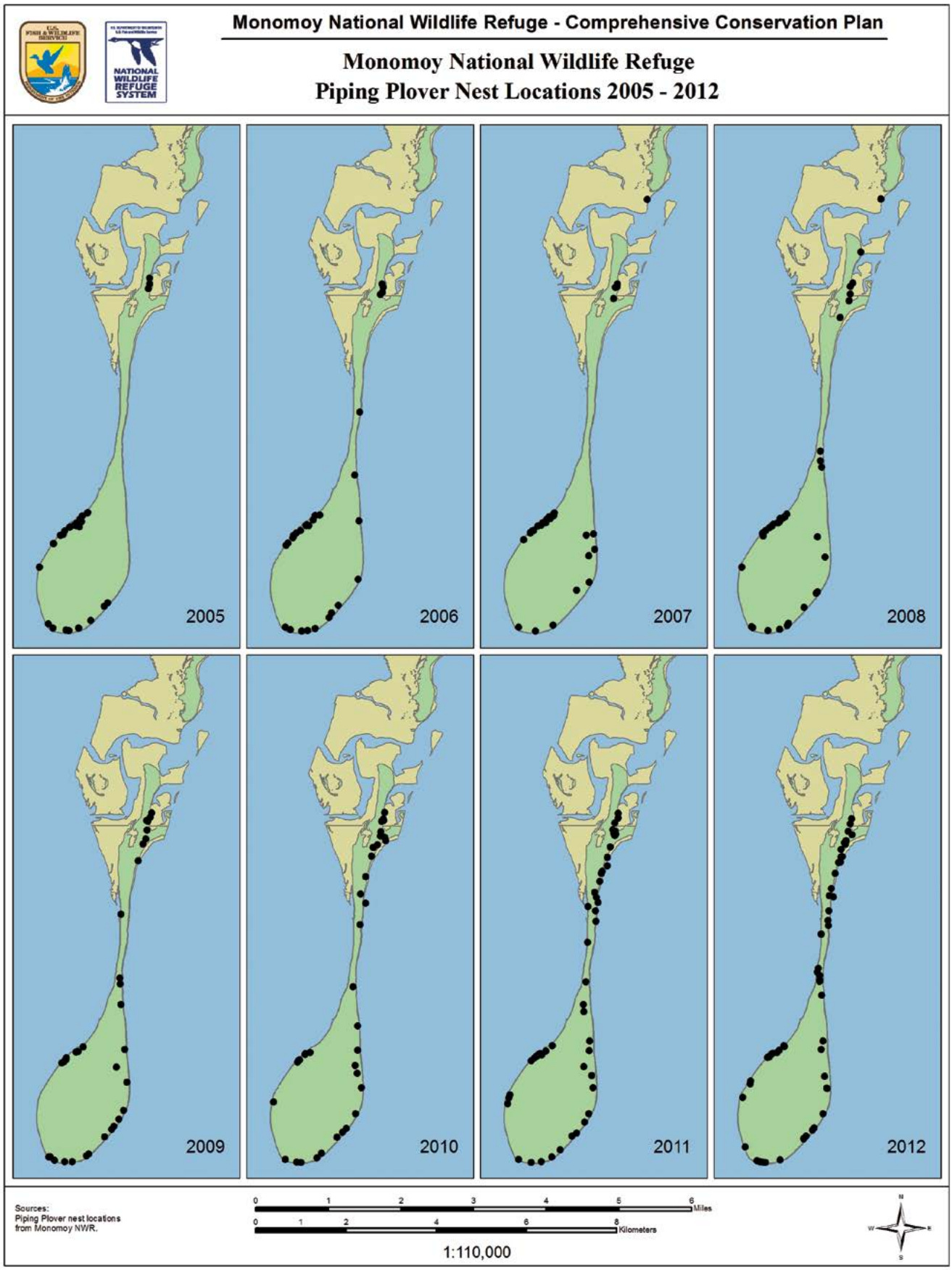
Monomoy National Wildlife Refuge - Comprehensive Conservation Plan
Monomoy National Wildlife Refuge
Piping Plover Nest Locations 2005 - 2012
2005
2006
2007
2008
2009
2010
2011
2012
Sources:
Piping Plover nest locations
from Monomoy NWR.
0 1 2 3 4 5 6 Miles
0 1 2 4 6 8 Kilometers
1:110,000
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Table 2.2. Piping Plover Nesting and Productivity at Monomoy NWR (1996 to 2014).

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
2013	1; p = 1.00	50; p = 0.34	1; p = 1.00	52	0.37
2014	1; p = 0.00	41; p = 1.00	2; p = 2.00	44	0.98

**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.*

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 courtship and nesting sites and limit disturbance to incubating adults or adults with chicks. 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. 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-19th 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 (Massachusetts Department of Fish and Wildlife (MA DFW) 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 1.0 fledged chick per nesting pair 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 is 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 decreasing 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. Roseate terns successfully nested near or within the structures and sound systems in 2011 through 2014. 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,

Black-crowned night heron

Gary M. Stolz/USFWS

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 17 years (1996 to 2014).

Predator management is an important part of the roseate and common tern restoration efforts on South Monomoy Island. 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 2014).

	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
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
2013	8; p = 1.13	0; p = 0.00	8	0; p = 0.00	0; p = 0.00	0	8
2014	8; p = 1.38	0; p = 0.00	8	0; p = 0.00	0; p = 0.00	0	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.

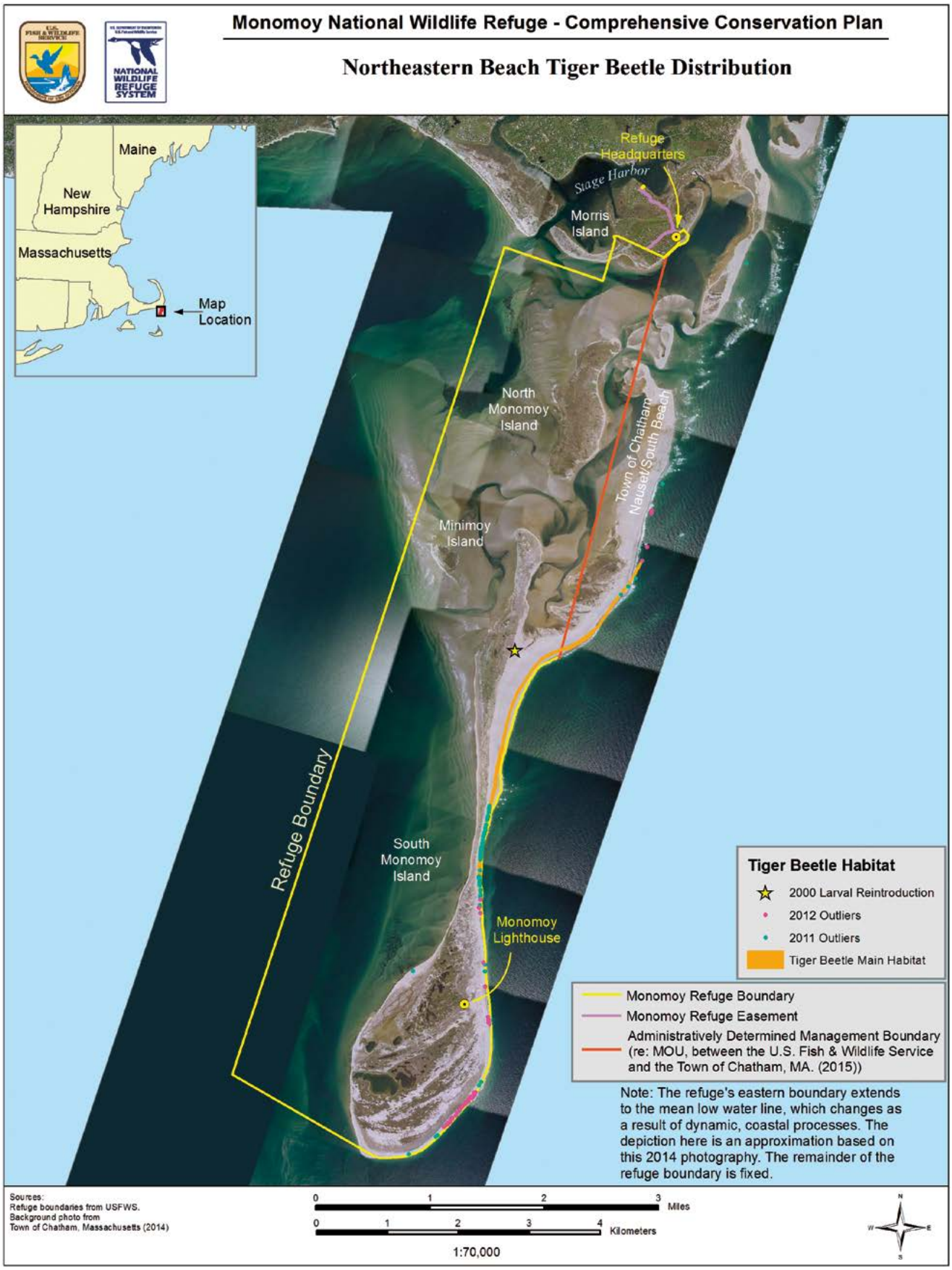
Currently northeastern beach tiger beetles can be found at two sites north of the Chesapeake Bay in Massachusetts: one on the south shore of Martha's Vineyard and one on South Monomoy and Nauset/South Beach in Chatham, Massachusetts. The successful establishment of a northeastern beach tiger beetle population is believed to require a long stretch of relatively wide beach with no over sand vehicles (OSV) 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, 5 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 2014.

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 2014. Map 2.4 shows the main tiger beetle habitat and the location of outliers from the main area in 2011 and 2012. The November 2006 land bridge joining Nauset/South Beach and Monomoy NWR developed at the center of the


Monomoy National Wildlife Refuge - Comprehensive Conservation Plan
Northeastern Beach Tiger Beetle Distribution
Maine
New Hampshire
Massachusetts
Map Location
Refuge Headquarters
Stage Harbor
Morris Island
North Monomoy Island
Town of Chatham
Nauset/South Beach
Minimoy Island
Refuge Boundary
South Monomoy Island
Monomoy Lighthouse
Tiger Beetle Habitat
2000 Larval Reintroduction
2012 Outliers
2011 Outliers
Tiger Beetle Main Habitat
Monomoy Refuge Boundary
Monomoy Refuge Easement
Administratively Determined Management Boundary (re: MOU, between the U.S. Fish & Wildlife Service and the Town of Chatham, MA. (2015))
Note: The refuge's eastern boundary extends to the mean low water line, which changes as a result of dynamic, coastal processes. The depiction here is an approximation based on this 2014 photography. The remainder of the refuge boundary is fixed.
Sources:
Refuge boundaries from USFWS.
Background photo from
Town of Chatham, Massachusetts (2014)
0 1 2 3 Miles
0 1 2 3 4 Kilometers
1:70,000

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 has been supportive of the refuge staff's work concerning the beetles.

Table 2.4. Northeastern Beach Tiger Beetle Translocated and Marked at Monomoy NWR (2000 to 2014).

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	1,228**
2013*	0	0	4,855**
2014*	0	0	5,335**

**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).*

Red Knot

In December 2014, the red knot was designated as threatened (effective January 12, 2015). The Final Rule published in the *Federal Register* for the listing of the red knot can be reviewed here: *http://www.fws.gov/northeast/redknot/pdf/2014_28338_fedregisterfinalrule.pdf* (accessed March 2015). A supplemental document to the listing was also made available (Rufa Red Knot Background Information and Threats Assessment) and can be found here: *http://www.fws.gov/northeast/redknot/pdf/20141125_REKN_FL_supplemental_doc_FINAL.pdf* (accessed March 2015).

Red knots 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 NWR and other participating sites) have confirmed the importance of Monomoy NWR 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, or 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 NWR 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* (accessed October 2015)), 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 USFWS 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* (accessed October 2015) database.

State Listed Endangered, Threatened, and Special Concern Species

The Massachusetts Natural Heritage and Endangered Species Program (NHESP) has officially listed a total of 176 species of vertebrate and invertebrate animals and 256 species of plants as State endangered, threatened, or special concern. "These are species considered to be at risk, or potentially at risk, of extirpation from Massachusetts, or at risk of global extinction. The three main criteria used to assess extinction risk are rarity in the State, population trend, and overall threat." (*http://www.mass.gov/eea/agencies/dfg/dfw/natural-heritage/species-information-and-conservation/mesa-list/*; accessed February 2015). Additionally, "plant species of known or suspected conservation concern that do not meet the requirements for listing under the Massachusetts Endangered Species Act may be included on the plant Watch List. This is an unofficial, non-regulatory list of plants that the NHESP is interested in tracking. Determining whether or not a taxon is under threat or in danger of extirpation from Massachusetts involves careful consideration of many factors, and each taxon is considered on a case-by-case basis." (*http://www.mass.gov/eea/agencies/dfg/dfw/natural-heritage/species-information-and-conservation/rare-plants/*; accessed February 2015).

The State definitions for endangered, threatened, and special concern are included below (NHESP 2008) and more information about the listing process can be found at *http://www.mass.gov/eea/docs/dfg/nhesp/species-and-conservation/listing-criteria.pdf* (accessed February 2015).

> **Endangered**—with reference to any species of plant or animal, means in danger of extinction throughout all or a significant portion of its range, or in danger of extirpation from Massachusetts, as documented by biological research and inventory (321 CMR 10.03).
>
> **Threatened**—with reference to any species of plant or animal, means likely to become endangered within the foreseeable future throughout all or a significant portion of its range, or to be declining or rare as determined by biological research and inventory, and likely to become endangered in Massachusetts in the foreseeable future (321 CMR 10.03).
>
> **Special Concern**—with reference to any species of plant or animal, means documented by biological research and inventory to have suffered a decline that could threaten the species if allowed to continue unchecked, or occurring in such small numbers, or with such a restricted distribution, or specialized habitat requirements, that it could easily become threatened within Massachusetts (321 CMR 10.03).

Monomoy NWR provides habitat for numerous state listed species (some of which are also federally listed). In particular, the refuge is mapped as Priority and Estimated Habitat (13th edition of the MA Natural Heritage Atlas) for 10 state listed species. "Priority Habitat is based on the known geographical extent of habitat for all State-listed rare species, both plants and animals, and is codified under the Massachusetts Endangered Species Act (MESA). Habitat alteration within Priority Habitats may result in a take of a State-listed species, and is subject to regulatory review by the NHESP. Estimated Habitats are a sub-set of the Priority Habitats, and are based on the geographical extent of habitat of state-listed rare wetlands wildlife and is codified under the Wetlands Protection Act (WPA), which does not protect plants. State-listed wetland wildlife species are protected under the MESA as well as the WPA." (*http://www.mass.gov/eea/agencies/dfg/dfw/natural-heritage/regulatory-review/regulatory-maps-priority-and-estimated-habitats/* (accessed February 2015).

Table 2.5. State-listed Species For Which Monomoy NWR is Designated Priority and Estimated Habitat.

Species	State Status	Federal Status
Roseate tern	Endangered	Endangered
Common tern	Special Concern	None
Arctic tern	Special Concern	None
Least tern	Special Concern	None
Northern harrier	Threatened	None
Piping plover	Threatened	Threatened
Pied-billed grebe	Endangered	None
Oysterleaf	Endangered	None
American sea-blite	Special Concern	None
Northeastern beach tiger beetle	Endangered	Threatened

The regional importance of the refuge to recovery of roseate terns, piping plovers, and northeastern beach tiger beetles has been discussed in detail in the previous section titled "Federally Listed Endangered or Threatened Species." The importance of the refuge to common terns, arctic terns, and least terns are discussed in detail in the following section titled "Birds."

The details of occurrence of northern harrier and pied-billed grebe on Monomoy NWR are less known. Breeding northern harriers decreased in Massachusetts beginning in 1955, likely due in part to loss of open field type habitats (Veit and Petersen 1993). Although there is some indication that this species is doing better than in recent years, numbers are still below their historic high points (MassAudubon 2013). Although northern harriers are known to nest on Monomoy NWR, the change in nesting numbers through time is unknown. Nesting northern harriers are not systematically surveyed, and staff take precautions to avoid walking through areas where northern harriers are suspected to be nesting (based on presence of adults) while conducting other work in an effort to minimize disturbance to nests and young. It is very likely, however, that protecting upland dune grass habitat benefits northern harriers by providing safe nesting space.

Breeding pied-billed grebes in Massachusetts have also declined since 1955 due to loss of freshwater marshes (Veit and Petersen 1993) and there is no evidence for recent increases in this population (MassAudubon 2011, 2013). Although pied-billed grebes historically nested on the refuge (MassAudubon 2003) their current nesting status is unknown. Refuge staff do not conduct standardized surveys for them. Pied-billed grebes are still observed on and around Monomoy NWR, including at the south end of South Monomoy Island, but most sightings are in late summer or fall, outside of the breeding season (*www.ebird.org* and *http://monomoybirds.org/bird-list/*; both accessed February 2015). Future protection of the freshwater ponds and marshes on the south end of South Monomoy Island may benefit this species by providing nesting habitat.

We similarly have little information for the occurrence and extent of oysterleaf and American sea-blite on Monomoy NWR because these species are not

monitored by refuge staff. Oysterleaf is a perennial low-growing wildflower that grows in sparsely vegetated sandy coastal habitats, generally above the wrack line but below the highest high tide lines. Threats to this species include trampling and soil disturbance from heavy recreational use by pedestrians and/or OSV (*http://www.mass.gov/eea/docs/dfg/nhesp/species-and-conservation/nhfacts/mertensia-maritima.pdf;* accessed February 2015). Oysterleaf was first (and last) documented on the refuge by NHESP in 1999, when one mature plant with a flowering shoot was discovered (Tom French, personal communication 2015). It is possible that more plants inhabit the refuge given that plenty of suitable habitat exists.

American sea-blite is a tall, fleshy annual plant that grows in saline habitats including sandy edges of salt marshes and tidal flats. Threats to this species also include trampling and soil disturbance from recreational use (*http://www.mass.gov/eea/docs/dfg/nhesp/species-and-conservation/nhfacts/suaeda-calceoliformis.pdf*; accessed February 2015). American sea-blite was first documented on the refuge in 1971 and last documented in August 1989 when several hundred plants were observed (Tom French, personal communication 2015). It is possible that this species still occurs on the refuge as well.

In addition to the 10 State-listed species in Table 2.5 above, dozens of other State-listed species (mostly birds) have been documented using the refuge. A complete list of these species can be found in appendixes A and B.

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.

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 widgeon, 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, personal communication 2011).

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 NWR provide winter food for wintering and migrating Atlantic brant. Midwinter waterfowl surveys are conducted annually coast-wide and include waters surrounding Monomoy NWR. Table 2.6 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 2.6. Mid-winter Waterfowl Surveys (January) for Waters Surrounding Monomoy NWR and Coast-wide (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	1,033	1	31	0	8	0	19
2006	683	52	64	293	1,746	67	67	2	40	0	0
2007	497 (20,280)	0 (1,417)	133 (7,663)	120 (11,144)	25,859 (37,831)	0 (15,85)	0 (1,68)	0 (5,324)	61 (8,125)	0 (1,161)	623 (8,707)
2008	795 (18,346)	0 (2,272)	18 (6,116)	433 (10,316)	578 (78,856)	16 (4,659)	0 (273)	0 (4,629)	51 (3,676)	0 (3,741)	8 (21,654)
2009	103 (18,877)	32 (1,908)	28 (9,312)	32 (11,105)	6,584 (65,676)	0 (1,037)	21 (1,437)	0 (3,288)	52 (4,316)	18 (3,524)	1 (12,337)
2010	522 (18,599)	0 (1,572)	70 (5,790)	126 (8,229)	108 (46,097)	0 (1,092)	0 (239)	2 (2,452)	14 (8,940)	0 (4,273)	2 (5,450)
2011	245 (16,589)	0 (1,213)	2 (2,032)	211 (11,299)	25014 (46,198)	0 (835)	0 (148)	0 (1,808)	4 (4,643)	0 (2,382)	26 (4,817)
2012	906 (30,591)	40 (15,50)	0 (3,860)	580 (16,579)	603 (41,076)	5 (5,587)	5 (698)	0 (3,153)	51 (15,025)	0 (4,534)	333 (7,111)

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). In March 1999, the refuge was designated as a WHSRN regional site based on a maximum 1-day count of approximately 21,000 shorebirds (WHSRN 2006; see 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 BCR 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 Service.

Monomoy NWR is an incredibly important stopover site for southward migrating shorebirds because of its location in the landscape and combination of high quality foraging and roosting habitats (Koch and Paton 2009, Koch and Paton 2013). 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 NWR 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).

Conservation of stopover sites that provide abundant food and a relatively disturbance-free environment is critical to the long-term future of many shorebird populations, especially those that concentrate at just a few stopover sites (Myers 1983, Senner and Howe 1984, Myers et al. 1987). Additionally, protection of high tide roosting sites is extremely important as undisturbed space is limited at high tides when tidal flats are covered with water. This is especially true in New England during peak southward migration (July and August) when shorebirds are vulnerable to disturbance from an increased presence of beach enthusiasts (Pfister et al. 1992; Koch and Paton 2009).

Migratory shorebirds that use Monomoy NWR as a stopover site forage during low tides on the expansive flats and in salt marsh habitats surrounding North, South, and Minimoy Islands and South Beach. Shorebirds that use the refuge during daytime high tides, or overnight, roost in the higher elevations of salt marsh and beach berm on the northeast and south sides of Minimoy Island, North Monomoy Island, and the area surrounding the land connection between South Beach and South Monomoy Island (Koch and Paton 2014; USFWS unpublished data). Shorebirds that forage at non-refuge sites during lower tides (such as red knots using the northern part of Pleasant Bay) also rely on the refuge for roosting habitat during higher tides when foraging habitat is inaccessible (Koch and Paton 2009; Harrington et al. 2010b; Brian Harrington, personal communication April 2014; USFWS unpublished data). For example, shorebirds can be seen bypassing North Beach and North Beach Island (which likely have higher rates of human disturbance) on route from foraging areas in northern Pleasant Bay to roosting areas at Monomoy NWR during higher tides. Monomoy NWR is also an important nocturnal roost site for shorebirds, including for hundreds of whimbrels (USFWS unpublished data).

Although exact movements of migratory shorebirds between refuge and non-refuge lands are not systematically quantified, and may not be consistent between or even within years, we recognize the great interchange of shorebirds that occurs among the sites, and the importance of Monomoy NWR for both foraging and roosting shorebirds. Most salt marsh habitat and much of the upland beach berm on the refuge are closed to public access from April through at least July, and sometimes through September, to protect nesting shorebirds and waterbirds. Roosting shorebirds likely benefit from these closures, but many shorebirds are still migrating through Monomoy NWR in September, October, and even November, and although the number of beach enthusiasts declines in the fall, September is still a popular month to enjoy the refuge (Koch and Paton 2009). Additionally, the majority of flats where shorebirds forage are mostly open to public access. Although some of the habitats used by shorebirds are not easily reached without a boat, and human disturbance is relatively low compared to other sites in Massachusetts, we recognize the potential for impacts from human disturbance. Therefore, in chapter 3 we discuss strategies for providing additional protection to foraging and roosting shorebirds on Monomoy NWR.

Data collected by volunteer birders conducting International Shorebird Surveys (managed by Manomet Center for Conservation Sciences) provide documentation of tens of thousands of shorebirds using Monomoy NWR (these data can be explored at *http://ebird.org/content/iss/*; accessed March 2015). Most of these surveys are conducted at higher tides when birds are more concentrated in smaller areas, often at roosting sites, and thus easier to count. Additionally, refuge staff quantified shorebird use of Monomoy NWR during lower tides, with more of a focus on foraging shorebirds. Standardized shorebird surveys were conducted on 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 2.7 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 8 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 2.7. 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)**

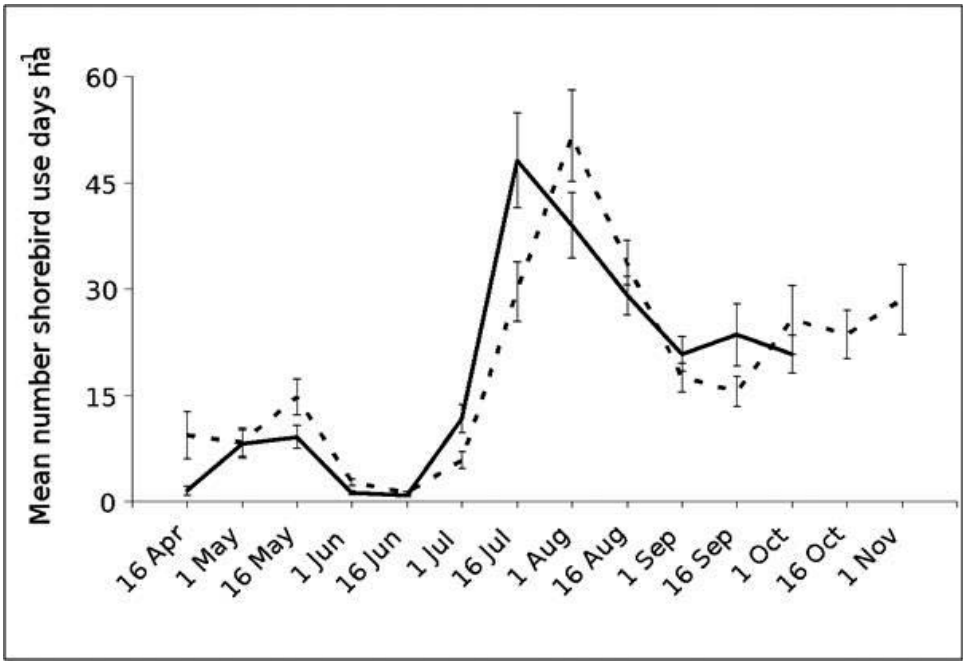
[a] *Additional shorebird species detected outside of plots include: killdeer, solitary sandpiper, spotted sandpiper, upland sandpiper, curlew sandpiper, stilt sandpiper, buff-breasted sandpiper, and red-necked phalarope.*

[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).

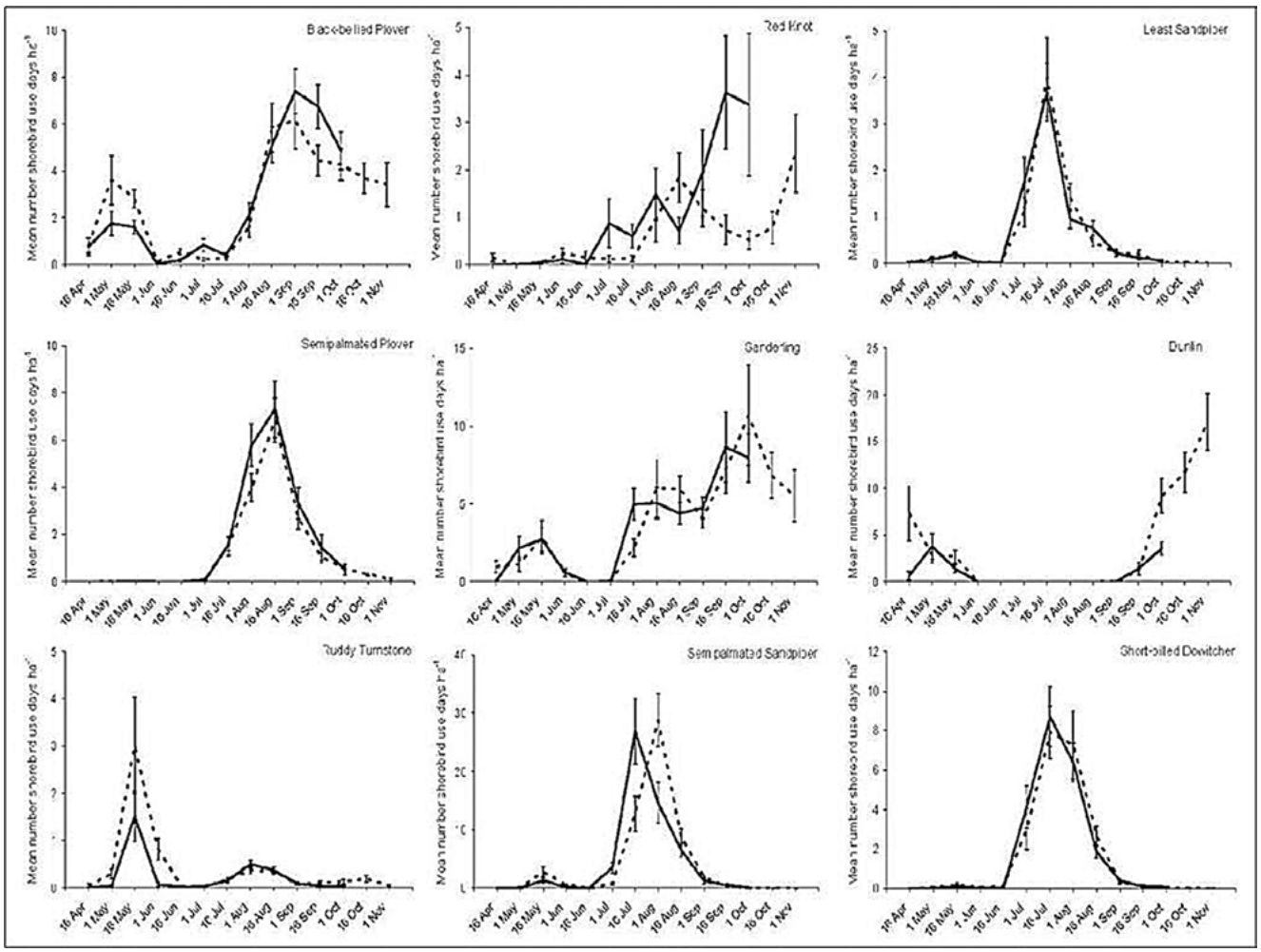
Figure 2.5. Seasonal Variation in Mean (±1SE) Shorebird-use-days for all Shorebirds Based on Semi-monthly Time Intervals at Monomoy NWR. Solid Line Represents 2006 and Dashed Line Represents 2007.



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 NWR 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 (±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 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 NWR within the last 30 years. Numbers of nesting American oystercatchers in the past 18 years is included in table 2.8, 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, and the refuge tallies 25 to 50 pairs annually, though actual numbers of nesting pairs are likely much higher. 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, personal communication 2011).

Table 2.8. American Oystercatcher Nesting and Productivity at Monomoy NWR (1996 to 2014).

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

Year	Number of Nesting Pairs; Productivity (p)			
	North Monomoy Island	South Monomoy	Minimoy Island	Refugewide
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
2013	8; p = 1.25	9; p = 0.56	5; p = 1.00	22; p = 0.91
2014	7; p = 0.43	4; p = 1.75	6; p = 0.67	17; p = 0.82

**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 1979, Nisbet 1973).

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 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). Since 2009, tern numbers have returned to levels of over 6000 pairs and have continued to increase slightly. Tern numbers have remained stable in large part due to habitat management being conducted on South Monomoy.

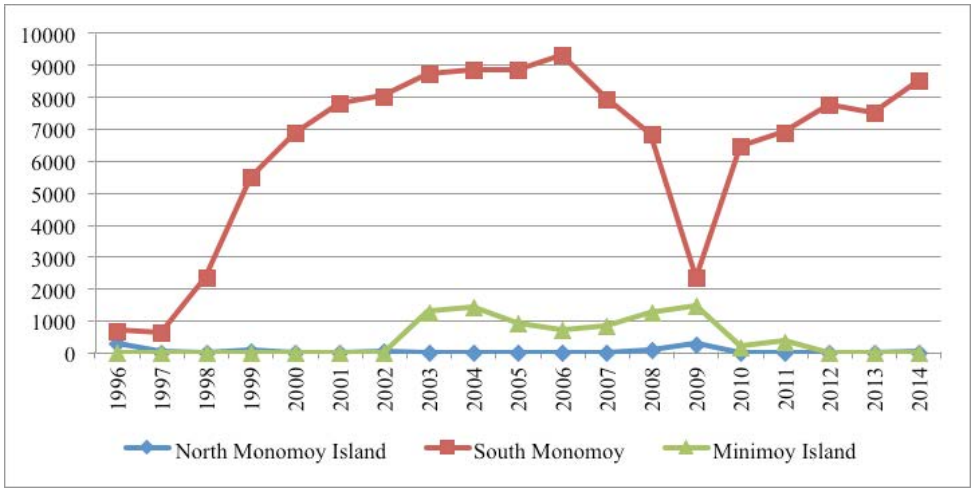


Figure 2.7. Nesting Common Terns on Monomoy NWR (1996 to 2014).

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 one of the largest tern colonies 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 2.9). 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, Massachusetts, 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 NWR. Similarly, in recent years when nesting numbers at Monomoy NWR have declined, numbers at Plymouth Beach have increased. Band resighting data confirmed that birds from Plymouth Beach

Common tern

Phylis Cooper/USFWS

were disproportionately represented and much more likely to be at Monomoy NWR than birds from warm-water sites in Buzzards Bay.

Table 2.9. Common Tern Productivity (1996 to 2014).*

Year	Common Tern Productivity
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
2013	1.65
2014	1.58

**Productivity is calculated for nests initiated during the A-nesting period which is defined by Massachusetts as occurring on or before June 20th.*

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 by 30 meter control plot and two 15 by 30 meter adjacent experimental plots were established on the east side of the north tip to test different vegetation manipulation techniques. In one experimental plot the vegetation was pulled out by hand, and in the other experimental plot the vegetation was weed-whacked and then covered with landscape cloth. Four additional 30 by 30 meter experimental plots were added between the fall of 2001 and the spring of 2002 and subjected to (1) herbicide application and raking, (2) herbicide application and burning, (3) raking only, and (4) burning only. Through both seasons of testing, productivity of terns and predator activity within the plots was closely monitored with the results from vegetation manipulation. Experimental vegetation manipulation during 2001 to 2002 showed that of the six treatments used,

burning and a combination of herbicide and burning produced a habitat type that most deterred nesting laughing gulls and enticed nesting common terns (USFWS 2007b). Although the combination of herbicide and raking produced the most significant alterations in vegetation structure, burning alone was the only type of management that actually resulted in a decline in the number of nesting laughing gulls that persisted for 2 years.

Since the vegetation work in 2001 to 2002, three controlled burns have been conducted on the refuge to improve nesting habitat for terns. On April 8, 2004, two 60 by 60 meter plots were burned on the southwestern edge of the colony. This area was one of the main areas of encroachment by laughing gulls. Baseline vegetation data was collected prior to the prescribed burn and changes in vegetation cover (dead and alive), open sand, and the amount of duff were measured after the burn, and after the nesting season that immediately followed the burn. Overall, the burn was successful in reducing the number of laughing gulls nesting in these plots while increasing the number of terns. Despite the success of the burn in 2004 however, nesting laughing gulls were again reaching high numbers and another burn was conducted on October 15, 2009. Refuge staff and Region 5 fire personnel burned the entire tern nesting area (36 acres on the north tip of South Monomoy). Refuge staff collected pre-burn vegetation data and post-burn vegetation data to compare percentages of woody species, green vegetation and thatch, and areas of open sand impacted by the burn. Vegetation data collection was continued annually after the burn in 2009 was completed, and it was determined in fall of 2011 that vegetation levels were reaching that of the pre-burn data, indicating the need to burn again. A burn was conducted in October 2012 over the majority of the northern tip of South Monomoy, excluding a small roseate tern nesting area where habitat was already desirable. Post-burn vegetation data has not yet been collected.

Prescribed fire has been used as a tool to thin out areas of vegetation that are considered too thick for tern nesting, and artificial nesting structures have been used to provide additional cover in areas that are too sparsely vegetated for terns. Several areas within the main tern nesting area on South Monomoy are completely void of vegetation. Beginning in 1997, approximately 100 tern boxes (Series 500, modeled after J. Spendelow, USGS/BRD, Patuxent Wildlife Research Center, Laurel, Maryland) have been placed throughout the colony in areas with little vegetation on South Monomoy. Although this type of box was designed specifically to attract nesting adult roseate terns and provide shelter for large mobile roseate tern chicks (USFWS 1999b), common tern chicks frequently use these boxes for shelter from predators and exposure to inclement weather on South Monomoy.

Large seabird colonies are often a breeding ground for avian disease. Since the documentation of salmonellosis outbreaks beginning in 2004, and the 2005 paralytic shellfish poisoning mortality on South Monomoy, disease monitoring has become a vital component of our biological monitoring program. The tern colony is monitored regularly for adult tern mortality and fledglings demonstrating symptoms of salmonellosis. The salmonella bacterium is often naturally present at low levels in seabirds and outbreaks commonly manifest in large colonies of nesting terns and gulls. Symptoms of salmonellosis include ruffled feathers, diarrhea, and severe lethargy. Shortly before death, birds may appear unsteady, may shiver, and breathe more rapidly than normal (USGS 1999). Spasms, paralysis, and discolored excretions around the vent are additional signs of salmonellosis. The salmonella bacteria can cause large-scale losses of colonial nesting birds, and once symptoms become readily apparent, death usually occurs within 12 hours. The source of the 2004 salmonellosis infection at Monomoy NWR has not been identified despite efforts to determine its origin.

Tern colony

Katrina Scheiner 2007

The colony is also monitored for large mortality events and unusual behavior that could be associated with HPAI (H5N1). The HPAI H5N1 virus has not yet been detected in the United States in either wild migratory waterfowl or domestic birds (USFWS 2006b). Mortality surveys were conducted from 2008 to 2010 in areas with concentrations of sensitive species (terns, gulls, and shorebirds), looking for groups of sick and dead birds. As part of a regional monitoring effort, refuge staff collected cloacal and pharyngeal swabs from 50 live adult common terns during the nesting season from 2008 to 2010. All samples collected and submitted to the National Wildlife Health Center in Madison, Wisconsin, tested negative for HPAI.

Least Terns

Least terns generally show high colony site tenacity (Burger 1984) and site fidelity (Atwood and Massey 1988), though their use of Monomoy NWR has varied widely from year to year. Large areas of least tern habitat are available on the refuge, though predator presence is a problem and may be the reason least terns have only nested in small numbers in most years. In 1970, there were three least tern colonies totaling 200 pairs on Monomoy NWR. Two least tern colonies produced young in 1979, and between 1980 and 1983, least terns were occasionally seen at the beginning of the breeding season. Unsuccessful least tern nest attempts occurred in 1984 and 1985, and the highest count (300 pairs) was recorded in 1987 (USFWS 1988). Monitoring least tern nest attempts may have been inconsistent in past years, but during most years within the last 18 years, all suitable least tern nesting sites have been carefully surveyed during peak nesting times and nesting birds have been censused during the State census window. Survey numbers are included in table 2.10. Most of the nesting least terns on the refuge have been utilizing South Monomoy (south tip, southwest, southeast, and northeast sides), but several pairs have attempted to nest on Minimoy Island when habitat was available. Obtaining accurate productivity estimates is difficult and can cause additional disturbance to nesting birds, but in most years, productivity has been qualitatively defined as poor. Predators (primarily gulls and coyotes) and overwash are often to blame for loss of eggs and chicks.

Table 2.10. Least Terns Nesting on Monomoy NWR (1996 to 2014).*

Year	South Monomoy	Minimoy Island**	Refugewide
1996	103	N/A	103
1997	6 (138)	N/A	6 (138)
1998	246	N/A	246
1999	103	N/A	103
2000	119	N/A	119
2001	16	N/A	16
2002	6 (50)	N/A	6 (50)
2003	62 (143)	0 (6)	62 (149)
2004	1 (229)	0 (1)	1 (230)
2005	93 (39)	0	93 (39)
2006	57	0	57
2007	32 (51)	0 (7)	32 (58)
2008	144 (6)	0 (5)	144 (11)
2009	5 (7)	3	8 (7)
2010	39 (11)	0	39 (11)
2011	104***	0	104***
2012	52 (152)	0	52 (152)
2013	261	0	261
2014	376	0	376

**The first number listed represents the A-period total (nests initiated on or before June 20th) and the number in parentheses represents the B-period total nest count (nests initiated after June 20th).*

***Minimoy Island was not monitored until 2003.*

****A ground nest count was not completed during the census window in 2011; only an adult count was done during the window. All other counts in this table are based on peak nest counts completed during the census window June 5 to 20.*

Staging Terns

Monomoy NWR hosts thousands of staging terns during the post-breeding season. Common and roseate terns are found in the highest numbers; there are smaller numbers of black terns, Forster's terns, arctic terns, and least terns. Occasionally sandwich and royal terns have been sighted on the refuge.

In late July, roseate terns begin moving to staging areas on Cape Cod, including areas of Monomoy NWR. Anecdotal evidence suggests that potentially 100 percent of the roseate tern population uses Cape Cod for a portion of the post-breeding period. The concentration of these birds implies that this period of their life cycle is largely important to their survival. Of the 13.24 square kilometers identified as important during the post-breeding period, 6.18 km^2 occur on Federal land (Cape Cod National Seashore and Monomoy NWR) (Jedrey, personal communication 2010).

Beginning in 1998, staging tern counts were conducted opportunistically by refuge staff and generally limited to the flats on the north tip of South Monomoy

Island. A high staging count of 10,890 terns was recorded on August 4, 1999. Beginning in 2007, staff from the Coastal Waterbird Program and USGS conducted staging counts on many different sites throughout Cape Cod, including the refuge, as part of their roseate tern monitoring program, resulting in much more consistent and intense coverage at the refuge. Results from their study have not been finalized. In 2010, refuge staff also began expanding the geographic area of the counts to include the connection of Nauset/South Beach and South Monomoy and areas further north on Nauset/South Beach.

Black Skimmers
Monomoy NWR lies on the northern edge of the black skimmer's breeding range. Over the last three decades, single pairs sporadically nested on the refuge, generally in association with common terns. The nesting population of black skimmers at the refuge climbed to three pairs in 1986 and then declined to zero pairs in the 1990s until 1996 and 1997, when five pairs were recorded (figure 2.8). Since that time, a few black skimmers have continued to nest on the refuge in most years; in many years the refuge has been the only nesting site in Massachusetts. Productivity for these nesting birds has been sporadic with some good years and poor years.

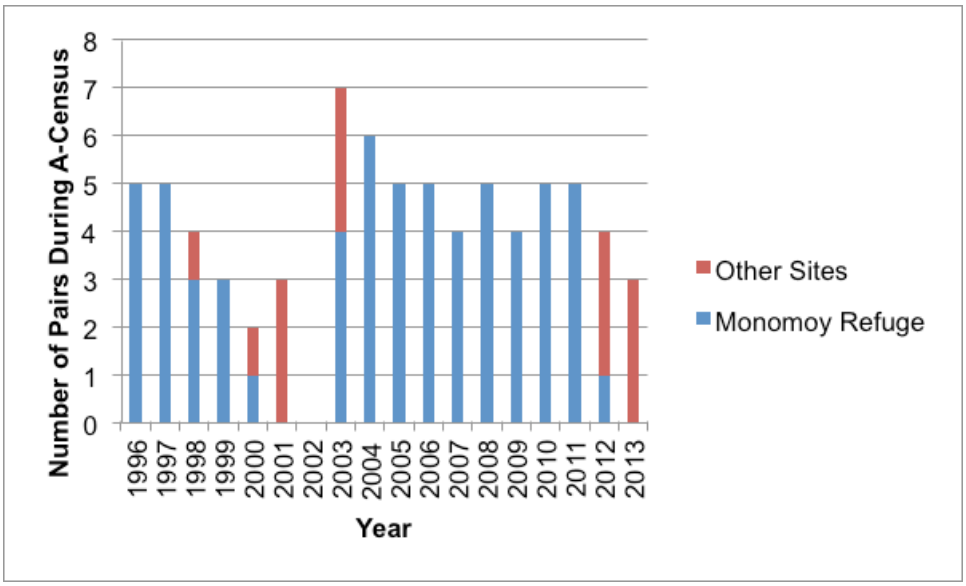


Figure 2.8. Black Skimmers Nesting at Monomoy NWR Compared to Other Sites in Massachusetts (1996 to 2013).

Gulls
Laughing Gulls
Laughing gulls, perhaps displaced from Muskeget Island, first colonized Monomoy NWR in 1971 and succeeded in establishing a colony adjacent to and within the tern colony at the northernmost tip of the refuge. Laughing gull numbers rose steadily during the 1970s to a peak of 1,000 pairs in 1981 (USFWS 1988), but then declined steadily; laughing gulls eventually stopped nesting by the mid-1990s (USFWS 1996b), which was most likely the result of continued expansion of the herring and great black-backed gull populations that encroached on tern and laughing gull nesting areas (USFWS 1996b, USFWS unpublished reports 1985 to 1994). Both laughing gulls and terns benefited from the lethal removal of herring and great black-backed gulls that began in 1996, and by 2002 the population of nesting laughing gulls had increased to 1,106 pairs (USFWS 2003a) and the numbers of pairs continued to increase through 2007 (figure 2.9; USFWS 2009e).

As the laughing gull population increased, their rapid population growth put them in direct competition with roseate and common terns. Each year laughing gulls are counted in conjunction with the annual tern census. See figure 2.9 for trends of nesting laughing gulls on Monomoy NWR.

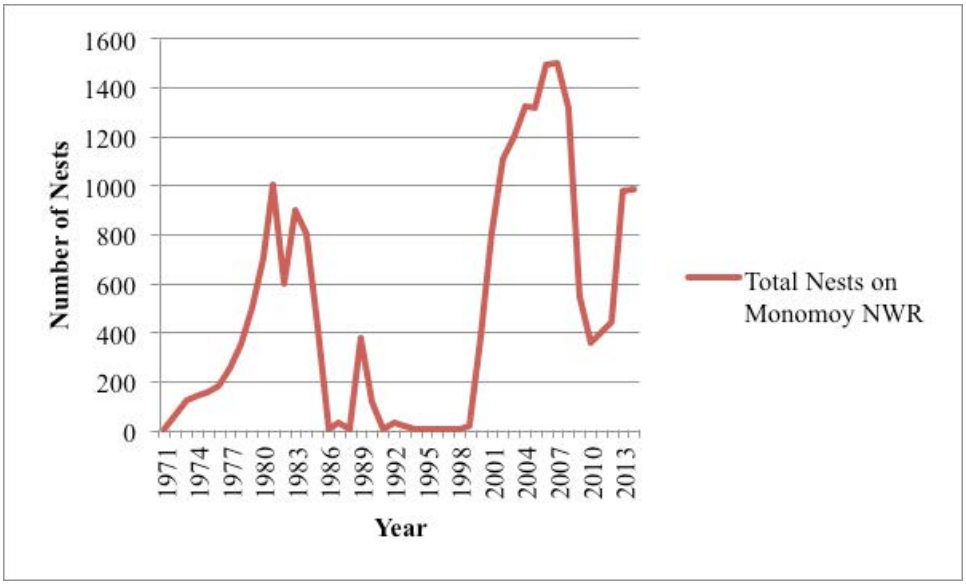


Figure 2.9. Number of Nesting Laughing Gulls Counted on South Monomoy (A-Census) 1971-2014. (The counts for 1972 to 1984 are estimates).

Habitat manipulation and nest destruction are tools that have been used to keep the laughing gull population low and decrease their competition with nesting terns. Refer to appendix J for more information on management techniques used to control the laughing gull population.

Great Black-backed and Herring Gulls

Although it has been reported that several herring gulls nested on Monomoy Island in 1924 (Forbush 1925), the recent history of herring gull nesting on Monomoy NWR started with 5 pairs in 1963 (Kadlec and Drury 1968). The colony growth in successive years was spectacular with 75 pairs in 1964; 420 pairs in 1965; 1,000 pairs in 1966; 8,000 pairs in 1969; and more than 15,000 pairs in 1980; but in 1995, only 5,200 pairs of herring gulls were found on the refuge. This drop in herring gull numbers may be correlated to the closing of landfills and poor census methods used during the census in 1995. Great black-backed gulls moved onto Monomoy soon after the herring gulls did; there were 75 to 80 pairs in 1965 and 1966 and about 175 pairs in 1972. By 1980, the great black-backed population had reached 3,300 pairs, and in 1995 had reached a total of 7,350 pairs, for a combined count of more than 13,000 pairs of the two large gull species (USFWS 1996b).

These counts (through the mid-1990s) are estimates however, and uncertainty and inconsistency in methodology over years reduces their reliability. In recent years, complete counts of nesting gulls have been conducted on North Monomoy Island in 2000 and 2007 (refer to table 2.11). In 2000, South Monomoy was surveyed using aerial photography; in 2007, it was surveyed using a stratified random-sample transect method. In 2000, 1,018 great black-backed gulls and 1,609 herring gull nests were counted on North Monomoy Island, but the aerial photography for South Monomoy Island was never fully analyzed. In 2007, 1,245 herring gull nests and 683 great black-backed gull nests were counted on North Monomoy Island. An additional 1,088 herring gull nests and 2,490 great black-

backed gull nests were estimated on South Monomoy, for a total refugewide count of 2,333 herring gull nests and 3,173 great black-backed gull nests.

Table 2.11. Great Black-backed Gull and Herring Gull Nests Counted in Areas A and B During May Gull Censuses in 1996 to 2007* on South Monomoy.

Year	Great Black-backed Gull		Herring Gull		Empty		Total		
	Area A	Area B	Area A	Area B	Area A	Area B	Area A	Area B	Total
1996	307	652	544	178	859	322	1,710	1,152	2,,862
1997	78	356	26	51	262	147	366	554	920
1998	7	259	0	10	6	99	13	368	381
1999	2	195	0	35	1	98	3	328	331
2000	0	139	0	33	0	86	0	258	258
2001	3	115	0	28	3	55	6	198*	204*
2002	3	114	0	56	0	47	3	217	220
2003	1	79	0	32	0	47	1	158	159
2004	4	59	0	14	0	104	4	177	181
2005	0	39	0	18	0	61	0	118	118
2006	0	12	0	3	0	43	0	58	58
2007	0	13	0	5	0	17	0	35	35

**No gull census took place in 2008 through 2012. Census numbers for 2013 are not final so are not provide in this table.*

Gull Control Efforts (1979 to 2008)

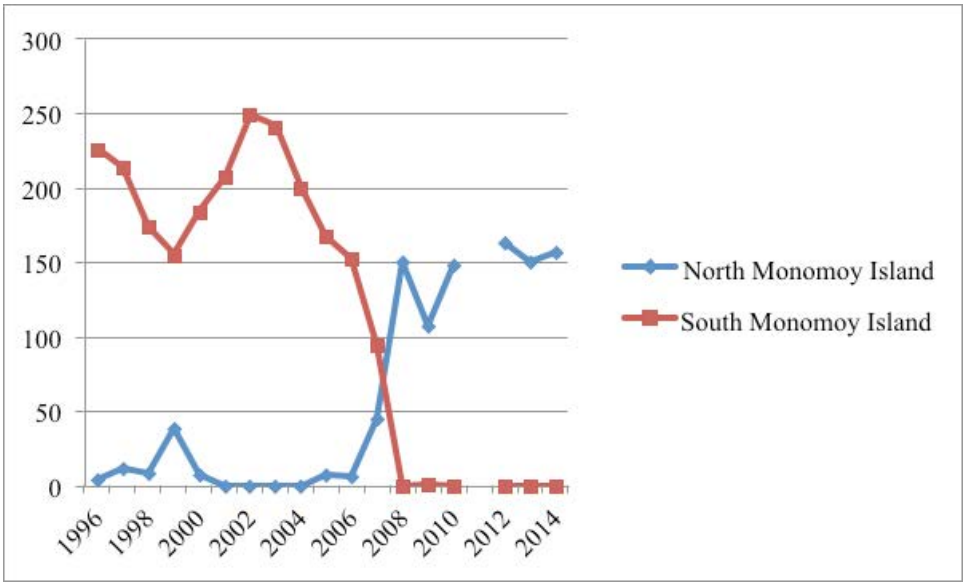
During the 1970s, tern populations on Monomoy NWR became restricted in area and declined in numbers, while nesting herring and great black-backed gull populations increased to very high levels and expanded to occupy extensive areas of the refuge, including former tern colony locations (USFWS 1988). Various efforts between 1979 and 1995 were unsuccessful at controlling the gull population on the refuge. In accordance with tasks outlined in the Piping Plover Recovery Plan, Roseate Tern Recovery Plan, ESA of 1973, and the goals of the Refuge System in 1996, which direct national wildlife refuge units to "preserve, restore, and enhance in their natural ecosystem (when practicable) all species of animals and plants that are endangered or threatened with becoming endangered," the Service proposed to strengthen ongoing efforts to manage habitat for nesting species on Monomoy NWR. The Avian Diversity Project began in 1996, and a contiguous 169.5-acre area (67.7 ha) was chosen on the north end of South Monomoy Island (designated Areas A and B) to provide gull-free nesting habitat. The Service has used a variety of techniques to control nesting gulls and maintain habitat for terns. Details of these efforts are described in appendix J.

Other Colonial Nesting Waterbirds

Monomoy is one of a few remaining nesting sites in the State of Massachusetts for colonial nesting wading birds. The number of nesting black-crowned night-herons on Monomoy NWR increased from 12 pairs in 1980 to 200 pairs in 1987, and this colony size has maintained over the years. Black-crowned night-herons nested each year on South Monomoy until recently, when they began transitioning to nesting sites on North Monomoy Island (figure 2.10). All wading birds nested on North Monomoy Island in 2008 through 2011, with the exception of one black-crowned night-heron nest on South Monomoy in 2009. Black-crowned night-herons nest primarily in rugosa rose, but also utilize bayberry, poison ivy bushes, and beach plum (especially on North Monomoy Island). Dissections performed at

the refuge and papers from other heronries in New England confirm that black-crowned night-herons at Monomoy feed primarily on sand lance, mummichog, assorted other small fish, Fowler toads, meadow voles, immature gulls, and tern eggs and chicks (USFWS unpublished data, Hall and Kress 2008).

Figure 2.10. Nesting Black-crowned Night-herons on Monomoy NWR (1996 to 2014).



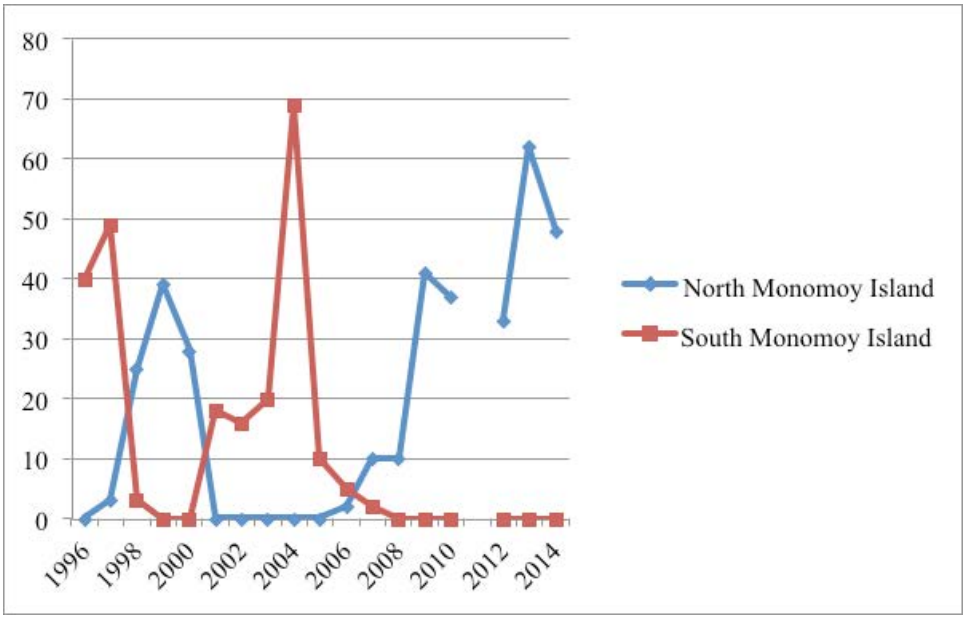
Black-crowned night-herons have been significant predators of tern eggs in past years. Black-crowned night-herons are deemed predatory only when disturbed terns are heard and then observed mobbing a heron walking through the colony in search of nests, or when herons are observed inside the tern colony actively eating tern eggs. Black-crowned night-herons observed flying over the colony or walking near the tern colony and not disturbing terns are not considered predatory and are not removed (Megyesi 1997). Refer to appendix J for more information about control of black-crowned night-herons on the refuge.

Monomoy's snowy egrets first became established on the refuge in 1981 and nest in association with black-crowned night-herons. Feeding habitat within a 5-mile radius of the snowy egret rookery provides ample food, primarily sand lance, mummichogs, and striped killifish (USFWS unpublished data). The nesting population peaked in 1987 with 90 pairs (USFWS 1988) and has fluctuated over the years. The refuge has averaged about 40 pairs in years when snowy egrets were present. In recent years, snowy egrets nested primarily on North Monomoy. In 2009, there were 41 nesting pairs of snowy egrets on North Monomoy Island (USFWS 2012) and in 2010, 37 nesting pairs (USFWS unpublished data), although numbers may be higher than recorded (figure 2.11).

Glossy ibis were recorded nesting in past years on the refuge. In 1999 one pair of glossy ibis nested on North Monomoy Island (USFWS 2000), and in both 2002 and 2004 one pair of glossy ibis nested on South Monomoy Island (USFWS 2003a, 2007b). There have been no glossy ibis nests documented on the refuge since 2004.

Great egrets also periodically nested on the refuge, with nests documented in 1996, 1997, 2005, 2008, 2010 through 2014.

Figure 2.11. Snowy Egrets on Monomoy NWR (1996 to 2014).



Raptors
Short-eared owls and great horned owls are seen on the refuge during the spring and summer months. Bald eagles and peregrine falcons are observed at Monomoy NWR during spring and fall migration and in winter. Other raptors seen on or around Monomoy NWR during migration include sharp-shinned hawks and Cooper's hawks, both State species of special concern. American kestrels, merlin, red-tailed hawks, northern harriers, and snowy owls are seen occasionally on the refuge during the winter months. Data from hawk watch surveys conducted on Morris Island by volunteer Don Manchester from 2001 to 2010 are summarized in table 2.12.

Red tail hawk

George Gentry/USFWS

Table 2.12. Hawk Watch Total Hours Observed and Species Counted by Year.

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
American kestrel	10	8	6	10	8	0	10	5	1	6
Bald eagle	1	1	0	0	0	1	0	0	0	0
Broad-winged hawk	1	0	1	0	0	5	0	0	0	1
Cooper's hawk	124	123	95	118	129	119	153	137	93	56
Merlin	36	34	43	45	30	0	28	45	21	24
Northern goshawk	2	0	0	7	3	1	4	2	1	1
Northern harrier	9	42	29	23	16	18	18	14	11	6
Osprey	8	11	13	24	10	26	24	19	27	31
Peregrine falcon	104	39	44	113	83	90	67	95	82	36
Rough-legged hawk	0	1	0	0	0	0	0	0	0	0
Red-shouldered hawk	2	0	0	0	1	0	3	1	2	2
Red-tailed hawk	2	e	7	45	42	90	59	49	48	32
Sharp-shinned hawk	1,062	754	406	692	549	1,442	802	939	575	291
Turkey vulture	12	19	21	30	29	26	30	53	30	29
Unidentified Accipiter	25	11	12	10	3	5	10	6	5	5
Unidentified Buteo	0	0	0	0	0	0	1	0	0	0
Unidentified Falcon	2	0	1	1	0	1	0	0	0	0
Unidentified Raptor	4	4	3	4	1	7	1	2	4	1
Total Hours Surveyed	207	214.5	248	254	136	249	214.5	213.5	145	112

Historically, short-eared owls, a State endangered species, nested on Monomoy NWR; however, no nesting has been recorded in recent years. In 1984, four pairs nested in the refuge, five pairs nested in 1985 and 1986, and two pairs nested in 1987 (USFWS 1988).

Great horned owls have nested in recent years on Monomoy NWR, but no official counts have been conducted (Iaquinto, personal communication 2011). Great horned owls have been active predators on the refuge in past years. Evidence of owl predation, including sightings of owls and pellets collected from the tern colony, has been documented in most years since 2004. For more information on predator management techniques refer to appendix J.

Northern harriers, a State threatened species, also nest on the refuge. Four northern harrier nests were found in the refuge in 1997, three nests in 1998, at least one nest in 1999, and three nests in 2000. The islands were not searched in their entirety during these and in subsequent years, and these numbers are likely an underestimate. In recent years, staff has been limited and the island has not been searched for nesting owls or harriers, though northern harriers are seen frequently on all portions of the refuge. Northern harriers are not controlled on the island or discouraged from hunting in the common tern colony.

Other Birds of Conservation Concern

Breeding songbird surveys were conducted on South Monomoy from 1996 to 2006. Earlier surveys (1996 to 2001) were conducted using a transect protocol and were limited to the northern half of South Monomoy. In 2001, we switched to

using a protocol that was developed by the USFWS and was standardized for all refuges in Region 5 to allow comparisons across refuges. This protocol consisted of 32 fixed points on South Monomoy that were surveyed annually from 2001 to 2006. During the 6 years, 62 species and 2,620 individual birds were recorded; however, many were flyovers of non-songbirds. Of the breeding songbirds, the most commonly recorded were red-winged blackbirds (379 recorded), common yellowthroat (292 recorded), song sparrow (290 recorded), savannah sparrow (247 recorded), and common grackle (116 recorded). Other songbirds recorded on surveys include tree swallow, horned lark, barn swallow, eastern kingbird, yellow warbler, gray catbird, salt marsh sparrow, American goldfinch, willow flycatcher, brown-headed cowbird, bank swallow, and cliff swallow (USFWS unpublished data). Refer to appendix A for a complete list of documented breeding songbirds on the refuge.

Point counts to detect salt marsh sparrows and other salt marsh species have been conducted on the refuge to collect baseline data for these habitats. Salt marsh sparrows breed actively in salt marsh habitats on the refuge. Though no surveys have been done to measure productivity, it has been confirmed that this species has bred on the refuge in each year surveys were conducted. Counts were conducted at one point on Morris Island three times annually between 2001 and 2005 and at six points on North Monomoy Island two to three times annually between 2005 and 2010 (no surveys were conducted in 2008). At least 5 years of survey data was collected for each point. In 2011 through 2014, as part of the Salt marsh Habitat and Avian Research Project (SHARP), point counts were conducted by seasonal staff associated with the University of Maine under the supervision of Ph.D. student Maureen Correll. These surveys conducted by the SHARP project will be used to investigate changes in tidal marsh bird populations on the refuge and in eastern Massachusetts over the past 20 years by comparing current data collection to over 20 years of historical data. In addition to point counts, rapid assessment vegetation surveys were completed as part of the study following protocols of the USGS Salt Marsh Integrity Project.

Two separate SUPs have been issued for additional research pertaining to salt marsh sparrows on the refuge in recent years. In 2011, Oksana Lane from the BioDiversity Research Institute (BRI) in Maine, collected blood samples from salt marsh sparrows on North Monomoy Island. Objectives of the research were to measure mercury exposure in adult and hatch year salt marsh sparrows by sampling blood and feathers. BRI took blood samples from 22 individuals and found that only four of these individuals had slightly elevated mercury levels (above 0.7 μg/g) (unpublished data, 2011 SUP#53514-11016 Annual Report) but were below the estimated reproductive success effect level of 1.2 μg/g in songbird blood (Jackson et al. 2011).

In 2013, as part of the SHARP project, Ph.D. student Jen Walsh, from the University of New Hampshire, collected blood samples from salt marsh sparrows on North Monomoy Island with an objective of confirming that the refuge was outside the zone of hybridization with Nelson's sparrows. The results of this work have not yet been reported to the refuge.

In 2011, volunteer James Junda founded the Monomoy Refuge Banding Station (MRBS) with cooperation of the refuge staff. It operated from 2011 to 2014 with volunteers and highly trained professional banders. Operations were based upon the protocols of other constant effort banding stations in the United States and Canada, with an emphasis on standardized research protocols (Junda 2013). Fall migration monitoring provides the basis for long-term trend analysis of migrating birds using the refuge. The protocol used on the refuge is designed to be comparable with the methodology of other fall migration banding stations.

The protocol includes regular monitoring, standardized census, banding, and incidental observations taken each day station staff were present.

The fall migration season extends from August 15 to November 15. In 2011, the banding station was open on 14 days; during 2012, the effort was increased to a total of 36 days, though coverage was intermittent due to weather unsuitable for banding. A total of 934 birds and one bat comprising 73 different species were captured and banded in 2011; during 2012, 1,787 individual birds of 79 species were captured. In total, 91 species have been banded at the MRBS between the 2011 and 2012 fall migration seasons. In addition to daily banding performed at the MRBS, banders attempted to trap saw-whet owls 3 nights in early November using playback calls. Ultimately they captured and banded two owls. A separate banding effort was also conducted by MRBS staff to sample salt marsh sparrows on North Monomoy Island. In total, 18 salt marsh sparrows were mist netted and banded during 2 days of netting.

The most commonly captured birds in the 2 years were myrtle warblers, tree swallows, red-breasted nuthatch, and savannah sparrows. The top 10 most common species captured over the 2 years can be seen in table 2.13. A number of species rare to the refuge were captured, including bay-breasted warbler, black-throated grey warbler, blue grosbeak, bobolink, clay-colored sparrow, lark sparrow, pine siskin, rusty blackbird, Townsend's solitaire, white-winged crossbill, and yellow-throated warbler.

Discussion about the possibility of erecting a wind turbine to provide power to the Monomoy Point light keeper's house prompted preconstruction surveys during 2010 and 2011 to determine bird use of the area during migration and the nesting season. Surveys were performed from mid-August through October in 2010 and from mid-April through September in 2011. While these surveys were designed to evaluate potential impact to birds resulting from a wind turbine (variables such as height of flight were recorded), they provide useful baseline data about frequency and abundance of bird use in this area.

Table 2.13. Most Common Species Captured at MRBS 2011 to 2012 (includes recaptures).

Species	2011	2012
Myrtle warbler	274	360
Tree swallow	157	286
Red-breasted nuthatch	0	162
Savannah sparrow	63	83
Golden-crowned kinglet	17	72
Slate-colored junco	12	75
Song sparrow	26	51
Pine siskin	0	49
Common yellowthroat	26	47
Palm warbler	12	46

Data are still being analyzed, but a preliminary summary is presented here. In 2010, staff recorded 1,107 observations comprising 3,938 birds within the proposed wind turbine survey area. Of the 2,582 identifiable birds, 53 species were recorded. The 2011 surveys resulted in 1,816 observations of 13,067 birds. From the 11,825 birds identified, 64 species were recorded. The most common species observed in the survey area in 2010 included tree swallow (1,790), house sparrow (136), yellow-rumped warbler (60), double-crested cormorant (59), and

bank swallow (56). The most common species observed in 2011 included tree swallow (9,779), red-winged blackbird (285), common tern (273), common grackle (257), and double-crested cormorant (198). The banding station was continued in 2013 and 2014.

Mammals

Marine Mammals

Gray seal, a Massachusetts species of special concern, and harbor seal are found on the refuge and in the surrounding waters. Gray seals use the refuge for hauling out and pupping. In fact, Monomoy NWR is the largest haulout site for gray seals on the U.S. Atlantic seaboard, and one of only two consistent sites in Massachusetts where gray seals pup. Gray seals use the refuge lands and waters all year. Gray seal pupping may be increasing, though there have never been high levels of pupping on the refuge. Many more gray seals pup on Muskeget, an island off of Nantucket. Gray seals start to group up in late autumn and pupping generally occurs from mid-December to early February. Pups are nursed for 3 weeks until they molt their white coat. Once the pups molt, they disperse and may be seen at distances relatively far from where they were born. Males will breed with females immediately following pupping.

Official counts of gray seal adults have not been conducted since the late 1990's, so an exact population estimate is not known. Since the population is always changing and is relatively plastic, it is difficult to narrow down how many individuals use the refuge lands and waters, but it is certainly in the thousands. In 1999, Margaret E. Barlas completed a study on the distribution and abundance of gray and harbor seals that included aerial surveys. In her study, the high count for gray seals on Monomoy was a May 1999 count of 3,322 individuals. No harbor seals were counted at that time, but the number has certainly increased in recent years.

Harbor seals are winter, not year-round residents on the refuge. They generally start arriving in refuge waters in early September. Harbor seal numbers increase slowly through the fall and winter period and then quickly drop off in March. Though harbor seals are still present, their numbers are not as high as in the past. Gray seals seem to be displacing harbor seals to some extent, but the two species will haul out together, with gray seals occupying the upper beach and harbor seals staying closer to the water. Peak pupping for harbor seals is in June and occurs elsewhere, mainly on the coasts of Maine and maritime Canada (Waring, personal communication 2010).

Terrestrial Mammals

Monomoy NWR's small terrestrial mammals, which include the masked shrew, northern short-tailed shrew, white-footed mouse, common muskrat, meadow jumping mouse, and meadow vole, serve as prey for the refuge's raptors. Of these, the meadow vole is the most abundant small mammal. Although none are known residents, the big brown bat, red bat, and hoary bat have also been recorded on Monomoy NWR (USFWS 1988). In 2010 and 2011, ultrasonic recordings were made to survey bats flying over the area surrounding the Monomoy Point Lighthouse, but data are still being analyzed. No other formal terrestrial mammal surveys have been conducted on the refuge since 1988.

When the island first became isolated from the mainland, the Service removed red fox. Mammal sightings were rare through the 1980s (long-tailed weasel (1983), Norway rats (1985), raccoon (1986)). Since 1995, mammals including red fox, raccoon, striped skunk, and Virginia opossum have been periodically noted on the refuge. In 2000, one striped skunk was seen; in 2001, a striped skunk was shot and removed from the refuge; and in 2011 skunk tracks were seen near the lighthouse. In 2007, a raccoon carcass was found near the lighthouse, and raccoon tracks were seen several times in 2010 through 2012. Tracks and a raccoon carcass were observed on Nauset/South Beach near the South Monomoy connection in 2012. No live raccoon were seen on the islands or South Monomoy

since 2005. Virginia opossum were seen or confirmed as present most years between 2006 and 2012, though they were only a problem for nesting birds in 2008. River otter were sighted in the fresh water ponds in 2007, 2011, and 2012. For more information on predation by small mammals on the refuge, refer to appendix J.

Evidence of coyote on Monomoy NWR was first recorded in 1996 (USFWS 1996b), and evidence of coyote denning has been observed in most years since 1998. Beginning in 1998, lethal coyote removal has been conducted to minimize depredation on nesting birds. The refuge has employed a variety of techniques that are outlined in appendix J.

It is possible that the presence of potential mammalian predators (i.e., coyote, red fox, domestic dog, fisher, mink, weasel, striped skunk, river otter, raccoon, opossum, and muskrat) will increase. Access to the island became easier for land-based mammalian predators with the connection to Nauset/South Beach in November 2006, and an increase was seen in mammal activity on South Monomoy. It appears that the February 2013 break in Nauset/South Beach could be contributing to a decline in the number of coyotes seen in the spring and summer of 2013 on the refuge.

Between 1960 and 1980, the white-tailed deer population on Monomoy remained fairly constant at 15 to 25 individuals. A high count of 30 deer was made in 1984, but during March and April of 1985, 11 winter and storm-killed deer were found; necropsies revealed the deer had been in poor health. An aerial survey conducted in January 1986 tallied 15 deer on the refuge, and the deer population has likely remained around 15 to 25 since that time (USFWS 1988), although no formal deer surveys have been conducted since 1986. More recent information on deer using South Monomoy Island is anecdotal and has come in large part from staff spending the summer working near the lighthouse.

Amphibians and Reptiles

No formal studies have been conducted to inventory amphibians or reptiles on Monomoy NWR; however Fowler's toad, American toad, eastern ribbon snake, and common garter snake are present on the refuge. Eastern hognose snakes have been confirmed on the refuge, though they are rare and have not been documented every year.

Sea Turtles

Five sea turtle species, green, hawksbill (rare visitor), Kemp's ridley, leatherback, and loggerhead can be found in the waters surrounding the refuge and are all protected under the U.S. ESP (see appendix A for species status). The National Marine Fisheries Service (NOAA-NMFS) is the lead agency for pelagic sea turtle recovery. The Massachusetts Audubon Society's Wellfleet Bay Sanctuary operates and maintains a sea turtle sighting hotline for southern New England boaters (*http://www.seaturtlesightings.org*; accessed July 2013). The sighting hotline website provides maps of sightings by turtle species, year, and month. The hotline maps and data points do not represent a systematic survey, nor an accurate count of sea turtles, but are helpful for characterizing sea turtle status and use near Monomoy.

The nearshore open waters of northeastern Nantucket Sound, including those west of Monomoy, are a primary June through September feeding location for adult leatherbacks turtles, the most commonly sighted species (*http://seaturtlesightings.org/monthmap.html*; accessed July 2013, Prescott, personal communication 2013) when jellyfish become abundant. July and August are the peak months for sea turtle sightings around Monomoy. Loggerhead turtles were also sighted almost annually since 2003, and Kemp's ridley turtles so common in Cape Cod Bay are sighted infrequently in the Nantucket Sound waters west of Monomoy. As water temperatures warm in the spring, sea turtles migrate north from tropical and subtropical waters to inhabit their northern

foraging grounds. Juveniles and, to a lesser extent, adults are found along the New England coast from May through November, when water temperatures are favorable, and return south before the onset of winter (NOAA 2013).

Threats to sea turtles in the marine environment include bycatch in commercial and recreational fisheries, vessel collisions, and marine debris entanglement and ingestion (NOAA 2013). Several species have been recovered or entangled in refuge waters in recent years. Since 1996, there have been nine documented sea turtle entanglements (six leatherbacks and three loggerheads) with fixed fishing gear (pots and weirs) on or near the refuge (map 2.5) (Landry, personal communication 2013). In 2008, a dead Kemp's ridley sea turtle was recovered within the refuge Declaration of Taking boundary. When dead or stranded sea turtles are discovered on the refuge they are reported to Mass Audubon, who manages immediate response for stranded sea turtles on Cape Cod, and to the NOAA Fisheries Service Northeast marine mammal and sea turtle stranding hotline. Given the potential that seasonal use of refuge waters within the Declaration of Taking boundary may be increasing, gear entanglement and vessel strike incidence for sea turtles may correspondingly increase during the 15-year plan period to a point where additional management actions may be required.

Fish

Aquatic species on Monomoy NWR are found in both freshwater and saltwater ponds and marshes. Freshwater ponds and marshes on South Monomoy Island cover more than 140 acres (USFWS 1988). There are no freshwater ponds or marshes on North Monomoy, Minimoy Island, or Morris Islands. The main freshwater ponds on South Monomoy Island are Big and Little Station Ponds; other small freshwater ponds and wetlands dot the island. The two main salt ponds on South Monomoy Island are Hospital Pond and Powder Hole. Almost 25 acres of salt marsh surround the 5-acre estuarine Hospital Pond at the northern end of South Monomoy Island. Powder Hole, which in the mid-1800s was a deep and extensive harbor, is now a shallow estuarine waterbody on the southwest end of the refuge.

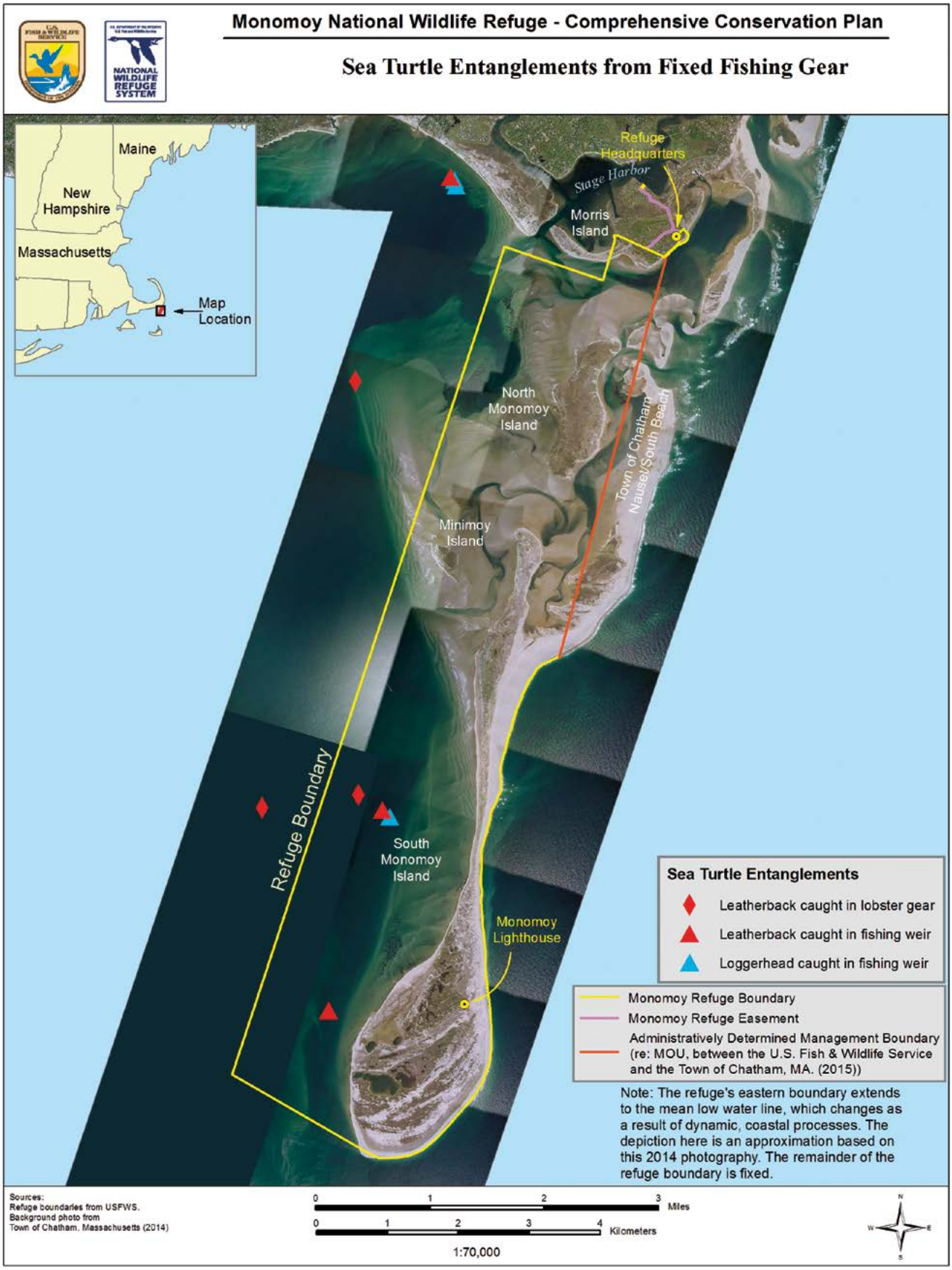
Freshwater Fish

Big Station Pond, approximately 32 acres, and Little Station Pond, approximately 11 acres, naturally formed on South Monomoy Island as deep saltwater lagoons, which subsequently became cut off from the ocean and are now freshwater ponds. Big Station Pond may occasionally get an influx of salt water from high storms (Iaquinto, personal communication 2011). Both are considered warm water ponds. Very little formal information about the fisheries and ponds on Monomoy is available; however, it is likely the ponds on the refuge have American eel, as well as mosquitofish and other small fish (Camisa, personal communication 2011). In 1951 and 1952, the Service stocked largemouth bass in these ponds and bass were abundant for a few years.

Saltwater Fish

A large number of fish species are found in Nantucket Sound and the Atlantic side of South Monomoy Island. These fish species are listed in appendix A, as compiled from the State of Massachusetts Division of Marine Fisheries (MA DMF) trawl surveys. The rich diversity of marine life is a result of the unique geographic location of Nantucket Sound. It is located along the confluence of the cold Labrador Current and the warmer Gulf Stream, creating an ecological transitional zone where the ranges of southern and northern species overlap (Center for Coastal Studies 2003).

The sand eel or American sand lance, a small fish abundant in the ocean waters around Monomoy, is an important food species for many larger fish and for colonial waterbirds nesting on the refuge (USFWS 1988). Striped bass and bluefish are commonly found in the nearshore waters in Nantucket Sound off South Monomoy Island.


Monomoy National Wildlife Refuge - Comprehensive Conservation Plan
Sea Turtle Entanglements from Fixed Fishing Gear
Maine
New Hampshire
Massachusetts
Map Location
Refuge Headquarters
Stage Harbor
Morris Island
North Monomoy Island
Town of Chatham Nauset/South Beach
Minimoy Island
Refuge Boundary
South Monomoy Island
Monomoy Lighthouse
Sea Turtle Entanglements
Leatherback caught in lobster gear
Leatherback caught in fishing weir
Loggerhead caught in fishing weir
Monomoy Refuge Boundary
Monomoy Refuge Easement
Administratively Determined Management Boundary (re: MOU, between the U.S. Fish & Wildlife Service and the Town of Chatham, MA. (2015))
Note: The refuge's eastern boundary extends to the mean low water line, which changes as a result of dynamic, coastal processes. The depiction here is an approximation based on this 2014 photography. The remainder of the refuge boundary is fixed.
Sources:
Refuge boundaries from USFWS.
Background photo from
Town of Chatham, Massachusetts (2014)
0 1 2 3 Miles
0 1 2 3 4 Kilometers
1:70,000

The Magnuson-Stevenson Fishery Conservation Act (MSFCMA) of 1976 established eight regional councils tasked with managing various fishery resources within Federal waters. The New England Fishery Management Council (NEFMC) and the Mid-Atlantic Fishery Management Council (MAFMC) are responsible for developing fishery management plans for species inhabiting Nantucket Sound. The Sustainable Fisheries Act (1996) amendment to MSFCMA requires NOAA NMFS and the management councils to identify and describe essential fish habitat (EFH) for federally managed species, and specify actions to conserve and enhance EFH. Congress defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 U.S.C. § 1802(10)). Additionally, management councils designate habitat of particular concern (HAPC) to areas within EFH that are ecologically important, sensitive to disturbances, or rare (50 CFR 600.815(8)). Designating HAPC is intended to specify high priority areas within EFH where managers should focus conservation efforts.

EFH designations occur in portions of open water within the Declaration of Taking boundary for 13 federally managed species of fish, including Atlantic cod, pollock, windowpane flounder, winter flounder, yellowtail flounder, white hake, silver hake, little skate, winter skate, ocean pout, Atlantic wolfish, smooth dogfish, and Atlantic bluefin tuna (table 2.14; NOAA 2009b, NEFMC 2012). Waters in the Declaration of Taking boundary have also been identified as habitat of particular concern for juvenile Atlantic cod (NEFMC 2012).

Table 2.14. Essential Fish Habitat at Monomoy NWR.

Common Name	Scientific Name	Life History Stages			
		Egg	Larval	Juvenile	Adult
Major Gadids					
Atlantic cod	*Gadus morhua*	X	X	X	
Pollock	*Pollachius virens*			X	
Flat Fish					
Windowpane flounder	*Scophthalmus aquosus*			X	X
Winter flounder	*Pseudopleuronectes americanus*		X		X
Yellowtail flounder	*Limanda ferruginea*			X	X
Hakes					
White hake	*Urophycis tenuis*		X	X	
Silver hake	*Merluccius bilinearis*	X	X	X	
Skates					
Little skate	*Raja erinacea*			X	X
Winter skate	*Leucoraja ocellata*			X	
Other Species					
Ocean pout	*Zoarces americanus*	X			X
Atlantic wolffish	*Anarhichas lupus*	X	X	X	X
Highly Migratory Species					
Atlantic bluefin tuna	*Thunnus thynnus*			X	X
Smooth dogfish	*Mustelus canis*	X	X	X	X

Source: Data assembled from the New England Fishery Management Council Essential Fish Habitat and Habitat Area of Particular Concern Designation Alternatives Draft 2012; and NOAA Fisheries Division of Highly Migratory Species Amendment 1 to the consolidated Highly Migratory Species Fishery Management Plan, June 2009.

Invertebrates

Countless species of marine invertebrates, including insects, shellfish, horseshoe crabs, and marine worms, amphipods, and other crustaceans inhabit the refuge's terrestrial and intertidal habitats. Many of these are a vital food source for shorebirds and seabirds (USFWS 1988). Although no formal, standardized surveys have been done to document abundance and diversity of invertebrate species, Leavitt and Peters (2005) compiled a table of benthic species that are likely to occur on the sandflats of Monomoy NWR. As stated in Leavitt and Peters (2005), the list, "was generated based on reported presence of the organisms in local sandflats coupled with further investigation into their life history details, primarily using Weiss (1995)." The table of likely species can be found in appendix A.

In 2007, refuge staff collected sediment core samples to quantify invertebrate species available for foraging shorebirds. A 10-cm diameter corer was used to a depth of 5 cm (sample volume of 393 cm^3), with samples collected during two sampling periods (July 7 to July 22 and August 23 to September 8), which coincided with peak migration periods of the most abundant shorebird species on the refuge (Koch and Paton 2009). A total of 375 samples was collected during each sampling period. All macrofauna (greater than 1 mm) were counted and classified into six categories: (1) amethyst gem clams; (2) mollusks (Phylum Mollusca, except *G. gemma*); (3) annelids (Phylum Annelida); (4) horseshoe crab eggs, membranes, or larvae; (5) arachnids/insects (Classes Arachnida and Insecta); and (6) crustaceans (Class Crustacea). A mean estimate of abundance/core of each macrofauna category was calculated for each sampling period and is in table 2.15 below. The mean abundance for each category was statistically different between time periods (Koch 2010).

Table 2.15. Macrofauna Abundance in Sediment Cores.

Prey category	(SE) $core^{-1}$	
	Period 1	Period 2
Gemma gemma	118.1 (5.50)	164.1 (10.18)
Phylum Mollusca	17.1 (1.33)	40.3 (2.82)
Phylum Annelida	2.7 (0.28)	3.9 (0.40)
Horseshoe crab eggs	0.9 (0.15)	0.4 (0.08)
Classes Arachnida and Insecta	0.5 (0.11)	0.7 (0.19)
Class Crustacea	3.4 (0.26)	4.9 (0.48)

Intertidal marine flats and nearshore marine waters support softshell clams, northern quahogs, blue mussels, bay scallops, sea scallops, razor clams, and surf clams. Shorebirds and gulls feed on shellfish in intertidal flats and mussel beds in Nantucket Sound, while sea ducks utilize subtidal shellfish.

Horseshoe Crab

The intertidal habitat at Monomoy NWR hosts one of the largest spawning sites for horseshoe crabs in Massachusetts (USFWS 2002). Horseshoe crabs are an important component of the Northeast coastal ecosystem and their eggs are an integral part of the coastal food web. Horseshoe crab eggs provide an important food source for birds, including gulls (Botton and Loveland 1993, Shuster Jr. 1982, Penn and Brockman 1994, Burger and Wagner 1995) and migrating shorebirds. In addition, horseshoe crab eggs and larvae are often eaten by minnows and juveniles of larger fish, (Harrington and Shuster Jr. 1999, Mugford 1975, USFWS 1988, Finley, personal communication 2011) including killifish species (Finley, personal communication 2011), such as striped killifish, eel species such as American eel, (Warwell 1897, deSylva et al. 1962), weakfish, northern kingfish, Atlantic silverside, summer flounder, winter flounder (deSylva

et al 1962, Penn and Brockman 1994), striped bass (Martin 1974), and white perch (Shuster Jr. 1982). Other fauna observed feeding on horseshoe crab eggs, hatchlings, and adults include sand shrimp (Price 1962), eight mollusk species (Perry 1940, as in Shuster Jr. 1982), fiddler crabs (Shuster Jr. 1958 as in Shuster Jr. 1982), blue crab, green crab, spider crab in Barnstable Harbor, Massachussetts (Shuster Jr. 1958 as in Shuster Jr. 1982), devil ray, (Teale 1945 as cited in Shuster Jr. 1982), puffers (Shuster Jr. 1958 as cited in Shuster Jr. 1982), sharks (Shuster Jr. 1982), and loggerhead sea turtles (Atlantic States Marine Fisheries Commission [ASMFC] 1998 and Musick et al 1983).

Robert Pos/USFW

Horseshoe crab

There is no known recreational fishery for the horseshoe crab, but they are commercially harvested for use as bait for American eel and conch or whelk fisheries. Horseshoe crab blood is also important to biomedical research and pharmaceutical testing (refer to chapter 3 for more details). Concern over the growing exploitation of horseshoe crabs has been expressed by State and Federal fishery resource agencies, conservation organizations, and fishery interests. Harvest closures in states south of Massachusetts in the early 2000's motivated harvesters to move their operations north. The increased harvesting pressure on Monomoy NWR caused refuge staff to review the position on horseshoe crab harvesting. At that time, one biomedical harvester was issued a SUP by the refuge to collect horseshoe crabs from refuge waters by SUP. Commercial harvesting for bait was never officially permitted, and beginning in 2000, refuge staff enforced a prohibition on all harvesting activity and denied further SUP's for biomedical harvesting. A local horseshoe crab harvester filed a lawsuit against the USFWS and the neighboring NPS as a result. The Service completed a comprehensive CD released to the public on May 22, 2002, and resurveyed the refuge boundary. The final decision to prohibit all horseshoe crab harvesting on the refuge is still enforced today.

Refuge staff conduct spawning counts in some years to provide a long-term index of the local population size; they also tag and re-sight tagged horseshoe crabs to learn more about local movement patterns and contribute to rangewide studies of harvest activities. Conducting spawning counts in concert with other sites in Massachusetts is important because of the role the refuge plays in overall recovery. The refuge also serves as a control site when evaluating the impacts of harvest at other sites on population, sex ratios, and mean size. Spawning surveys were first conducted on the refuge in 2000, when the ban on harvesting began. Between 2000 and 2002 a study was conducted that compared spawning and sex ratios on four sites on Cape Cod including Monomoy NWR and Nauset Estuary consistently had the lowest sex-ratios of the four sites (Monomoy NWR 1:1.9, Nauset Estuary 1:1.6). In 2000, Monomoy NWR had significantly lower ratios (more females to males) than either Pleasant Bay or Cape Cod Bay. There was both a lower frequency of females and a higher frequency of males at the non-refuge sites (James-Pirri 2012). Spawning indices at Monomoy were 1:1.9 in the original survey period between 2000 and 2002, and were 1 to 1.8 between 2008 and 2009 (James-Pirri et al. 2005).

Tagging has been conducted in cooperation with the Maryland Fisheries Resource Office every year since 2001 (see table 2.16 for total number of crabs tagged). Data are used to track changes in populations over time, document movement between embayments, and document impacts of harvest activity.

Table 2.16. Total Number of Horseshoe Crabs Tagged on Monomoy NWR (2001 to 2014).

Year	Number of Males	Number of Females	Total crabs Tagged	Total Number of Resights Reported*
2001	510	328	838	19
2002	398	150	548	43
2003	332	104	436	14
2004	291	118	409	20
2005	288	303	593	19
2006	266	134	400	14
2007	299	147	446	19
2008	394	48	442	13
2009	347	139	486	28
2010	377	85	462	34
2011	438	156	598	54
2012	612	191	803	55
2013	304	80	384	91
2014	451	60	511	64

**The number of re-sights includes crabs from one cohort that have been re-sighted in multiple years.*

Since tagging began in 2001, 332 crabs have been re-sighted and reported. Between 2001 and 2007, tags were reported to a hotline at the refuge office, but reports were often incomplete. In 2008, the refuge began using disc tags issued by the Maryland Fisheries Resource Office, which included a tag re-sight phone number at that office. With Monomoy NWR's formally joining this project, resightings can be much more efficiently collected by volunteers at one location and, therefore, information on resightings since 2008 is likely more complete (Iaquinto 2013, personal comment). Approximately half of the crabs reported as being alive when resighted since 2008 (73 in total) were reported by beachcombers. Crabs are also reported by a variety of other observers, including refuge staff, sport or commercial fishermen, and biomedical companies. Though harvest is not allowed on the refuge, some crabs are likely captured for bait or bleeding outside the refuge boundary, and reported. Most of the 73 crabs reported alive were released, though 5 were kept for bait, 3 were bought or sold, and 1 was reported as "other." One hundred four of the crabs resighted were reported as being found dead; the majority of these were reported by beachcombers. Only 7 crabs were reported with an unknown status (USFWS unpublished data). Seventy-six percent of the crabs resighted since 2008 were found in the Chatham area. Forty-four crabs were found in different towns, though the majority of them were on Cape Cod, the islands of Martha's Vineyard and Nantucket, or immediately adjacent towns surrounding Buzzard's Bay. One crab was found in Fenwick, Delaware, and must have been transported by artificial means.

Insects

Portions of South Monomoy Island were surveyed as part of the Virginia Tech piping plover study mentioned in the Federally Listed Endangered or Threatened Species section of this document. Researchers collected invertebrates on South Monomoy. The invertebrates found in largest numbers were flies (Order Diptera), beetles (Order Coleoptera), and crustaceans (Order Crustacea) (Keane 2002).

Informal surveys of dragonflies (Order Odonata) were completed on several trips to South Monomoy Island by Blair Nikula, Jackie Sones, and Jeremiah Trimble in the 1990s. The species present during these surveys have been listed in appendix A, though it is likely that additional species occur on the refuge as occasional visitors from the mainland or vagrants from farther afield. (Nikula, personal communication 2013).

Hairy-necked tiger beetle, bronzed tiger beetle, and margined tiger beetle, also commonly listed as salt marsh tiger beetle, are also present on the refuge, along with one species of robber-fly (family Asilidae) (Kapitulik, personal communication 2011).

Invasive Species

No formal inventory has been done of invasive species on the refuge, although *Phragmites* and rugosa rose are known to exist on Monomoy NWR. Rugosa rose is used by herons, egrets, and gulls as nesting habitat and has not been controlled on the refuge. *Phragmites* occurs in both shallow, freshwater marshes and intertidal habitats (Gucker 2008). This species is a persistent and hearty perennial plant that can reach heights up to 20 feet tall and out-compete native plant species (Gucker 2008). *Phragmites* often forms single-species stands with thick mats of roots and rhizomes.

In July 2003, refuge staff collected *Phragmites* samples from 12 different stands (map 2.6) on South Monomoy Island and submitted them to Cornell University to determine if they are the native or introduced genotypes. All samples (including the two stands discussed below) were diagnosed by Dr. Bernd Blossey as the introduced genotypes.

In 2011, efforts were made to control the spread of *Phragmites* in the main tern colony on South Monomoy. A small stand occurs in a low-lying, centrally located area within the South Monomoy common tern colony. This particular stand provides protection and cover for predators such as coyotes. A second stand occurs south of the primary nesting area, providing an additional space to conceal predators. *Phragmites* control work was not continued in 2012 due to time constraints and poor weather during the months of September and October.

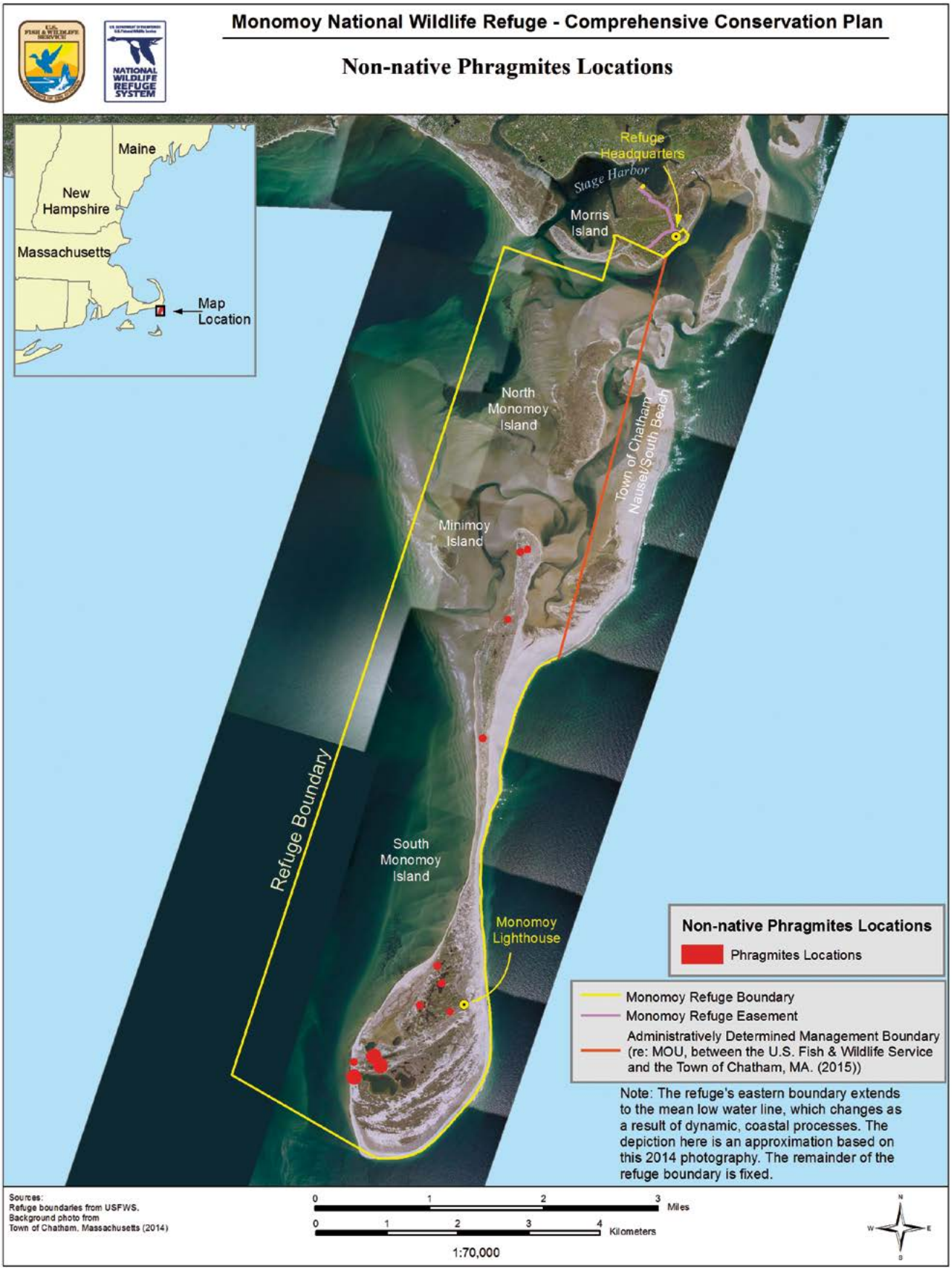
Mute swans are an exotic species of waterfowl introduced from Europe sometime in the late 1800s. Mute swans are very aggressive during nesting season and have been documented killing the young of other nesting waterfowl nearby. In 1996, 12 adult mute swans were observed in the refuge, although no formal surveys were conducted. Mute swans are lethally removed by refuge staff in order to prevent the establishment of a mute swan population on the refuge.

Refuge Visitor Services Program

The Refuge Improvement Act designated six priority public uses on national wildlife refuges: hunting, fishing, wildlife observation, photography, environmental education, and interpretation. As detailed in the Service's "General Guidelines for Wildlife-Dependent Recreation," (605 FW 1), we will strive to meet the criteria for a quality wildlife-dependent recreation program.

All of the six priority public uses are currently occurring on the refuge, although the refuge has never officially been open for waterfowl hunting. Based on staff observations and refuge-led programming, opportunities for the remaining five priority uses are being provided in varying degrees, and are in demand by visitors and residents of Chatham and the surrounding area. All of these activities are sufficiently provided elsewhere on Cape Cod, including on adjacent Town land and the Cape Cod National Seashore. As such, refuge land restrictions do not eliminate the opportunity for those public uses elsewhere in the Chatham area.

In recent years, the Service has recognized the importance of connecting children with nature. Scholars and health care professionals are suggesting a link


Monomoy National Wildlife Refuge - Comprehensive Conservation Plan
Non-native Phragmites Locations
Maine
New Hampshire
Massachusetts
Map Location
Refuge Headquarters
Stage Harbor
Morris Island
North Monomoy Island
Town of Chatham
Nauset/South Beach
Minimoy Island
Refuge Boundary
South Monomoy Island
Monomoy Lighthouse
Non-native Phragmites Locations
Phragmites Locations
Monomoy Refuge Boundary
Monomoy Refuge Easement
Administratively Determined Management Boundary (re: MOU, between the U.S. Fish & Wildlife Service and the Town of Chatham, MA. (2015))
Note: The refuge's eastern boundary extends to the mean low water line, which changes as a result of dynamic, coastal processes. The depiction here is an approximation based on this 2014 photography. The remainder of the refuge boundary is fixed.
Sources:
Refuge boundaries from USFWS.
Background photo from
Town of Chatham, Massachusetts (2014)
0 1 2 3 Miles
0 1 2 3 4 Kilometers
1:70,000

between a disconnection with the natural world and some physical and mental maladies in our Nation's youth (Louv 2005).

We strive to promote the concept of connecting children and families with nature in all of our compatible wildlife-dependent recreational opportunities. We look to our partners such as the Friends of Monomoy, Mass Audubon, the NPS, the Town, and others to help us develop and assist with both formal environmental education and informal programming to utilize the outdoors as a classroom.

When developing plans for recreational uses, the refuge staff first evaluates the potential for negative impacts to wildlife, and completes a CD to ensure that the use does not materially interfere with purposes of the refuge or the mission of the Refuge System. The refuge seeks locations and creates designs that would provide high quality wildlife experiences for visitors, while also taking into account the ability to maintain programs and facilities over time with existing resources and funding. Refuge efforts are increased by assistance from our Friends group, volunteers, and other partners, without whose help we would be unable to develop or deliver current and proposed recreational programs.

The USGS, in collaboration with the USFWS, conducted visitor surveys for selected refuges nationwide; Monomoy NWR was among those chosen. During the summers of 2010 and 2011, with help from volunteers, the refuge requested contact information from visitors. The USGS used this information to contact and interview participants. The information collected was presented in a report, National Wildlife Refuge Visitor Survey Results: 2010/2011 (Sexton et al. 2011), made available to the public. The individual results for Monomoy NWR provide a summary of trip characteristics and experiences of a sample of visitors. These data can be used to inform decision-making efforts related to the refuge, such as visitor services management, transportation planning and management, and during the planning of this draft CCP/EIS. This effort will allow for a better understanding of visitors' recreational, educational, and informational experiences, and will measure satisfaction with current services, access, and facilities.

In the survey results report, we learned that 70 percent of visitors were aware of the role of the Service in managing national wildlife refuges, and 84 percent aware that the Refuge System has the mission of conserving, managing, and restoring fish, wildlife, plants, and their habitat. While most visitors are not aware of the day-to-day refuge operations that occur, they realize the refuge plays an important role in conservation. Of those who responded, approximately 75 percent traveled beyond 50 miles to visit the refuge, 50 percent of whom stated that visiting the refuge was one of many equally important reasons for their trip.

The visitor characteristics showed that nearly all (93 percent) surveyed visitors to Monomoy NWR indicated that they were citizens or permanent residents of the United States. Only those visitors 18 years or older were sampled. Visitors were a mix of 53 percent male with an average age of 59 years and 47 percent female with an average age of 54 years. Visitors, on average, reported they had 17 years of formal education (graduate or professional school). The median level of income was $75,000 to $99,000. Visitors to the refuge were predominantly Caucasian (96 percent).

Based on visitation estimates, approximately 68 percent of visitors are participating in wildlife-dependent recreational uses. In the USGS survey, 94 percent of respondents stated they were satisfied with the recreational activities and opportunities available. Although each visitor may have individual reasons to visit the refuge and stay for varying lengths of time, it became clear through conducting this survey that those visiting are individual families (as opposed to large groups), with 84 percent of visitors using private vehicles to access Morris Island. This statistic points to the parking congestion we have been facing at the refuge for many years, which has resulted in decreased

access to potential visitors unable to locate an available authorized parking spot. Respondents stated they were likely to use a boat that goes to different points on refuge waterways; an offsite parking lot that provides trail access; a bus/tram that provides a guided tour; and a bike share program. We intend to address these access needs in the implementation of the transportation study through the strategies identified in chapter 3 (available online at: *http://www.fws.gov/refuge/monomoy/* (accessed October 2015).

Some uses, such as sport fishing or birdwatching, require wildlife and are considered priority public uses. By law, we are to facilitate all priority public uses that are compatible on the refuge. Others, such as swimming, sunbathing, or dog walking, do not require wildlife. These latter uses are not priority public uses and do not need to be offered by the refuge. In this section, we describe the priority, non-priority, and unauthorized uses that have been occurring on the refuge in recent years.

People come to the refuge for a variety of reasons. Table 2.17 describes refuge visitation in 2014.

Table 2.17. Number of Visitors by Activity in 2014.

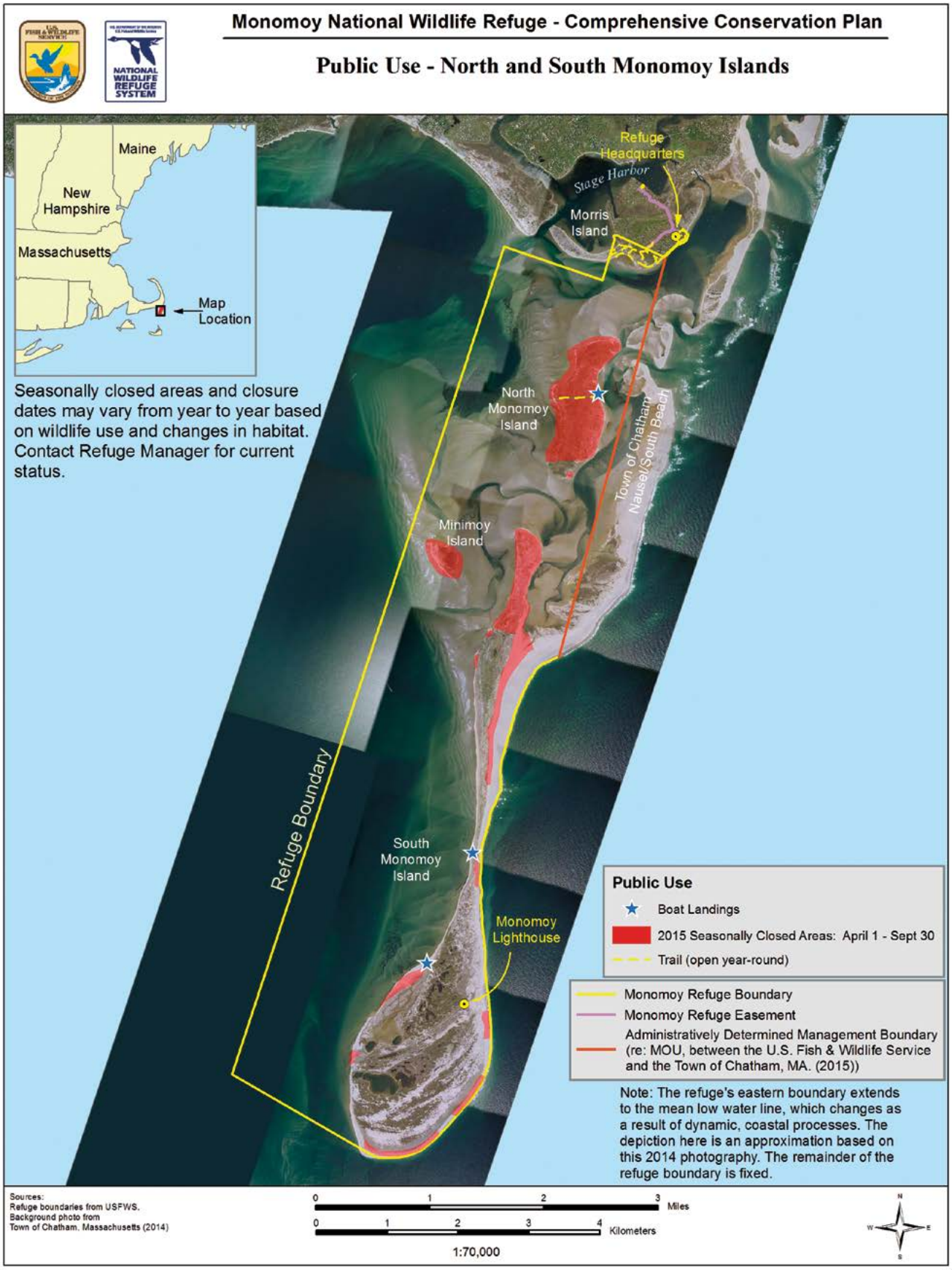
Activity	Visitors
Visitor center	13,800
Other non-priority public uses	9,135
Wildlife observation	6,020
Special events	0
Fishing	2,100
Nature photography	515
Interpretive programs onsite	580
Environmental education programs onsite	0
Total	32,150

Priority Wildlife-Dependent Public Uses

Described below are the current opportunities the refuge provides for engaging in priority public uses as defined by the Refuge Improvement Act of 1997. Portions of the refuge are closed seasonally to protect wildlife, as shown in maps 2.7 and 2.8. Visitors may drive, walk, or bicycle to the visitor contact station, beach, and trails on Morris Island. Parking is somewhat limited at this site. North Monomoy Island and South Monomoy are accessible by boat or, in season, by commercial ferry, which offers opportunities for wildlife viewing and fishing. The refuge is open from 1/2-hour before sunrise to 1/2-hour after sunset, except for surf fishing on Morris Island, which is allowed 24 hours a day.

Wildlife Observation and Photography

A 3/4-mile trail, the Morris Island Trail located on Morris Island, winds through a variety of coastal habitats and offers a unique opportunity to access two viewing locations. Overlooks along the trail provide views of the refuge's North Monomoy Island and South Monomoy Island. There is a small trail on North Monomoy Island; there are no formal trails on South Monomoy Island. Historically, a boat was needed to access both North Monomoy Island and South Monomoy Island, but with the connection of South Monomoy Island to Nauset/South Beach in 2006, visitors could walk 5 miles to the refuge from Chatham's Lighthouse Beach. The February 2013 breach made this impossible. Visitors reach the islands by private boats or, in season, by commercial ferries that operate on the refuge under a SUP. These remote locations provide superior landscape and seasonal wildlife viewing opportunities in a nationally designated wilderness area.


Monomoy National Wildlife Refuge - Comprehensive Conservation Plan
Public Use - North and South Monomoy Islands
Maine
New Hampshire
Massachusetts
Map Location
Seasonally closed areas and closure dates may vary from year to year based on wildlife use and changes in habitat. Contact Refuge Manager for current status.
Refuge Headquarters
Stage Harbor
Morris Island
North Monomoy Island
Town of Chatham Nauset/South Beach
Minimoy Island
Refuge Boundary
South Monomoy Island
Monomoy Lighthouse
Public Use
Boat Landings
2015 Seasonally Closed Areas: April 1 - Sept 30
Trail (open year-round)
Monomoy Refuge Boundary
Monomoy Refuge Easement
Administratively Determined Management Boundary (re: MOU, between the U.S. Fish & Wildlife Service and the Town of Chatham, MA. (2015))
Note: The refuge's eastern boundary extends to the mean low water line, which changes as a result of dynamic, coastal processes. The depiction here is an approximation based on this 2014 photography. The remainder of the refuge boundary is fixed.
Sources:
Refuge boundaries from USFWS.
Background photo from
Town of Chatham, Massachusetts (2014)
0 1 2 3 Miles
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Monomoy National Wildlife Refuge - Comprehensive Conservation Plan
Public Use - North Monomoy Island
North Monomoy Island
Trail (open year-round)
The red shaded areas are seasonally closed to public access. Areas may change from year to year based on wildlife use and changes in habitat. Contact Refuge Manager for current status.
Public Use
Boat Landing
Trail (open year-round)
2015 Seasonally Closed Areas: April 1 - Sept 30
Sources:
Refuge boundaries and public use data from USFWS.
Background image from the Town of Chatham, 2014
0 1,000 2,000 3,000 Feet
0 200 400 600 800 Meters
1:10,000

Fishing
The Monomoy NWR offers superb recreational fin fishing opportunities from late spring through fall, as well as softshell clam and quahog harvesting. Anglers are allowed to surf fish in any of the areas open to public access, as well as 24-hour fishing on Morris Island. Striped bass, bluefish, bonito, and false albacore are among some of the species commonly fished from shore or boat. All State regulations apply, and anglers are required to have a State saltwater fishing license. Recreational shellfishing areas are more restrictive and visitors must possess a Town shellfishing permit. The only shellfishing to date that has been found compatible and is, therefore, authorized on the refuge is softshell clam harvesting using traditional hand tools. Know that other types of shellfish, lobster, conch, and whelk harvesting has occurred in refuge waters, but the refuge has never officially been opened to these uses.

Commercial fishing guides facilitate recreational fishing on the refuge. Captains are required by the MA DMF to obtain a for-hire fishing permit to operate in State waters. We know that commercial guides work on the refuge, but SUP's have not been issued to any guides on the refuge. Because commercial fishing guides have, for the most part, not interacted with refuge staff, we have little information about the number of guides that are operating on the refuge, the number of recreational anglers that are being commercially guided, or where and when they fish.

Hunting
Monomoy NWR has never been officially opened to waterfowl hunting, although we know that there is a long history of waterfowl hunting in the open waters off Monomoy Island. The Monomoy Branting Club of Boston was established near Shooter's Island and Inward Point in 1862 as steam powered the industrial revolution and leisure time increased (Roscoe 1995, Phillips 1932). Warren Hapgood of Boston, one-time president of the Massachusetts Fish and Game Association, was an original founding member sportsman, along with Chatham locals including George Bearse, Alonzo Nye, David Nye, and Washington Bearse, who assumed the roles of member-guides and caretakers. The club was established near the Common Flats where the Bearse and Nye families found success earning part of their annual livelihoods market gunning for shorebirds and waterfowl during the pre-Civil War decades. Several of the original buildings remained standing at the site until salvaged by the Service in 1953 (figure 2.12; USFWS 1953 unpublished) as their destruction by the encroaching sea became imminent.

Figure 2.12. Monomoy Branting Club of Boston Buildings, Storm-battered Just Prior to Demolition in 1953, Built Near Shooter's Island and Inward Point After the Club Was Established in 1862 (USFWS 1953 unpublished).

Atlantic brant was the principle game sought by club members in sink boxes (Deane 1885) each spring from 1863 to 1909, when spring brant hunting was abolished (Bent 1925, Phillips 1932). Fall sport hunting continued, but was generally less successful than spring hunting due to differing seasonal migration patterns (Bent 1925, Phillips 1932). The log of brant hunting effort and harvest kept by club members (Phillips 1932, Roscoe 1995) and popular articles of the day (Deane 1885) give some insight into the conditions and methods of that era.

The club log (Phillips 1932) records 12,091 brant harvested during spring hunts spanning 2,127 days (about six brant per day) from 1863 to 1909 (figure 2.13). Peak harvests such as the 1867 all-time high of 715, occurred at 3-year to 5-year intervals, apparently coinciding with good nesting success; more than half the brant harvested were juveniles. Conversely, poor harvest years such as the 1895 all-time low of 29 brant, also occurred at 3-year to 5-year intervals, and generally coincided with years of poor juvenile recruitment when young birds were less than 15 percent of the total harvest. Weather and climatic conditions were noted most often as affecting club hunting success during the early years. By 1875, notations in the log indicate user conflicts were beginning on the Common Flats with small boats (especially scallopers), fish weirs, other hunters, and shipwreck/salvage; these continue through the remainder of the record. In 1885 to 1888, geomorphology changes to the protective Nauset Beach were noted as altering brant flight patterns and adversely affecting hunting success.

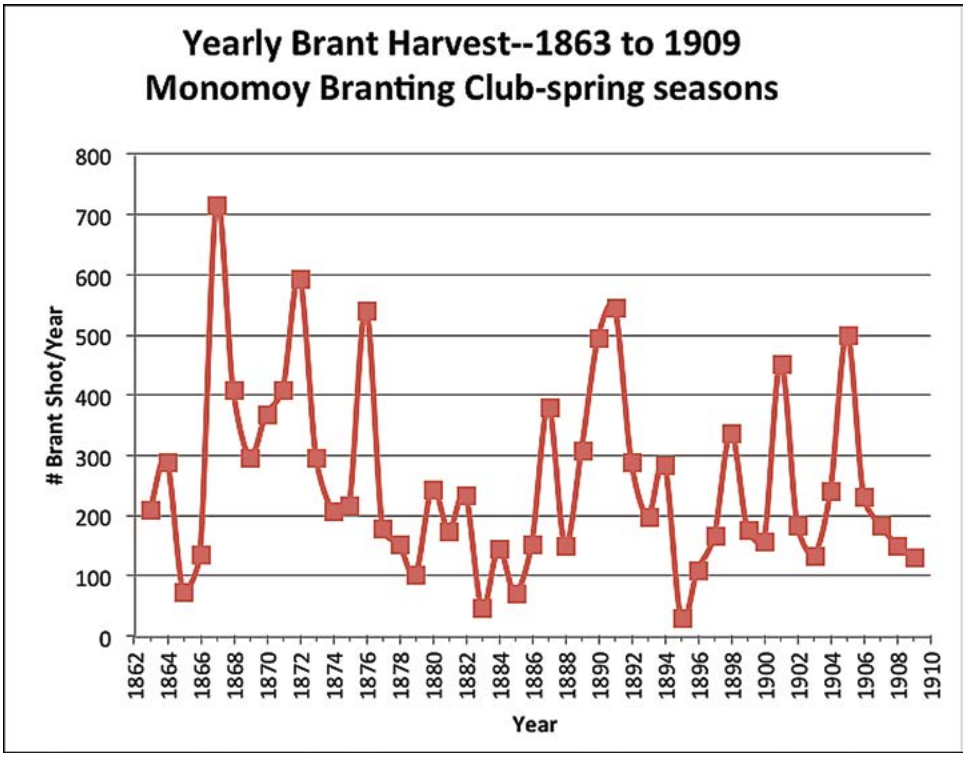


Figure 2.13. Monomoy Branting Club's Annual Brant Harvest.

Sport hunting for waterfowl on and around Monomoy continued increasing in popularity through the late 1800s, spawning rival clubs and entrepreneurs catering to growing numbers of sportsmen such as the Monomoy Shooting Club, of which William "Billy" Bloomer became the proprietor in 1898, assisted by Josiah Hunt (Roscoe 1995). But as concerns over continental waterfowl and

shorebird population declines grew into the early 1890s, so did opposition to sport hunting (Bent 1925), including opposition to the 1923 efforts by the Monomoy Branting Club to gain title to Shooter's Island (Roscoe 1995). Indications of a major decline in the previously abundant eelgrass the brant depended upon for food had become evident by 1931 to 1932 (Phillips 1932), as Monomoy began to come under consideration for establishing a new migratory bird refuge.

Today, waterfowl hunting occurs in the Chatham area and commercial guides market waterfowl hunts around Monomoy, but none have requested a refuge permit to operate within the refuge. It is likely these commercial guides are not aware the refuge has never been opened for waterfowl or any other form of hunting. The actual numbers of commercial guides operating within the refuge, the number of waterfowl hunters that are being commercially guided, where or when they hunt, or what they harvest is unknown.

Interpretation

The refuge headquarters and visitor contact station are located on Morris Island and contain wildlife-themed exhibits and informative brochures. There is also a "Junior Ranger" children's discovery area inside the contact station where young visitors can learn through hands-on activities about the refuge's resources. These activities include scavenger hunts and a "Let's Go Outside" backpack that visitors can take out onto the refuge. The refuge has one official trail at this time, called the Morris Island trail, which is ¾-mile long. The Morris Island Trail has interpretive panels that inform visitors about the refuge's purpose and natural resources. There are additional trails available for walking that extend beyond the Morris Island Trail. Refuge staff, volunteers, and interns offer guided walks and programming throughout the summer months.

Visitors who utilize ferry services also have the opportunity to learn about the refuge while en route to the ferry drop-off sites on North Monomoy Island and South Monomoy Island. Two ferry services have been issued SUP's to bring anglers and birders to the refuge. One of these also brings seal watchers to the refuge. However, there are other charter boats bringing seal watchers to the waters around the refuge. These operators do not have a permit from the Service to conduct their business on the refuge, and we have been made aware of incidents of seal harassment from some of these boat operators. Refuge staff have no information on the numbers of passengers that come to the refuge for seal watching, nor do we have any information available about the number of charter boats that are operating on and near the refuge.

Environmental Education

Currently, the refuge does not develop and implement formal environmental educational programming. Occasionally, refuge staff conduct educational programming upon request to local schools, colleges, and universities, and we may work with partners to provide environmental education on the refuge. Any areas open to the public are suitable for organized environmental education to occur.

Other Refuge Public Use Activities—Current or Potential

In general, for a public activity to be allowed on a national wildlife refuge, it must first be found appropriate and compatible, in compliance with Service policies (see chapter 1). Activities that were found compatible for Monomoy NWR in 1994 are: beachcombing, hiking/backpacking, jogging/walking, birding, natural and cultural history tours, photography, picnicking, commercial ferry service, snowshoeing, research, sunbathing/swimming, and wildlife observation. We reviewed the 1994 findings during this CCP planning process. Some of our findings have changed. All of our findings are documented in appendix D.

The following lists and describes other public use activities that occur or are likely to occur within the intertidal zone of the refuge and in the adjacent subtidal, benthic zones, and water column, which can impact refuge management and wildlife using the refuge. We previously have not managed some of these uses, but look at all of them in this document to determine the benefits or impacts of these uses. Activities that occur within the open waters within the Declaration of Taking are also described below.

Kiteboarding: This is a relatively new use that has been observed adjacent to the refuge and within the Declaration of Taking boundary. Individuals use a large kite to help them move through shallow water areas rapidly. Although it occurs on the surface of the water, both the kite and the shadow it casts have the potential to disturb birds on shore. This sport is popular around Hardings Beach and the area known as the Morris Island Cut (*http://www.mychatham.com/kitesurfing.html*, accessed January 2015). Kite boarding appears to have replaced "windsurfing" or "sailboarding" in popularity as recreational equipment technology has evolved over the past few decades.

Personal watercraft: Personal watercraft, such as wave runners and jet skis, are not allowed within the Cape Cod National Seashore boundary, within Pleasant Bay, or within the Southway Channel. However, wave runners are allowed within Nantucket Sound and frequently are within the Declaration of Taking refuge boundary on the west side.

Kayaking and Paddleboards: Kayakers and, to a lesser extent, stand-up paddleboarders are often observed using the waters in and around the refuge or pulled up on refuge shorelines during the warmer months. Most of these day trips originate from and return to mainland sites, especially the Morris Island Road causeway that affords vehicle parking and carry-in access to both Outermost Harbor and Stage Harbor; these are a relatively short and sheltered paddle to North Monomoy Island and the connection to South Monomoy Island. At this time, the carry-in/out of kayaks or canoes from refuge parking on Morris Island is prohibited.

Shellfish Harvesting: The MA DMF established 17 designated shellfish growing areas in the Town, encompassing 101,763 acres. Three are located in or adjacent to Monomoy NWR, with Monomoy Island (SC47) being the largest designated area at 37,831 acres. Nearly 80 percent of the harvestable intertidal shellfish flats in the Town are located in SC47. Not all of these intertidal flats are within the refuge's Declaration of Taking. Shellfish harvesting is permitted with Town and State permits. The State permit requires shellfishermen to file an annual harvest report with the State and to identify the specific areas harvested. This does not tell us, however, how much of the harvest occurred on the refuge.

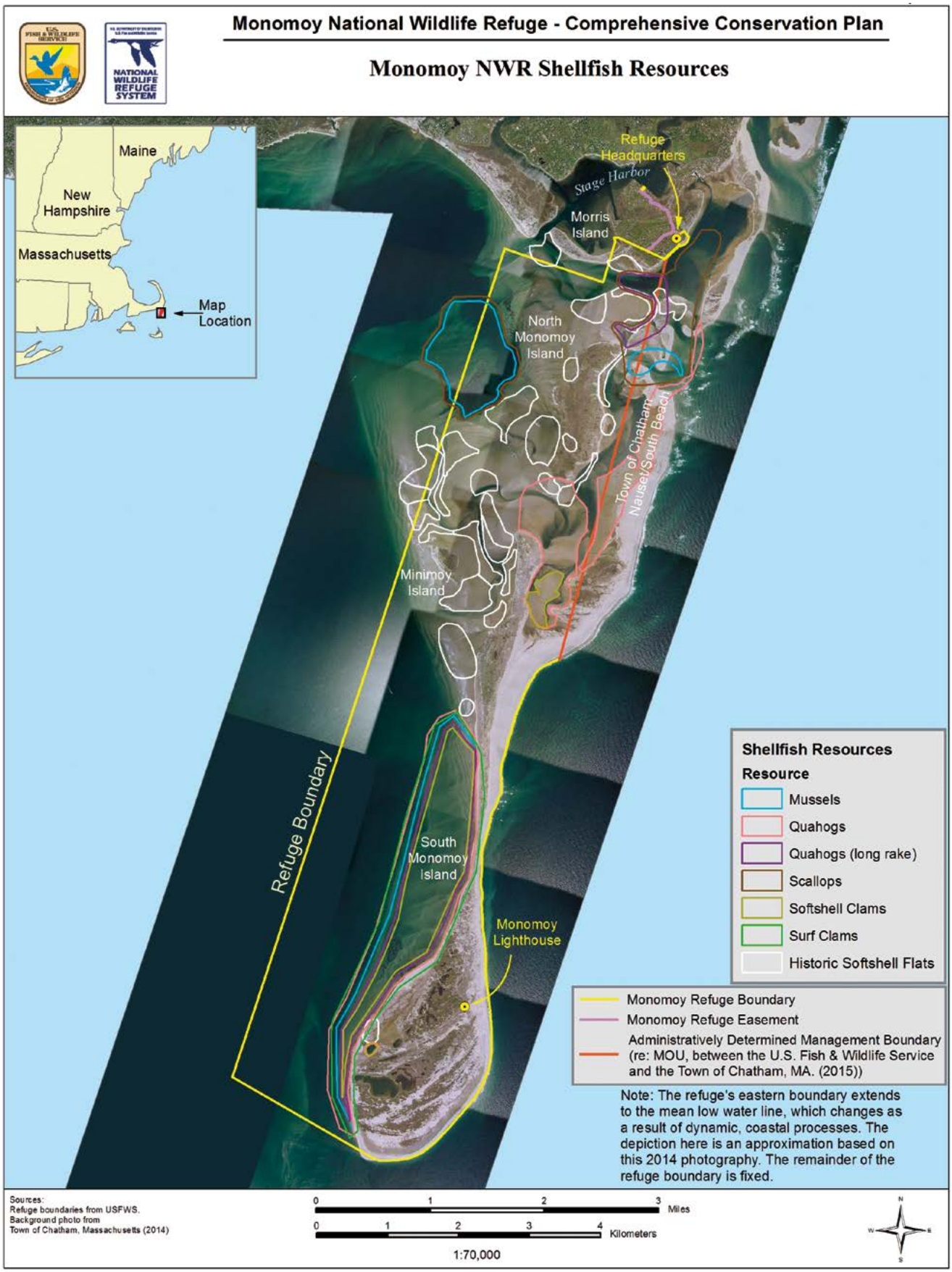
Clamming: For over 150 years, the Monomoy area has been known as one of the most productive clamming areas in Massachusetts. In fact, the first shellfish regulations enacted by the Town about clamming took place in 1781 (Town of Chatham 2014). Traditionally harvested species are softshell clams, quahogs (hard-shelled clams), and surf clams. Softshell clam harvesting became a lucrative fishery after the 1978 break and subsequent shifting of sands and creation of sandflats. In the past, shellfishing has been concentrated on the point of Morris Island, the Common Flats, and the Powder Hole area. The majority of shellfish harvesting in recent years on the refuge has occurred in intertidal habitat (and in very shallow subtidal areas adjacent to intertidal habitat), primarily on the western side of North Monomoy Island (especially the southern end) and South Monomoy Island (especially the northern end), the eastern side of Minimoy Island, the area between Morris Island and North Monomoy

Island, the area between North Monomoy Island and South Monomoy Island, and the area between the refuge and Nauset/South Beach (the Southway). Many of the intertidal shellfish harvest areas listed above lie within the Monomoy wilderness boundary. Refer to map 2.9 for locations. Softshell clam harvest using pumps takes place in several designated locations within Chatham, and occurred occasionally within Powder Hole on South Monomoy as recently as 2011, after which the Town's shellfishing regulations were formally amended (February 21, 2012), by the Board of Selectmen, following a public hearing on the rule change to exclude the practice in Powder Hole (Town of Chatham, Board of Selectmen Meeting Minutes for February 21, 2012, available online at: *http://www.mytowngovernment.org/02633*; accessed May 2013). The principal reason for excluding Powder Hole from the designated site in Chatham was that harvesting using hydraulic pumping could not be conducted in the manner required by the Town as little to no area remained in the Powder Hole basin that met the water depth requirement at low tide.

Softshell clam harvesters in coastal New England typically use short hand-rakes, spend most of their time bent over at the waist or on hands and knees harvesting patches of shellfish, and traverse the exposed mudflats only to move among patches (Burger 1981, Leavitt and Fraser 2004). Shellfishers at the refuge usually land their boats adjacent to harvest areas, arriving around the midpoint of the falling tide. The boat is anchored and often grounds as the tide continues falling. Harvesters spend most of their time harvesting shellfish in localized patches. Harvesters can turn over approximately 40 m^2 of sediment in a low tide event (Leavitt and Fraser 2004). In 2005, it was estimated that an average of about 170 to 180 softshell harvesters specifically targeted the Monomoy flats (Leavitt and Peters 2005).

Quahogs are hard-shelled clams that are often harvested using pumps that suspend the sediment and make the quahog float to the surface, where they are collected. Quahog harvesting using pumps does take place within open waters in the southwestern corner of the refuge. Hydraulic quahog harvest is allowed in waters deeper than 20 feet and in precisely defined areas (Town of Chatham 2014). Quahogs are also harvested using bull rakes, often from shallow drafting boats in water, and only in sub-tidal waters (Town of Chatham 2014). In some intertidal areas of Monomoy NWR, quahog populations have established and can be harvested when the intertidal areas are exposed. The physical act is much like harvesting softshell clams, but the individual is usually standing upright and scrapes the sediment surface with a longer hand-held rake. Bull raking has become a common occurrence on the refuge (particularly near Minimoy Island) and has also occurred within Powder Hole in the past.

Sea (surf) clam harvesting: Sea (surf) clam harvesting is not currently occurring within the submerged lands and open waters on the refuge (Town of Chatham 2014). Sea (surf) clams are present in the shallow water within the Declaration of Taking boundary along South Monomoy Island (map 2.9). The hydraulic sea clam fishery is regulated by the Commonwealth and is open to all harvesters. The Town has jurisdiction over hand harvesting and salting of sea clams (Town of Chatham 2015b). Sea clams "can occasionally be found on tidal flats, and can be harvested with hand-tools" (Town of Chatham 2015a). There is currently no commercial harvest for sea clams in Town waters, but "if there were a commercially viable set best accessed by hand tools, there is a high probability one or more commercial harvester(s) would take advantage of the opportunity. There is a small "sushi grade" market for sea clams not harvested hydraulically as non-hydraulically harvested clams tend to be less sandy" (Town of Chatham 2015b).


Monomoy National Wildlife Refuge - Comprehensive Conservation Plan
Monomoy NWR Shellfish Resources
Maine
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Map Location
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Stage Harbor
Morris Island
North Monomoy Island
Town of Chatham Nauset/South Beach
Minimoy Island
Refuge Boundary
South Monomoy Island
Monomoy Lighthouse
Shellfish Resources
Resource
Mussels
Quahogs
Quahogs (long rake)
Scallops
Softshell Clams
Surf Clams
Historic Softshell Flats
Monomoy Refuge Boundary
Monomoy Refuge Easement
Administratively Determined Management Boundary (re: MOU, between the U.S. Fish & Wildlife Service and the Town of Chatham, MA. (2015))
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Background photo from
Town of Chatham, Massachusetts (2014)
0 1 2 3 Miles
0 1 2 3 4 Kilometers
1:70,000

Mussel harvesting: The Town allows mussel harvesting year-round, but the refuge has never been open to mussel harvesting. Small vessels drag dredges (no larger than 36 inches in width) in sub-tidal areas. The use of teeth or rakes on dredges is prohibited (Town of Chatham 2014) as is hydraulic dredging (Town of Chatham 2015a). Mussel harvesting has occurred in the open waters north of North Monomoy Island. We have no information on how often this has occurred, when it occurred, and how many people harvest mussels in this area. According to the Town (Town of Chatham 2015a), "the last economically viable set of mussels occurred outside the Declaration of Taking in 1999 on the traditional mussel beds between South Beach and North Monomoy Island (locally referred to as "Big and Little Mussels Flat")." Mussel dragging occurred in shallow waters along the northwestern and the eastern flats of North Monomoy Island from 2008 to 2011 (map 2.9). Harvesters redirected their efforts from these areas in 2012 to take advantage of more productive flats located in Chatham Harbor. Mussel harvesting still occurs around North Monomoy Island, however, it is limited in scope compared with prior years (Gagne, personal communication 2013). These mussel beds are often vital for wintering waterfowl, especially common eider. Additionally, mussels are an important food for staging and migrating American oystercatchers and migrating red knots; staff have documented declines in both of these species in areas where mussel harvesting has occurred in recent years.

Bay scallop dragging: Scallop harvesting is conducted on and around the refuge from November through March. The refuge has never been open to scallop harvesting. Small dredges are dragged through dormant eelgrass beds where scallops reside. The Town requires that all scallop dredge frames measure 36 inches or less in width. The use of teeth or rakes on scallop dredges is prohibited (Town of Chatham 2014). Scallops are currently harvested from subtidal eelgrass beds located along the western side of North Monomoy Island, the Morris Island Channel, and the northern end of the old Southway Channel (between North Monomoy Island and Nauset/South Beach; see map 2.9). Prior to the 1978 break, scallop dragging of subtidal areas occurred throughout the western boundary of the refuge; the shallow waters and sea grass beds were a highly productive area for bay scallops. It was theorized that, with the Southway closed off, the flats would slowly subside, eventually changing the western boundary back into a scallop fishery. However, if the 2013 break in Nauset/South Beach persists, the future direction of the fishery will remain uncertain.

Whelk (Conch) harvesting: Channeled whelk and knobbed whelk are harvested on and around the refuge from mid-April to mid-December (MA DMF 2014). The refuge has never been open for conch harvesting. Pots baited primarily with horseshoe crabs are used to catch whelk. The total reportable landings for whelk in SC/47 from 2007 through 2011 were estimated at approximately 144,622 pounds (table F.21; MA DMF; Dealer Reports, May 2010 and January 2013). During this period, whelk landings in SC47 have increased from a low of 18,611 pounds in 2007 to 42,982 pounds in 2011 (table F.21).

Razor clam harvesting: The Town indicated that this is a sub-tidal fishery which "may be the least predictable of all the shellfisheries" (Town of Chatham 2015a). To the best of our knowledge, razor clam harvesting is not currently occurring on the refuge, but is occurring nearby. Razor clams have previously been harvested on the refuge and may be again in the future, as regional conditions change. There was a robust razor clam fishery in Chatham in 2012 and 2013. Razor clams were harvested using salt injection in Wellfleet, Truro, and Eastham in 2005 and 2006. In this process, a salt solution is injected into the sandflats, and when razor clams expel themselves, a harvester collects the clams on the surface. According to the Town, "dry salting (salt not in a water solution) or broadcast salting (spreading dry salt over a tidal flat) is prohibited (Town of Chatham 2015a).

Oyster harvesting: We are not aware of any oyster harvesting occurring on the refuge; however, it is occurring in areas adjacent to the refuge as noted below under "Aquaculture." We do not address oyster harvesting further in this plan.

Aquaculture: The Town propagates and distributes, or seeds, shellfish spat adjacent to the Morris Island portion of the refuge. Young shellfish (quahogs, scallops, and oysters) are reared and moved from nursery sites and placed in subtidal areas, including sites adjoining the Morris Island unit of the refuge and in the Southway. The Town has not seeded any flats adjoining other portions of the refuge or within the Monomoy Wilderness for many years and has no such intentions, since shellfish populations continue to sustain themselves naturally in these areas (Moore 2011). The Town has not undertaken any softshell clam propagation or seeding to date.

Commercial Fisheries: Nantucket Sound supports a diversity of commercially harvested fish and invertebrate species such as flounder, sea bass, scup, mackerel, striped bass, bluefish, lobster, and squid. The marine fishery resources of Nantucket Sound are monitored and managed by the NMFS—a branch of the NOAA, the NEFMC and the MAFMC (established by the MSFCMA), and the MA DMF. The ASMFC coordinates interstate management activities for wide-ranging species, including lobster, striped bass, bluefish, black sea bass and others (ASMFC 2013).

Nantucket Sound, which encompasses waters within the refuge's Declaration of Taking boundary, is designated as NOAA Fisheries Statistical Sampling Area 538 and MA DMF Statistical Reporting Area 10 (SRA 10). MA DMF monitors State-permitted commercial fishing activity for certain fisheries and gear types in State waters within 3 miles from the coast. NOAA Fisheries has jurisdiction over federally permitted commercial fishing activities in all Federal waters between 3 and 200 miles offshore. The 1983 Magnuson-Stevens Act was amended by Congress to give the Commonwealth of Massachusetts exclusive regulatory jurisdiction and authority throughout Nantucket Sound, notwithstanding the existence of a pocket of Federal waters within the center of the sound. NOAA Fisheries and MA DMF collect independent and overlapping commercial fishing data. Federal permit holders are required by NOAA Fisheries to submit vessel trip reports that include information on fishing location, gear type, and species caught during each fishing trip (NOAA 2012). MA DMF collects commercial harvest data through seafood dealer reports (Standard Atlantic Fishery Information System) and until recently, annual catch reports identifying species caught and effort. Under the catch reporting system, fishermen were not required to report fishing locations for fin fish harvest, with the exception of certain gear types. Beginning in 2010, MA DMF implemented a new comprehensive trip-level reporting system that collects harvest information from all State permit holders for all species. This change will help fill gaps in datasets, standardize data collection across State and Federal agencies, and facilitate data pooling between organizations (MA DMF 2013a).

Some commercial fishing occurs in refuge waters, particularly in the southwest corner of the Declaration of Taking boundary; however, we currently have very little information on the extent. Commercial fishing is regulated by the MA DMF and the NMFS. The waters of the refuge constitute less than 1 percent of MA DMF SRA 10 (Nantucket Sound) and consequently the amount of commercial activity in this area is proportionately small. Commercial landings data for SRA 10 do not exist on a small enough spatial scale to accurately depict fishing activity specifically within the refuge Declaration of Taking boundary; nevertheless, landings data from SRA 10 are helpful for characterizing the commercial fishing industry in Nantucket Sound.

MA DMF commercial fin fish landings from SRA 10 are reported for 2010 and 2011 to help characterize the commercial fin fish resource in Nantucket Sound. The data includes landings from Massachusetts permit holders as well as from NMFS vessel trip reports for individuals holding both State and Federal permits. The short timeframe of the dataset available under the State's new reporting system limits the ability to make inferences about long-term population trends. Despite this, these data establish a useful baseline for future use. The commercial fin fish landings reported by MA DMF for SRA 10 for 2010 and 2011 averaged 963,195 lbs (436,897 kg). Fin fish catches during this time period were heavily composed of summer flounder, bluefish, scup, black seabass, striped bass, haddock, spiny dogfish, butterfish, cod, menhaden, and skate (table 2.18). These species represent approximately 93 percent of commercial fin fish landings reported by MA DMF from SRA 10 in 2010 and 99 percent of the landings in 2011.

Table 2.18. Massachusetts Commercial Fin Fish Harvest (live pounds) in Nantucket Sound (SRA 10).

Species	2010	2011
Bluefish	89,437	190,577
Bonito, Atlantic	*	*
Butterfish	24,521	6,388
Cod, Atlantic	20,601	26,270
Cunner		*
Cusk	*	*
Dogfish, smooth	*	
Dogfish, spiny	27,503	113,957
Flounder, plaice, American (dab)	1,490	362
Flounder, sand dab (windowpane)	*	
Flounder, summer (fluke)	238,061	287,087
Flounder, winter	16,602	1,558
Flounder, witch (gray sole)	4,838	1,102
Flounder, yellowtail	2,083	5,185
Goosefish	9,533	1,262
Haddock	33,482	12,001
Hake, Atlantic, red	*	
Hake, Atlantic, white	4,749	*
Hake, silver (whiting)	*	*
Herring, Atlantic, sea	*	
King whiting	*	
Mackerel, Atlantic	336	1,093
Menhaden	21,141	1,471
Perch, ocean (redfish)	*	*
Pollock, Atlantic	5,003	3,587

Species	2010	2011
Puffer, northern		*
Scup	203,126	182,145
Sea bass, black	89,984	94,507
Sea robins		*
Skate, little	*	
Skate, winter	*	*
Skates	10,075	15,685
Striped bass	82,721	85,119
Tautog	2,170	5,377
Triggerfishes	*	
Tuna, albacore		*
Tuna, bluefin	2,377	1,825
Tuna, yellowfin		*

Source: MA DMF Trip-level and NMFS Vessel Trip Reports.
**Confidential*

The commercial lobster fishery is managed from New Jersey to Maine by the ASMFC. The commission's interstate Fishery Management Plan divides Massachusetts into seven lobster conservation management areas that the MA DMF regulates (Dean 2010). Monomoy NWR is located within the Outer Cape Lobster Conservation Management Area (MA DMF 2014).

The lobster fishery in Nantucket Sound does not appear to be a major fishery. According to the Massachusetts lobster fishery statistic for 2006, more than 82 percent of the lobster harvest in territorial waters came from areas north of Cape Cod (Statistical Reporting Areas 1 through 7) (Dean 2010). Of the total commercial lobster harvest reported for Massachusetts coastal waters in 2006 (8,854,669 pounds), only 0.2 percent came from SRA 10.

The total State-reportable lobster landings for SRA 10 (Nantucket Sound) from 2001 through 2011 were estimated at approximately 265,779 pounds (table 2.19). During this period, lobster landings averaged 24,162 pounds, with a high of 41,741 pounds in 2002 and a low of 9,244 pounds in 2009 (table 2.19). It is not known how many lobsters are harvested commercially from within the refuge's Declaration of Taking boundary.

Table 2.19. Massachusetts Commercial Lobster Landings for SRA 10.

Year	SRA	Lobster Pounds
2001	10	23,828
2002	10	41,741
2003	10	23,862
2004	10	27,796
2005	10	30,200
2006	10	21,699
2007	10	18,037
2008	10	17,725

Year	SRA	Lobster Pounds
2009	10	9,244
2010	10	22,668
2011	10	28,979

Source: MA DMF Annual and Trip-Level Catch Reports

Commercial fisheries utilize a variety of gear types in Nantucket Sound. These are described below in table 2.20. The Cape Cod Commercial Fishermen's Alliance website provides a good overview of the region's commercial fishery and gear types employed (*http://www.capecodfishermen.com/the-fishermen*; accessed January 2015).

Table 2.20. Massachusetts Commercial Fin Fish Harvest Proportion by Gear Type in Nantucket Sound (SRA 10).

Gear Category	2010	2011
Gillnet	6.2%	13.9%
Hook	24.8%	32.0%
Other	1.4%	0.2%
Trap	8.1%	8.1%
Trawl	53.5%	40.5%
Weir	6.1%	5.3%

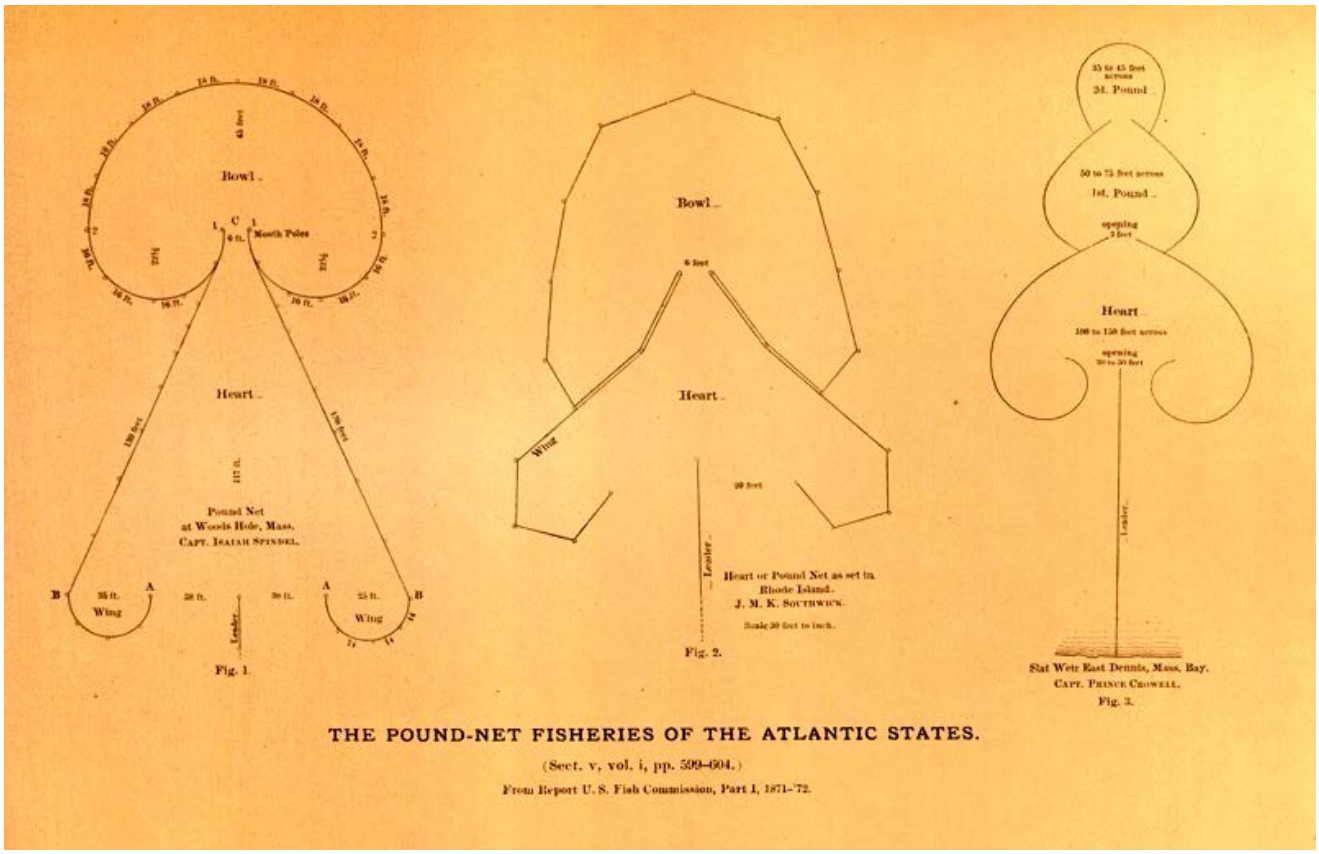
Fixed gear—Fish Weirs: Although historically used throughout Cape Cod, Chatham is one of the few Massachusetts towns to permit fish weirs, also known as trap nets or pound nets. Monomoy Trap Company currently has trap grants (permits) to operate up to nine seasonal fish weirs within Nantucket Sound. Four of these trap grants are located within the refuge's Declaration of Taking boundary.

A fish weir consists of a series of hickory posts and nets of varying mesh sizes assembled in the water to create three distinct parts: the leader, the heart, and the bowl (Jones 2005). Posts are placed in areas of soft sand using a saltwater pump that only temporarily disturbs the sediments (Nichols, personal communication 2015). Figure 2.14 displays a variety of structure arrangements that have historically been used along the Atlantic coast and are similar to the design currently employed in Chatham. "The weir is positioned perpendicular to the shoreline and acts as a guide in which schools of migratory fish travel along its leader to the deeper end of the structure" (E. Eldredge, personal communication 2014) or the bowl. Some fish remain in the bowl, swimming freely, until they are harvested with small handheld dip nets or a larger kill-devil if necessary (Nichols, personal communication 2015). Others escape the trap prior to harvesting.

Fish weirs are typically used for harvesting "squid, scup, black sea bass, mackerel, bluefish, butterfish, bonita, false albacore, herring, and Spanish mackerel" (S. Eldredge, personal communication 2014). Non-target fish as well as seals and sea turtles occasionally swim into these nets and become trapped, though entanglements are relatively rare and the animals are most often released alive by fishermen. In fact, grey seals have been documented entering the weir nets to eat fish and squid from the catch as they are drawn to the nets by the

groups of schooling fish contained in the bowl (Nichols et al 2014). However, a loggerhead sea turtle was caught in a fish weir located within the Declaration of Taking boundary in 2007; staff removed the turtle from the net and transferred it to the Sea Turtle Salvage Network.

Figure 2.14. Several examples of a trap net set-up (Goode 1887)



Fixed gear—Fish Pots: A limited number of fish pots occur within the refuge's Declaration of Taking Boundary, and are used to catch scup and black sea bass. Fish pots are similar in design to lobster pots and are usually fished singly or in trawls of multiple pots (not to exceed 2,500 feet in length).

Fixed gear—Lobster Pots: Commercial lobster pots occur throughout the refuge's Declaration of Taking boundary. Pots are fished as either a single pot per buoy, or strung together in "trawls" of multiple pots (not to exceed 2,500 feet in length). The season is closed annually from January through March (MA DMF 2013b).

Fixed gear—Whelk (Conch) Pots: The commercial conch fishery is open from mid-April to mid-December (MA DMF 2014). Wood and wire pots are used to catch channeled whelk and knobbed whelk within the refuge's Declaration of Taking boundary. The pots are open at the top and are generally baited with horseshoe crabs. Pots are placed on sandy bottoms, usually near sea grass beds at depths of 1.5 to 27 m. Pots can be fished singly or in trawls consisting of up to 40 pots (Stevenson et al. 2004).

Mobile gear—Hook and Line (including handlines): Both striped bass and bluefish are commercially harvested in refuge waters. The striped bass

commercial fishery is a hook and line-only fishery, with the season going from mid-July until the quota is filled (MA DMF 2013a). The commercial bluefish harvest generally starts in Nantucket Sound with the return of migrating bluefish schools beginning in May and closes once the quota is met or the bluefish migrate southward again in October (MA DMF 2013a). Commercial hook and line fishing for striped bass and bluefish occurs primarily in rips along the southern tip of South Monomoy Island; however, fish are also harvested in nearshore open waters throughout the Declaration of Taking boundary. Other species harvested commercially using hook and line gear (e.g., demersal longline) include black sea bass, cod, haddock, pollock, flounder, hake, and other groundfish, and dogfish (*http://www.capecodfishermen.org/the-fishermen*; accessed December 2013).

Mobile gear—Mid-water and Otter Trawls: Trawls are essentially large nets towed behind boats through the water at different depths, with large or coarse mesh toward the front that progressively decreases to finer mesh toward the rear of the net with the net kept open by trawl doors. The trawl doors and net opening function to herd fish into the finer meshed rear section of the net. Mid-water trawls target pelagic species suspended in the water column above the bottom, only infrequently contacting bottom substrates. Rope trawls are commonly used in the mid-water Atlantic herring and mackerel fisheries. Otter trawls target bottom-dwelling groundfish including cod, haddock, pollock, flounder, hake, dogfish, skate, and monkfish and, therefore, are in almost constant contact with the bottom. The 50-foot groundfish trawler the Joanne A III is the last remaining such vessel operating as a day boat from Chatham Harbor *(http:// ccchfa.org/media/documents/MTF_Amaru_2.2013.pdf;* accessed May 2013). Trawling does not likely occur within the Declaration of Taking boundary due to the shallow depths and heavy boating traffic.

Mobile gear—Troll Lines (commercial): These are a series of baited hooks or lures attached to two to four main troll lines by leaders, towed behind the tow vessel at different depths through the water column, rarely touching bottom, and separated using outriggers. Troll lining as described above does not occur within the Declaration of Taking boundary. However, some local fishermen sometimes use the term "troll line" when referring to demersal longline gear included in the above hook and line discussion.

Mobile Gear—Strike Nets and Gill Nets (commercial): Strike nets are set out in a circle, and then the boat runs in a circle to move the fish, into the net, which is hauled back immediately harvesting the fish alive. Strike nets are most commonly used locally to harvest bluefish during the warmer June 1 to October months (*http://www.capecodfishermen.org/bluefish*; accessed December 2013). Gill nets are anchored, or surface or drifting vertical walls of webbing, buoyed on top and weighted at the bottom, designed to capture fish by entanglement, gilling, or wedging (322 CMR 12.00(7)). Different mesh sizes are what determine the size classes of fish taken by these nets. Cod, haddock, flounder, pollock, hake, dogfish, skate, and monkfish are the species most commonly taken using bottom tending or "sink" gillnets in the Monomoy region during winter months (*http://www.capecodfishermen.org/the-fishermen*; accessed December 2013). Gillnet use is however prohibited in Nantucket Sound, including nearshore waters around Monomoy from April 1 to November 15 (Chapt. 130, 322 CMR 4.09).

Placement of moorings (commercial and recreational): There are no existing moorings within the Declaration of Taking. However, in the summer of 2007, a commercial fishing boat (approximately 65 feet in length) placed a mooring block, which likely weighed about 5,000 pounds, on the west side of North Monomoy Island just outside the refuge boundary. The lack of mooring space within the Town is a potential problem and we anticipate possible future interest in placing moorings within the refuge.

Dredging: The USACE permits limited dredging within the Declaration of Taking near the refuge boundary. The entrance to Stage Harbor in the northwestern corner of the refuge is dredged almost annually. There is interest by some citizens and businesses to maintain (dredge) the channel that separates Morris Island from North Monomoy Island. Where previously we had supported dredging the Morris Island channel, we are now concerned about adverse impacts to refuge lands from this activity. We must allow the Stage Harbor dredging to occur, and will evaluate all other requests for dredging in refuge waters to protect the Federal ownership interest of the refuge.

Beach renourishment: The Service allowed beach nourishment and revetment installation on the Morris Island portion of the refuge in the winter of 1998 and 1999. In 2005, the Cape Cod Commission approached the Service regarding beach renourishment on Morris Island, which we declined to support. However, the refuge beach on Morris Island has suffered significant erosion in the last 3 years, and we now realize that beach renourishment on Morris Island is not only beneficial but necessary. The Service has met with the USACE and the Town to discuss the possibility of placing dredged material in the refuge, including possibly near Minimoy Island. The refuge would be willing to consider this activity if it would benefit beach nesting birds. In the last 5 years, Minimoy Island has annually hosted as many as 40 to 50 pairs of roseate terns, 1,000 pairs of common terns and piping plovers, American oystercatchers, and black skimmers.

Refuge Uses Found Not Compatible—Current

Horseshoe Crabs: During the 1990s, horseshoe crabs were harvested from Monomoy NWR. There was an active market during that time for using the crabs in the production of Limulus amoebocyte lysate (LAL) (Novitsky 1984), an extract of blood cells from the horseshoe crab developed by the biomedical industry to detect pathogenic endotoxins in injectable drugs and implantable medical devices (Berkson and Shuster Jr. 1999). While (commercial) horseshoe crab harvesting for biomedical use was previously determined to be an appropriate and compatible use on the refuge, in 2002, all horseshoe crab harvesting was found incompatible with the refuge's purpose and mission, based on new scientific data, and has not been allowed since. That CD provided a thorough synthesis of information available at that time. A summary of the justification for finding all horseshoe crab harvesting not compatible at Monomoy NWR is presented here.

> Both types of harvest result in horseshoe crab mortality. Although crabs harvested for biomedical use are eventually returned to the waters, some mortality still occurs during the transport, handling, and bleeding process, and this mortality may be significant (Walls and Berkson 2000, Leschen and Correia 2010). Additionally, horseshoe crabs' reproductive cycle makes them vulnerable to over-exploitation. The reproductive strategy of congregating in large numbers on beaches to spawn makes them easy targets for any harvester in both the intertidal and subtidal areas close to spawning beaches. Shallow water harvesters focus their efforts on high tides when the horseshoe crabs are moving into shallow waters to breed. The gentle topography of the west side of Monomoy NWR (including North Monomoy Island and the north tip of South Monomoy Island) allows horseshoe crab harvesters to easily collect animals in the intertidal areas on spawning beaches, and, in the subtidal areas, on their way to the spawning beaches. Because this species does not breed until reaching 9 to 10 years of age, declines in populations may not be realized for many years, and populations will be slow to recover from overharvesting.
>
> Resulting loss of spawning crabs and eggs may impact migratory birds. Harvest for the biomedical industry and the commercial bait

fishery both target gravid females that are collected as they approach, or while on, spawning beaches. It is likely that these uses result in a decrease in the number of horseshoe crab eggs that are deposited on the beaches in the year of harvest. In Delaware Bay, the reduction in spawning horseshoe crabs resulted in a 70 percent decline in horseshoe crab eggs (Tsipoura and Burger 1999), and this decline has been linked to subsequent declines in shorebirds on the New Jersey shores (Niles and Clark 1997). A number of species of shorebirds rely on Monomoy NWR during the spring and fall migration for habitat for feeding and resting, and we have confirmed that horseshoe crab eggs are one of the food items consumed by shorebirds at Monomoy NWR. While we have not identified all of the species that feed on horseshoe crab eggs on the refuge, this information is consistent with numerous studies from Delaware Bay that document the importance of horseshoe crab eggs to shorebirds during the spring migration. Given that Monomoy NWR is a critical spawning site for horseshoe crabs and is a critical migratory stopover site for shorebirds, it is likely that horseshoe crab eggs are an important food item in shorebirds' diets and a critical part of the food web on Monomoy NWR.

Refuge law enforcement has apprehended individuals harvesting illegally for bait within the refuge Declaration of Taking boundary. The NPS also does not allow harvesting of horseshoe crabs within their boundary of the Cape Cod National Seashore. The horseshoe crab harvest appropriateness and compatibility questions were again re-examined during development of this CCP in light of additional new scientific and monitoring information that has become available. A new finding that horseshoe crab harvest is not an appropriate use of refuge lands is included in appendix D.

Refuge Archaeological, Historical, and Cultural Resources

Cultural resources include a wide variety of objects and locations that are evidence of past human activities. These resources may exist below ground, such as archaeological sites, or may be encountered above ground, as with historic buildings and other structures, in addition to landscapes, viewsheds, or ceremonial sites. The Federal Government is legally responsible for the preservation and management of cultural resources that are located on Federal lands, and must consider the potential impacts of Federal actions on cultural resources wherever they may exist.

Monomoy NWR contains a variety of known cultural resources dating as far back as Paleo-Indian cultures. These include Pre-Contact Native American sites on Morris Island, and the former locations of the historic Whitewash Village, seasonal cottages and camps, shipwrecks, and U.S.C.G. lifesaving stations on South Monomoy Island. The most well known cultural resource on refuge lands is the Monomoy Point Light Station, which includes the lighthouse, keeper's house, and small oil house, and is listed in the NRHP. In general, archaeological resources on the refuge may be at risk due to erosion and natural forces.

Because very little of the refuge has received systematic archaeological sampling, it is possible that many archaeological sites, both Native American and European-American, remain unknown and await discovery. As sites are added to the inventory, the Service will have an enhanced ability to manage them as Federal regulations require.

Native American Archaeological Sites

No Native American sites have been recorded on South Monomoy Island or North Monomoy. During the Pre-Contact and Contact periods, Native Americans likely visited or settled upon the 8-mile peninsula from which the Monomoy barrier islands were later formed, but exposure to the elements and lack of vegetation has meant that local landforms (e.g., dunes and swales) were subjected to extensive erosion and movement. As a result, Native American archaeological

deposits dating to the Pre-Contact period may be deeply buried on the two islands, or may have been deflated by shoreline erosion and no longer exist.

Two Native American sites have been recorded on refuge property at Morris Island. Both were shell middens of unknown date, reported by artifact collectors in the mid-20th century; little information currently exists for these sites. A third shell midden site, which produced pottery and triangular projectile points, was reported on Morris Island, outside of the refuge boundary. Evidence at this latter site suggests the island was occupied during the Woodland period, so it can reasonably be inferred that Morris Island, in general, witnessed Native American occupation during that time period, and that the Monomoy peninsula to the south was likely settled as well.

Two archaeological surveys related to Federal undertakings have been performed on refuge property. One small survey investigated a boat landing location on Morris Island, and testing was conducted at the Monomoy Point Light Station prior to the rehabilitation project at the light keeper's house. Neither survey recovered any Native American artifacts. No comprehensive archaeological study, such as an overview, has been conducted for the refuge as a whole. It should be assumed that the likelihood for unrecorded Native American archaeological sites is high in all undeveloped locations within the refuge, unless systematic professional sampling has demonstrated the absence of such resources. Areas of comparatively stable ground on the margins of estuaries and shellfish habitats are lands more likely to have been used in the past and represent zones of higher archaeological sensitivity.

The CCP and its management alternatives are required to comply with the NHPA (Section. 106), which entails consultation with federally recognized American Indian Tribes. The Mashpee Wampanoag Tribe and the Wampanoag Tribe of Gay Head (Aquinnah) are the federally recognized Tribes that are directly descended from the Native Tribes that occupied southeastern Massachusetts and the Cape Cod region during the European contact period. The Service consulted with these Tribes as part of the CCP process.

Historic Structures and Archaeological Sites

The following information was taken from the files onsite at the Service's Region 5 office in Hadley, Massachusetts.

Monomoy Point Light Station

In 1823, a lighthouse with an iron lantern room and wooden tower extending above the roof of a brick keeper's house was built on Monomoy Point (formerly known as Sandy Point). This lighthouse had a fixed white light illuminated by eight lamps with reflectors. The Monomoy Point Light, along with the Great Point Light on Nantucket Island, marked the entrance to Nantucket Sound for vessels in the Atlantic.

In 1842, I.W.P. Lewis, a civil engineer with the U.S. Lighthouse Survey, recommended replacement of the entire light station. In 1849, a new 40-foot cylindrical cast-iron tower was built (the existing lighthouse). The two-story wooden keeper's house was also constructed. According to an inspection report dated in 1850, the new iron lighthouse was "neither large enough, nor high enough, nor stiff enough." The lack of stability was due to poor footings. The earlier tower, which was masonry, began coming apart from the strong winds. The tower was later lined with brick to reduce the sway and provide insulation from the winter cold and summer heat.

The first lightship, Light Vessel No. 2, was placed at Pollock Rip in 1849 to assist the lighthouse on Monomoy Point in alerting ships to the dangerous currents. Light Vessel No. 2 was at Pollock Rip from 1849 to 1875. Eight lightships were on station at Pollock Rip from 1849 to 1969 (*http://home.comcast.net/~debee2/mass/Monomoy.html*; accessed February 2012).

Monomoy Point Light Station

Kate Iaquinto/USFWS

The Lighthouse Board recommended upgrading the lighthouse to a second-order light in 1872 to better guide vessels through the waters; however, Congress never approved the recommendation, and the tower was instead painted red to increase its daytime visibility. In 1892, trusses were fastened to the tower in a short-lived attempt to increase stability and prevent vibration.

The opening of the Cape Cod Canal in 1914 enabled coastal vessels to avoid the dangerous waters around Monomoy Point. When the Chatham Light was refitted with increased power in 1923, the Monomoy Point Lighthouse was decommissioned. The government sold the station to George Dunbar, the first of several private owners, who made few changes to the property. By 1958, all equipment and glass in the light lantern had been removed. The property was sold to the Audubon Society in 1964 (Historic American Engineering Record).

The Society made several improvements to the keeper's house, which served as a destination for guided tours viewing the extensive bird populations on Monomoy. The Service acquired the property in 1977.

The Monomoy Point Light Station is a structural complex listed on the NRHP. Rehabilitation of its three structures, the 40-foot tall, cylindrical, cast-iron tower, keeper's house, and brick oil house, began in August 2010 (Oak Point Associates 2009). An archaeological investigation completed prior to the rehabilitation project found extensive evidence resulting from domestic occupation of the keeper's house (Binzen, personal communication 2010). The light station structures are on lands excluded from the Monomoy Wilderness when designated in 1970, but the site is largely surrounded by refuge lands designated as wilderness that must be crossed to access the structures.

U.S. Life Saving Stations

The waters surrounding Monomoy Point were historically the most hazardous in the Northeast, due to the shallow shoals, strong rip currents, and storms forming where the Atlantic Ocean meets Nantucket Sound. More than 3,000 shipwrecks have occurred in the waters surrounding Cape Cod over the last 300 years. After the U.S.L.S.S. was established in 1872, three life-saving stations were built on Monomoy. Despite the lighthouse and the use of lightships, there were numerous additional shipwrecks off Monomoy Point.

The first station was built on Morris Island near the current refuge administrative complex and designated as LSS #13 Chatham. The second station, LSS #14 Monomoy, was located below Inward Point, near a cluster of cottages that were known as the Hammonds Bend Camps. A third station, Monomoy Point, was built at the southern tip of Monomoy, and subsequently expanded to a U.S.C.G.base complete with a residence and equipment building in addition to the original lifesaving station structure. None of the structures from the lifesaving stations still exist, although some scant surface evidence of the U.S.C.G. station buildings is still visible.

Seasonal Camps and Fishing Facilities
According to an account from Harry D. Ellis, who resided on the island circa 1900, "Between Inward and Monomoy Points stood three weir shanties, occupied by the crews which operated the weirs. The weirs were placed off the west shore (in Nantucket Sound) and as a convenience the boats and gear were kept at these shanties." No evidence of the shanties of the Consolidated Weir Company is visible today. During the same period, the Monomoy Branting Club had at least three buildings that were used seasonally by sportsmen. These structures no longer exist.

Seasonal Cottages
The seasonal settlement at Hammonds Bend comprised about two dozen cottages and outbuildings. Families maintained a tradition of summer visits to these modest and remote abodes. Although these residences no longer exist, photographic evidence from the mid-20th century shows they were single-story dwellings sided with wood shingles.

Located closer to the Monomoy Point Light Station were other small cottages, also no longer extant, that made up the Jones Small Camp, the Edward J. Tripp Camp, and the John T. Mason II Camp.

Whitewash Village
During the early 1700s, a deep natural harbor at Powder Hole near Monomoy Point attracted a settlement that would come to be known as Whitewash Village. Local historians have reported various descriptions, although accounts of life for the historic village are scarce, as Chatham lost its Town records to a fire in 1827 and its parish records during a fire at the Congregational Church in 1861 (Seufert-Barr 1995). The settlement was dealt a blow when its harbor was washed away during a hurricane around 1860.

The account from H.D. Ellis describes the community as it existed during the early 1900s:

> At Monomoy Point itself was a cluster of dwellings occupied by the lobster fishing fraternity. Some were built along the shore of the Powder Hole, almost a circle where the tide flowed and ebbed and made a deep little body of water… I do not now recall the names of all the Pointers but on "this side" of the Powder Hole came first the abode of old Bill Bloomer. Next was our Ellis cottage, followed by houses of George Bloomer and young Bill Bloomer both sons of old Bill. Then came the old store which in previous times had fitted out fishing schooners… The old store was kind of a divider between the two sides… The Point Coast Guard Station had not been built during the earlier years of our stay, but the Monomoy Point Light was there.

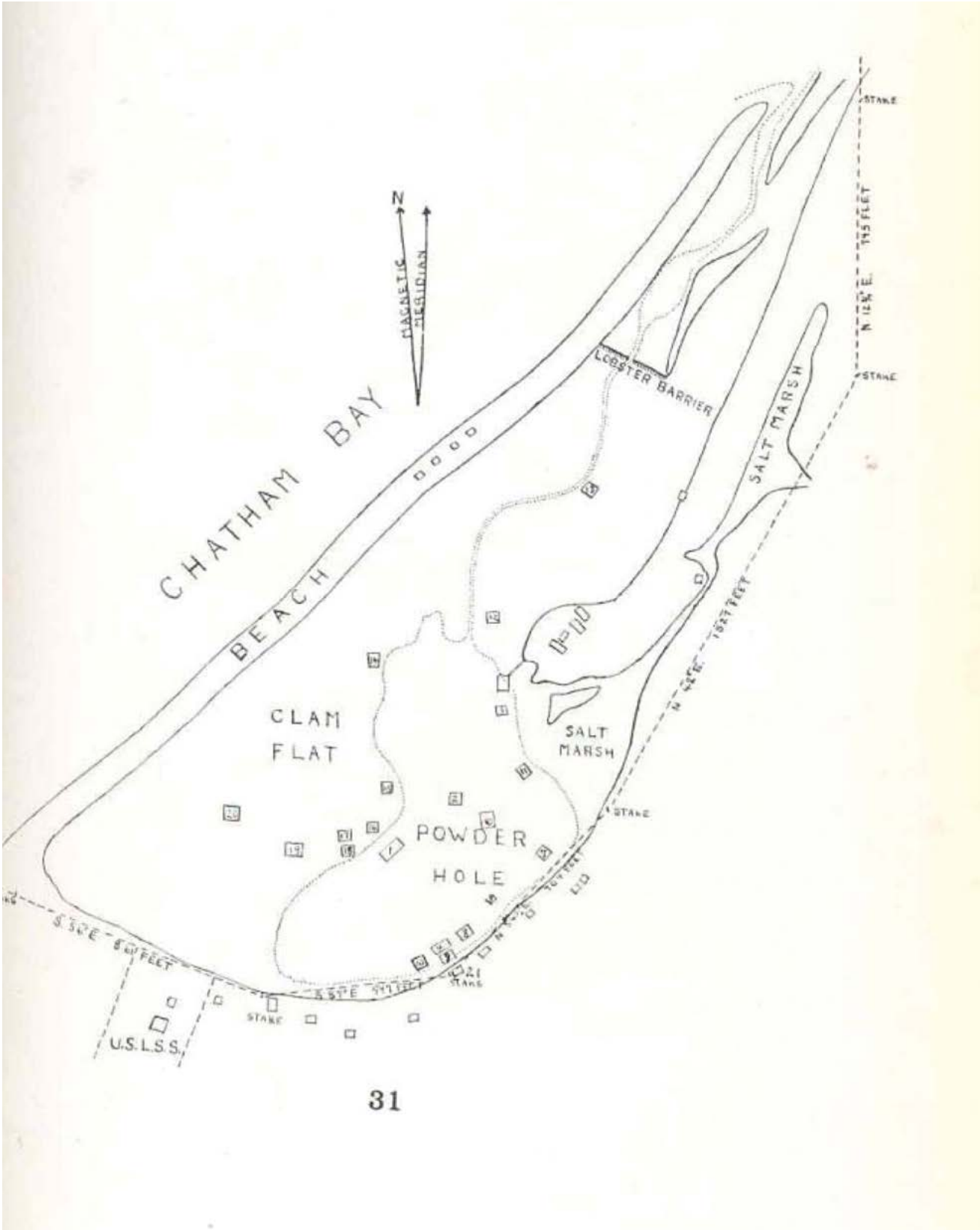
> All of these residents (lobster fishermen) were for the summer only. We are speaking of the era when all the boats had sail power only, making it necessary to live as close as possible to where the [lobster] pots were set. These years were the late eighteen hundreds and early nineteen hundreds… The houses at the Point were built of lumber and laths which were picked up along shore. At that time there was a considerable amount of flotsam and jetsam which came from wrecked vessels and in some cases where the deck load was thrown or washed overboard. The finished lumber came from Chatham.

A report to the Commonwealth of Massachusetts on the status of the quahog fishery described the Powder Hole during the period 1905 to 1910 when it served as a field laboratory for early quahog culture and growth experiments (Belding 1912), including a site map (figure 2.15), as follows:

> During the period from 1905 to 1910 [quahog] growth experiments were conducted in the Powder Hole…The natural aquarium of several acres, teaming with shellfish life, was leased for experimental purposes by the Commonwealth, and proved by its protection and variety of natural conditions in a limited area, a most satisfactory location for a quahog investigation. In 1906 a small shanty was fitted up as a laboratory, and a raft of 20×10 feet was anchored in the deeper water of the Powder Hole. Growth experiments for a period of four years were conducted by suspending boxes of sand from the raft at various depths, while several methods of spat collecting were tried. In the flats and waters of the Powder Hole, under different conditions as regards current, soil, and depth of water, a number of cultural experiments were established.
>
> In former years the Powder Hole was a spacious harbor where hundreds of vessels could anchor, but the sand bars have so shifted that at the present time nothing remains but an almost enclosed body of water of perhaps 3 acres, connected to the ocean on the bay side by a narrow opening through which a dory may enter at high tide. The opening changes constantly, owing to the shifting nature of the sand, and has successively worked from the south to the north side, closed and reopened again at the south at intervals of one and a half years. A large part of the original harbor is now dry land or salt marsh, while on the north and west side is a sand flat of 3 acres, which until 1910 contained an abundant quantity of softshell clams. The harbor itself is slowly diminishing in size, due to the encroachment of the sand, and will doubtlessly eventually become a small pond, not connected with the ocean.
>
> The water on the north and west sides averaged 15 and 18 feet in depth, gradually shoaling to the south and east. In the shallow water the soil was covered with an abundant growth of eelgrass. The rise and fall of the tide was about 1 ½ feet on the average, but extremely erratic, as the force and direction of the wind and position of the opening were important in determining the amount of water passing through the narrow inlet.

The channel connecting the Powder Hole and the ocean became blocked during the summer of 1908, with the result that there was a stagnation of the water in the Powder Hole during part of the growing months.

Figure 2.15. Powder Hole, Circa 1910 (Belding 1912).



Today, little evidence of the historic Whitewash Village exists on the ground surface because the buildings had minimal foundations and the vicinity has been affected by sand activity such as erosion and dune formation. A variety of archaeological deposits and features may be preserved beneath the ground surface, but also have been subject to wind and erosion. All the buildings at Whitewash Village (consisting of approximately one dozen cottages and outbuildings) were either destroyed by storms or demolished by the Service after establishment of the Monomoy NWR. No formal study has been conducted to map and inventory historic archaeological resources at the refuge. The historic archaeological record at the refuge may possess research value as an opportunity to investigate an early American fishing village, if any associated archaeological resources still possess integrity.

Regional Socioeconomic Setting

Economic Overview

The Town has a very long fishing history, and maintaining a vibrant fishing industry is very important to the Town. Chatham is a tourist destination because of its scenic beauty, beaches, seals, and its vibrant and artistic downtown. Many homeowners are retirees or maintain their primary residence elsewhere. Chatham, one of the older townships of Cape Cod, was settled in 1656 by a handful of Pilgrims, whose surnames still dominate the Town's census list. The Town was later incorporated in 1712. Originally a farming community, its inhabitants found deep-sea fishing more lucrative. Fishing has been a part of Chatham's cultural identity for over 3 hundred years. Abundant stocks of groundfish such as Atlantic cod, haddock, redfish, hakes, and flounders supported Chatham's fishing industry throughout much of its history. In the early 1700s, Chatham's fleet was one of the largest in New England, consisting primarily of small day boats fishing close to shore for cod, mackerel, and shellfish. In these early years, fishing fueled the local economy and many residents either fished or were employed in trades related to fishing (*http://www.wickedlocal.com/chatham/news/x422900698/Smaller-fleet-fewer-fish-but-after-300-years-fishing-still-defines-Chatham?zc_p =1#axzz2PSYG7wUH*; accessed April 2013).

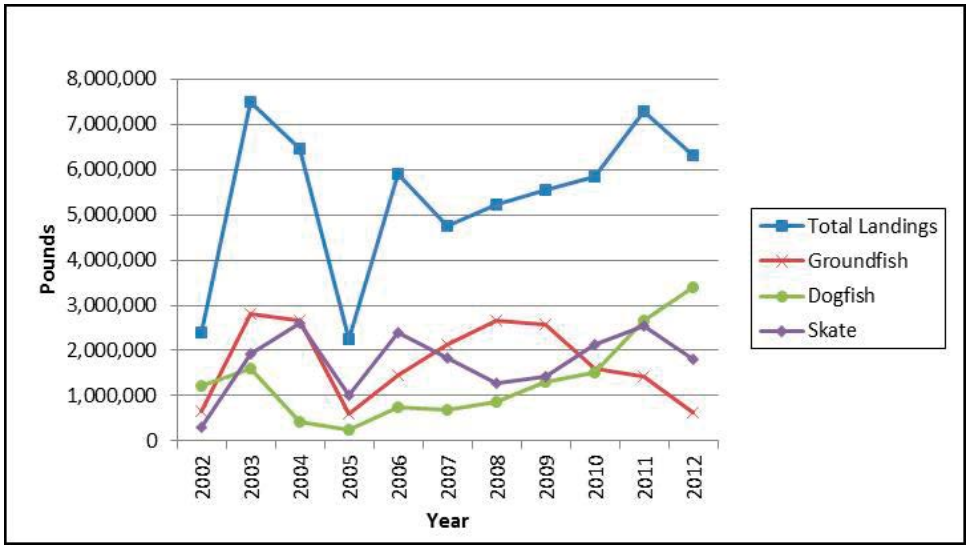
By the late 19th and 20th centuries, large fleets of schooners sailing from Gloucester and Boston targeted cod and other groundfish along offshore banks from Cape Cod to Newfoundland. The majority of cod were preserved with salt prior to the vessels returning to port. Overfishing by the early hook-and-line fleets was occurring at this time and stocks of Atlantic halibut and other species began to decline. At the turn of the 20th century technological innovations such as refrigeration and railroad transportation expanded the commercial market for fresh fish. Steam-powered trawl vessels quickly replaced sailing schooners. At the end of World War I, following the introduction of the diesel powered trawler, the number of targeted species increased. Trawlers shifted from harvesting primarily cod to harvesting species such as haddock, redfish, and flounders throughout the 1930s, 1940s, and 1950s.

In the early 1960s, groundfish stocks faced additional exploitation from factory-based trawlers from eastern Europe and Asia that harvested unsustainable amounts of haddock, hake, and herring from New England waters. A quota-based management system was instituted in 1970 to regulate foreign catches and reverse the severe declines experienced by most groundfish species during this period. The MSFCMA of 1975 officially ended the participation of foreign fishing fleets in U.S. waters within 200 miles of the coast. Following the elimination of the foreign fleets, some stocks rebounded, only to be overfished again by

domestic fleets. Stock biomasses of many groundfish reached record lows in the early 1990s, prompting the passage of the Sustainable Fisheries Act of 1996, which requires that overfished populations be restored (*http://www.nefsc.noaa.gov/history/stories/groundfish/grndfsh1.html*; accessed April 2013).

The ability of the Chatham fishing fleet to survive in a constantly changing industry is a testament to its adaptability. Following record low numbers of groundfish in the early 1990s, some species began showing signs of recovery in 2003, when 2.8 million pounds of groundfish were landed at the Chatham Fish Pier (figure 2.16). Since 2009, groundfish landings have plummeted and less than 700,000 pounds were landed at the pier in 2012 (less than 30 percent of the cod quota was caught). In the absence of the more lucrative groundfish species, the fleet has been forced to target less profitable species like skate and dogfish. Dogfish landings have drastically increased from 232,360 pounds in 2005, to over 3.3 million pounds in 2012 (figure 2.16). Together, skate and dogfish represented 82 percent of the total 2012 landings at the Chatham Fish Pier (*http://www.ccchfa.org/media/documents/CCC.FutureofChathamFishing.2.28.13.pdf*; accessed April 2013).

Figure 2.16. Chatham Fish Pier Landings 2002 to 2012. Source: Chatham Fish & Lobster Company Inc. and Nantucket Fish Company Inc.



Population Demographics

Although the population of Massachusetts grew by approximately 3 percent between 2000 and 2010, Barnstable County decreased in population by the same amount (U.S. Census Bureau 2010). At the same time, the region became more diverse, with an increase of 56 percent of people who identify themselves as Hispanic or Latino, and a 4 percent decline in the number of people who describe themselves as white (U.S. Census 2010). The number of Cape Cod residents identifying themselves as Asian increased by 63 percent, the Native American population increased by 7.2 percent, and the black population by 2.3 percent (U.S. Census Bureau 2010).

The most significant trend in the Cape Cod region is the decline in the younger demographic—a decrease of 21.09 percent in persons "18 and under" between 2000 and 2010. According to the U.S. Census Bureau (2010), approximately 2.6 percent of the population in Chatham census-designated place (CDP) is 5 years of age or younger, approximately 9.8 percent of the populations is between the

ages of 5 and 19, approximately 88.6 percent is age 18 years or older, and about 40 percent of the area's population is 65 years or older.

Employment rates in Barnstable County decreased by approximately 3 percent between 2000 and 2010. The average per capita income in 2010 for Chatham is $57,006; Barnstable County has an estimate of $33,435, which is equivalent to the per capita income for the State. The average family income in Chatham is $163,316—60 percent higher than the State's average family income of $64,509 between 2006 and 2010 (U.S. Census Bureau 2010).

In 2010, Chatham had a local population of around 1,400. Its labor force is about 40 percent of its population and in 2010, nearly 9 percent of its labor force reported being unemployed. The largest employers in the area, in terms of employment, were (1) the arts, entertainment, recreation, and accommodation and food services; (2) finance and insurance, real estate and rental and leasing, and educational services; and (3) health care and social assistance (U.S. Census Bureau 2010). Together, these three industries employed about 43 percent of the total workforce. Construction and retail trade also employed about 20 percent of total employment, a significant portion of the labor force.

Economic Sectors, including Recreational and Commercial Activities

As previously described, the refuge consists of lands located on Morris Island, North Monomoy Island, South Monomoy Island, and open waters within the Declaration of Taking. The visitor contact station on Morris Island is accessible by car. North Monomoy Island and South Monomoy Island, the majority of which is designated as wilderness, are accessible primarily by ferry or private boat. Motor boats are allowed in the Monomoy wilderness area because the Wilderness Act allows the use of motor boats to continue where these uses have already been established and deemed desirable by the Secretary of the Interior (16 U.S.C. § 1133(d)(1)). There is no supply of potable water on the refuge. The refuge is open year-round, with most visitation occurring during the summer tourist season from late spring to early fall. The refuge offers wildlife viewing sites, hiking trails, and extensive fishing opportunities.

Most refuge visits, especially those to the Monomoy Islands, occur between May and October, peaking in June, July, and August. The heaviest visitation is at the headquarters complex and the point on Morris Island, near Godwit Bar on North Monomoy Island, the southern third of South Monomoy Island, and the northern tip of South Monomoy Island (Inward Point). In recent years, surf casters have utilized most of the edges of North Monomoy Island and the waters surrounding the northeast end of South Monomoy Island. Popular shellfishing areas change even more frequently, but the flats on the north end of South Monomoy, the south end of North Monomoy Island, and the east side of Minimoy Island have been used the most since 2007. Birdwatchers who frequent North Monomoy Island often utilize the access corridor that bisects the salt marsh and leads to expansive flats on the west side where shorebirds forage (Koch, personal communication 2011).

Additionally, many summer visitors come to the refuge primarily to sunbathe and swim. Popular areas include the beaches of Morris Island, the east side of North Monomoy Island adjacent to the boat channel, sandbars between the islands, and the beach just west of Powder Hole.

In 2012, the refuge reported that a total of 33,150 people visited the refuge. The expenditures associated with the recreational activities of Monomoy visits, including fishing, wildlife viewing, and beach and water recreation contributed slightly less than $260,000 to regional output (Maillett 2013). Monomoy NWR and adjacent Nauset/South Beach are unmatched on the Cape for opportunities

to view a wide variety of migrating shorebird species. In addition, the wilderness status and difficulty of access create a unique environment for visitors to experience its solitude and naturalness. The variety of refuge wildlife attracts birdwatchers from throughout the Northeast, and many birding clubs and other outdoor recreational groups organize field trips to Monomoy NWR. Two for-hire vessel operators have provided ferry services to the refuge and/or seal tours for several years. In addition to the wildlife watching cruises offered by Outermost Harbor and Monomoy Island Ferry, both the Massachusetts Audubon Society and the Cape Cod Museum of Natural History offer longer guided trips. These groups plan seasonal visits for small groups (i.e., fewer than 30) primarily to observe migratory shorebirds. Participants pay a fee to the organizations, which then arrange for transportation to the refuge and an interpretive guide.

Shellfishing

Over the course of the last 20 years, Chatham has been one of the top shellfish producing towns in the Commonwealth of Massachusetts. Collectively, Chatham has a total of 101,763 acres available for shellfishing in 17 State-designated shellfish areas. Several of these areas are commonly harvested for softshell clams and quahogs during low tide periods. Of these areas, Monomoy Island (SC47) is the largest designated area at 37,831 acres, representing nearly 80 percent of tidal shellfish areas. In fact, the Monomoy area, which has no seasonal shellfish closures, has a greater relative importance in the entire area. In contrast, many of the tidal areas within the Town are conditionally approved for harvest. This usually means that these areas will be closed to harvest if fecal coliform bacteria levels exceed National Shellfish Sanitation Program standards, common during warmer months.

In 2011, nearly 1.4 million live pounds of shellfish were harvested in the Chatham area, and more than one-half of the harvest originated from Monomoy. About 50 percent of the Monomoy harvest was northern quahogs (786,632 live pounds). In 2011, Monomoy shellfishermen also landed more than 20,655 pounds of bay scallops, 10,449 pounds of softshell clams, and 42,982 pounds of whelks.

A brief description of the types of shellfish harvested in Chatham waters follows.

Mussels

Mussel harvesting has occurred in the open waters north of North Monomoy Island. We have no information about specific mussel harvests on the refuge or how often this has occurred. The Town provided the following information: "The harvesting effort is determined by the extent of the mussel bed and typically ranges from one to ten vessels involved in the fishery. Vessels targeting mussels usually employ at least two permit holders, though if three or more work on a vessel, only two Individual limits can be filled per vessel per day. Therefore, a good mussel set could employ upwards of 20 plus individual permit holders. The last successful mussel set in Chatham was in 2008 in Pleasant Bay" (Town of Chatham 2015a). Over the past 20 years, on average, the typical mussel harvest has been about 28,000 bushels (Maillett 2013). Mussel harvest was the primary reason for the record total harvest levels in 1990, 1991, 1992, and 2008. Mussels have also been harvested out of Chatham Harbor.

Softshell Clams

In 2002, the peak year for softshell clam harvest in Chatham, the total amount of harvest was 78,000 bushels (Maillett 2013, Town of Chatham 2005b). According to the Shellfish Constable's annual reports, the majority of the harvest, not only in the peak year of 2002 but for all years, came from Monomoy and Nauset/South Beach. Since that peak year though, harvest levels have dropped precipitously. In 2009, the total amount of softshell clams harvested was 4,000 bushels, only

about 5 percent of the 2002 peak harvest. In 2011 the harvest of softshell clams rebounded to nearly 18,000 bushels. According to the 2010 Shellfish Constable report, the increasing harvest of softshell clams is now primarily coming out of the north side of town (Chatham Harbor and Pleasant Bay). The recent decline in the harvest of softshell clams has been attributed to the changing geophysical conditions of South Monomoy Island.

Quahogs
In contrast to the softshell clams, quahog harvests have shown a steady and stable increase between the years 2001 and 2008, and have pretty much stayed between 10,000 and 20,000 bushels per season (Maillett 2013). The average annual harvest over the past 20 years has been about 14,000 bushels. Common Chatham shellfish areas where quahogs are harvested include Monomoy, Oyster Pond, and Mill Pond. Oyster Pond, however, is conditionally approved by the State and subject to seasonal shellfish closures.

Razor Clams
We have little information about razor clam harvest on the refuge. The Town indicated this was not occurring on the refuge because it is a sub-tidal fishery (Town of Chatham 2015a), but there are sub-tidal areas on the refuge so there is potential for this fishery to occur on the refuge. According to the Town, "The razor clam fishery may be the least predictable of all the shellfisheries. The commercial success of this fishery is the quick adaptation and response of harvesters. Razor clams are very particular to their surrounding environment and will "move" when conditions become unfavorable. Though razor clams can be found in most all marine environments throughout Chatham, economically viable razor clam sets occur predominately in "new sand, such as what occurred in Pleasant Bay in 2012-2013…Many factors limit accessibility for harvesters making the fishery self-limiting " (Town of Chatham 2015a). The Town was not able to predict the future growth of this fishery, stating "There is no predicting ANY shellfishery within such a dynamic area. As with any fishery, the "set" will determine the effort" (Town of Chatham 2015a).

Bay Scallops
Bay scallops are typically not as plentiful in Chatham's waters compared to other species. Typically, annual harvest levels are around 500 bushels (Maillett 2013), although there can be "spikes" in scallop landings affected by market values and local abundance. For example, 2009 was a banner year when the Town reported more than 10,000 bushels of bay scallops harvested. Not since 2001 has the Town reported a bay scallop harvest greater than 1,000 bushels. These scallops were mainly harvested from the "southway" between Nauset/South Beach and Monomoy, the outer part of Stage Harbor, and Oyster River.

Commercial Fishing
There is some commercial fin fishing occurring in refuge waters, particularly in the southwest corner of the Declaration of Taking. Fishermen have historically harvested striped bass, bluefish, black sea bass, scup, fluke, lobster, whelk, and sea clams in Nantucket Sound and the subtidal waters of the refuge. Because the open waters of the refuge constitute a minor portion of the fishing zones, the amount of activity in this area is small and the majority of the fish in this area are harvested though rod and reel. We have no information about the economic value of this catch.

Guided Recreational Fishing
Monomoy NWR provides exceptional fishing opportunities. Sport fishing activities on the refuge have been a significant factor in the local economy; recreational fishing and guided excursions to the Monomoy NWR in 2012

contributed close to $100,000 in visitor spending to the local economy (Maillett 2013). Guide fees vary by the type of fishing and amount of time on the water. Typical rates for fishing the flats from a boat for a party of one or two anglers ranged from $375 for 4 hours to $575 for an 8-hour session. Wade fishing tends to cost less, from $250 for a 6-hour trip to $300 for an 8-hour trip, plus ferry fees ($15). Guide fees do not include tips, which typically run about 20 percent (*http://www.fishingthecape.com*; accessed February 2011).

Transportation and Wildlife Watching Services

There have been two principal ferry operators who provide the public transportation to Monomoy NWR and the flats—Monomoy Island Ferry and Outermost Harbor. In addition to providing transportation to the refuge, these ferry operators have also provided boat tours around the island for wildlife viewing (primarily seals).

Monomoy Island Ferry

The Monomoy Island Ferry Company has Rip Ryder, a 32-foot, twin engine power boat with a capacity of 20 passengers in addition to the captain. The company has been operating for over 20 years and boards passengers right on Morris Island, at the refuge headquarters. During the last decade, the Rip Ryder shuttled both fishing passengers and birders back and forth to North Monomoy Island and Nauset/South Beach for a fee. This service was effectively suspended in 2012. The company now primarily offers 90-minute seal cruises, which depart the refuge at 9:30 a.m., 11:30 a.m., 1:30 p.m., and 3 p.m. In 2012, the charge was $35 per adult and $30 per child. Monomoy Island Ferry will also shuttle birding group trips to South Monomoy Island, using either a small vessel for groups of six or fewer or a larger vessel for groups of 12 or fewer, at a charge of $360 for the small vessel and $720 for the larger vessel (*http://www.monomoyislandferry.com/*; accessed February 2013).

Outermost Harbor

Outermost Harbor Marine operated a shuttle to both North Monomoy Island and Nauset/South Beach for fishermen, birders, and recreationalists. In 2009, the charge was $20 per person for shuttle service to Monomoy NWR. Outermost Harbor Marine operates out of the marina off Seagull Road, approximately one-half mile south of Chatham Light (*http://www.outermostharbor.com/*; accessed March 2011). In 2013, Outermost Harbor Marine suspended its water taxi service to the refuge for business reasons (*http://outermostharbor.com/water-taxi/*; accessed February 2013).

Overall, recreational visits to the refuge contribute about $1,500,000 to the Town's economy (Maillett 2013).

Refuge Contributions to the Local Economy

The operation of the Refuge System not only provides wildlife with habitat but also provides visitors with opportunities to enjoy a variety of wildlife-dependent recreational and educational activities. Where it contributes to the purpose of the refuge and is compatible, an economic use such as haying or timber removal may be allowed. The operation of an individual refuge is much like that of any small business. Refuge budgets are spent on salaries, expenses, and payments, much of which are spent within the local community.

In fiscal year 2012, Monomoy NWR employed a refuge manager and two permanent biologists, one full-time term wildlife biologist, one part-time student employee, two seasonal biological technicians, and several seasonal interns. Salaries for the year were about $235,000 for the full time workers and about $80,000 for the seasonal workers.

The Refuge Revenue Sharing Act of 1935, as amended, provides annual payments to taxing authorities, based on acreage and value of refuge lands. We have contributed refuge revenue sharing payments to the Town since the refuge was established. Money for these payments comes from the sale of oil and gas leases, timber sales, grazing fees, the sale of other Refuge System resources, and from congressional appropriations. The actual refuge revenue sharing payment varies annually because Congress may or may not appropriate sufficient funds to make full payment. Payments are based on one of several formulae. In Massachusetts, the payments are based on three-quarters of 1 percent of the appraised market value. The purchase price of a property is considered its market value until the property is reappraised. The Service reappraises their properties every 5 years.

The actual Refuge Revenue Sharing payments made to the Town by the refuge for the FY 2008 to 2014 are shown in table 2.21. The most recent refuge revenue sharing payment was based on 7,604 acres. When the next appraisal occurs, it will be based on the official acreage figure for the refuge at that time.

Table 2.21. Refuge Revenue Sharing Payments for Monomoy NWR.

Fiscal Year	2007	2008	2009	2010	2011	2012	2013	2014	Total 2007-2014
Payment	$32,805	$25,452	$23,917	$22,533	$24,146	$22,690	$26,629	$24,924	$203,096

Monomoy NWR also spent approximately $63,000 (FY 2011) annually on materials and services to operate the refuge (Maillett 2013). Again, most of this money was spent locally.

Refuge Administration

Refuge Establishment and Special Designations

Monomoy NWR was established on February 10, 1944, through a Declaration of Taking by the Secretary of the Interior (District Court of the United States for the District of Massachusetts, Misc. Civil No. 6340). This taking extends from the MLW line on the eastern shores of the refuge and to an area within Nantucket Sound identified by latitude/longitude coordinates on the western side. Included within the Declaration of Taking are all the lands lying above MLW including a portion of Morris Island, all of Monomoy Beach, North Monomoy and South Monomoy Islands, Shooters Island, all land covered by the waters of landlocked ponds, and all islands, islets, sand bars, and tidal flats lying in Nantucket Sound, Chatham Bay, and Stage Harbor, all lying within the specific exterior limits. This rough acreage was estimated in 1944 to be about 3,000 acres, which roughly corresponded to the land area above mean high water, although the written description of the entire Declaration of Taking area well exceeded that amount as it used some explicit boundary points and MLW along the eastern shore. The boundary established by of the Declaration of Taking recognized that geophysical processes would change the shape and location of the refuge, and all lands and waters above mean low tide, as well as other features that are submerged within the fixed western boundary, were to remain as part of the Monomoy NWR. This land was acquired, "together with all accretioned land and singular water and riparian rights and other rights, tenements, hereditaments and appurtenances thereunto belonging or in any wise appertaining." The Declaration of Taking was upheld by the District Court of the United States on June 1, 1944. It is noted that the official acreage of the refuge was not accurately determined at the time of taking, which significantly exceeded 3,000 acres.

The refuge boundary is fixed by specific coordinates on the north, west, and south and is ambulatory on the east. Because of this, the size of the refuge changes over time as lands move, erode, or accrete. In 2000, a global positioning survey along the mean high and MLW lines was conducted. The acreage

determined to be above the high water line was 1,838 acres, the acreage above the MLW line was 3,599 acres, acreage submerged under water was 4,005 acres, and the total acreage within the Declaration of Taking was 7,604 acres. In 2001, the Service's Chief Surveyor reviewed the survey and found that the map was an accurate depiction of the conditions as of September 15, 2000 (Kopach 2002).

Submerged lands within the fixed boundary are included based on historical records that indicate an emphasis on controlling and restoring these lands due to their value for waterfowl. The extensive sea grass beds on the west side of Monomoy Island were recognized for their value to wintering waterfowl, in particular. Throughout the initial designation process for the refuge, the Monomoy area was recognized as an "outstanding waterfowl area" and as "one of the finest shorebird beaches in North America" (Salyer 1938) and for the eelgrass (*Zostera*) beds in shoal waters northwest of Inward Point on the Common Flats (Griffith 1938) that were described as "dense" beds in 1929 (Hotchkiss and Ekvall 1929). The biological values of this area helped define the initial refuge boundary. Deeds are to be interpreted consistently with the framer's intention, and it is clear from the historical records that areas containing sea grasses formed an important basis for establishing the refuge, therefore, including these submerged lands within the fixed western boundary is appropriate.

Also within the Declaration of Taking are transitory rivulets that run through the refuge or may form channels or bays stretching across areas of lower water. Based on geomorphological advice concerning the integrity of an intertidal system and upon approaches based on international treaty and Supreme Court cases, the surveyors drew straight lines across the "headlands" of such features rather than tracing MLW up and through these landforms. We believe this is the correct cartographic approach to follow.

Additionally, the transfer of submerged lands to the Commonwealth of Massachusetts as a result of the 1953 Submerged Lands Act did not include lands within the exterior perimeter of the Declaration of Taking. These lands have been subject to Federal jurisdiction and control since refuge establishment, although actual refuge management of these submerged and tidal lands has been limited. In subsequent litigation by the Commonwealth of Massachusetts on the 1953 Submerged Lands Act, Massachusetts claimed all of the waters of Nantucket Sound, which included the waters west of Monomoy within the Declaration of Taking. The Supreme Court held that the submerged lands west of Monomoy Point were not Massachusetts' internal waters at the time of the formation of the Union. Therefore, the submerged lands within the Declaration of Taking were already acquired as Federal land (by condemnation), excepted from the Submerged Lands Act, and subject to Federal jurisdiction and control when the Commonwealth received the surrounding lands in 1953.

Included in this area, and therefore falling under refuge jurisdiction, is the area of open water in the Morris Island channel that was land when the refuge was established. This area clearly lies within the coordinates of the Declaration of Taking.

The ambulatory east boundary of the refuge moves as the MLW line moves. Monomoy Island itself has shifted west since the refuge was established; as described earlier in this chapter, it has split into North and South Monomoy Islands. This is a dynamic system, so the eastern boundary will never be static, and refuge acreage figures will constantly change over time as land and water characteristics change. The dynamic nature of this ambulatory boundary, along with the southward movement of sand from the Atlantic facing sandy beaches to the north and the slow filling in of the Southway and the creation of salt marsh in what had formerly been open waters, creates complications related to locating legal property boundaries and jurisdictional issues.

The Declaration of Taking defined the Monomoy NWR eastern boundary (Atlantic Ocean side), as MLW. As long as South Monomoy Island remained an island, the eastern boundary was not in dispute, but once Nauset/South Beach attached to it in 2006 after years of gradually infilling, a new boundary reflecting the joinder of Nauset/South Beach and South Monomoy Island needed to be identified. Further complicating the boundary determination is that South Beach is a continuation of Nauset Beach, which was the original landform defining the southern boundary in the designation of Cape Cod National Seashore in 1960 under NPS jurisdiction. The national seashore designation extends 1/4-mile out (seaward) from the MLW line, and there are now areas where the NPS jurisdiction overlaps with Service's jurisdiction.

The Town, NPS, and Service all had interests and rights in the ownership and management of parts of Nauset/South Beach at the time the final attachment occurred. In 2007, an agreement (called the "handshake agreement") with the Town, the NPS, and the Service was temporarily established for management of the joinder area. The attachment point, or "thread," was vague, but the three entities agreed that the Service would manage all lands west of the thread and the Town would manage all lands east.

In 2008, a signed MOU formalized the handshake agreement among the NPS, the Service, and the Town. The MOU contained an agreement among the parties to establish a management boundary for use in determining jurisdictional authorities among and between parties. This boundary was intended to be temporary until a permanent solution regarding Department of the Interior jurisdiction (the overlap of the Cape Cod National Seashore onto Monomoy NWR) was resolved.

Since the establishment of this short-term agreement in 2008, the land connection grew longer and wider. It became very difficult to define a line that demarcated the point of physical connection at mean low tide (the thread). Because all parties to the MOU maintained effective communication and working relationships, the difficulty defining a line demarcating this changing area did not become an issue throughout the 5 years of the agreement. However, at the expiration of the MOU in January 2013, we did not have an agreement on how to define a new boundary.

Monomoy National Wildlife Refuge shoreline

Claire Revekant 2014

This lack of agreement on a new boundary coincided with the final development of the Monomoy draft CCP/EIS. Then, in February 2013, South Monomoy became an island once again with a break in Nauset/South Beach. The legal and management questions remained complex, but our initial legal analysis indicated that 717 acres of Nauset/South Beach that had attached to South Monomoy were now under the jurisdiction of the Service. This calculation brought the total refuge ownership to 8,321 acres, which was the number we presented to the public in the Monomoy draft CCP/EIS.

While some agreed with the legal reasoning behind our assertion to ownership of part of Nauset/South Beach, the Commonwealth of Massachusetts, the Town, and many individuals did not. Uncertainty remains about the precise boundary location. Therefore, after the public comment period for the draft CCP/EIS closed, in June 2015 the Service worked with the Town of Chatham Select Board to develop a new MOU and administratively determine a management boundary on Nauset/South Beach (see appendix L). The management boundary line was drawn from the northeasterly most point of open water within the Declaration of Taking to the point where this line crosses Nauset/South Beach on the Atlantic Ocean. The Monomoy Lighthouse, which is a fixed location, became the reference point from which this line was drawn; but the management boundary ends at the Atlantic Ocean.

While the Service and Town remain in disagreement over the precise location of the legal boundary between our respective ownerships, this mutually agreed upon management boundary provides for Town management over much of the area that the Service had preliminarily determined to be lands of the United States. The agreement will be in effect for the next 15 years and is extendable by mutual agreement of both parties. The MOU facilitates cooperation between the Service and the Town on resource protection, public access and use, while both parties continue working toward settling the more complex question of the precise location of our common legal boundary.

The NPS is not a party to the new MOU, even though they had been one of the signatories of the 2008 MOU. The fundamental protections that apply to all of Nauset/South Beach as part of the Cape Cod National Seashore remain in effect. The NPS interprets Nauset Beach as extending to the point on South Monomoy Island where the connection first occurred in 2006. In the area where the Seashore's 1/4-mile offshore jurisdiction might overlap with refuge lands above MLW, we agree that the most restrictive rule of either agency involved would prevail. This addresses the issue of a jurisdictional overlap, and also preserves the intent of Congress that the Atlantic coast from Provincetown to the tip of Monomoy Island would be officially protected by the Federal Government.

In the course of the new MOU development, it was acknowledged that the Nauset/South Beach landform is shifting to the west. A review of recent aerial photography affirms that the northern tip of the part of Nauset/South Beach located below the 2013 (and subsequent 2014) breach is moving toward South Monomoy Island. Also, sand is being pushed west into the Southway in the vicinity of the inlets created by the breaches. Because this landform is different than it was when the refuge acreage was established for the Monomoy NWR draft CCP/EIS, the new refuge acreage is larger than some might expect based on the new MOU. Using the 2014 aerial photography that was used as the base for depicting the management boundary, the upland/saltmarsh area east of the Southway that is now under Town management totals 574 acres. The upland area is decreasing as sand is deposited in the Southway particularly adjacent to South Monomoy Island. The new refuge acreage, for purposes of this final CCP/EIS, is 7,921 acres.

If, today, you were to calculate the acreage figures for both the refuge and the part of Nauset/South Beach that will remain in Town management, completely different acreage figures would be identified. As previously stated, the Monomoy NWR is a dynamic system, and therefore the actual refuge acreage is also variable and dynamic, with the potential to change on a daily basis. Since it is necessary to fix an acreage figure for the purposes of planning and revenue sharing, we are using an acreage value that derives from the 2015 MOU's location of the management boundary based on 2014 aerial photography.

Wilderness Designation

On October 23, 1970, Monomoy NWR was afforded additional protection when Public Law 91-504 designated as wilderness most of the land and intertidal areas within the refuge. The wilderness area designation extends to MLW. Wilderness designation imposes constraints on how lands and waters within the wilderness area can be used. The use of motorized equipment and mechanized transport is not generally allowed in wilderness areas. Motorized boating is allowed in Monomoy's waters because it was an established use when the wilderness designation occurred. Section 5 of Public Law 91-504 provides that wilderness areas shall be administered in accordance with the provisions of the Wilderness Act (Public Law 88-577), and Section 4(d)(1) of that law allows that the use of motorboats, where already established, may be permitted to continue (subject to restrictions deemed desirable).

There were two tracts of land that were excluded from the wilderness areas: Inward Point and Powder Hole. These areas were excluded from the Monomoy Wilderness because they contained summer cottages and other facilities still being used or in private ownership. Except for the light station, these facilities no longer exist, and land title has since transferred to the United Sates for all parcels. The Powder Hole exception also included 4 acres that were owned by the Massachusetts Audubon Society at the time of wilderness designation. This private inholding contained the Monomoy Point Light Station, which was subsequently purchased by the Service and added to the refuge. The law establishing the Monomoy Wilderness identified the two exceptions as approximately 90 and 170 acres, but later Regional Director Richard Griffith more accurately measured them as being 73 acres (Inward Point) and 137 acres (Powder Hole). In 2001, Service surveyors recalculated the size of these areas to 595 acres, as the exclusion areas extend to MLW. Although these two areas were excluded from the wilderness designation, Congress intended for the Secretary of the Interior to manage the entire area consistent with the concept of wilderness (House of Representatives, Report No, 91-1441). Due to the dynamic nature of the landscape, the configuration and actual acreage of the Monomoy Wilderness has constantly changed over the past 40 years. Those lands lying west of the management boundary designated in the June 2015 MOU for addressing the eastern refuge boundary with the Town on Nauset/South Beach are considered a natural expansion the Monomoy Wilderness and managed as wilderness.

The Monomoy NWR planning team initiated a wilderness review, as required by refuge planning policy, to determine if portions of the refuge (lands and waters in fee title ownership) that were excluded from the original 1970 wilderness designation were suitable for detailed study as wilderness study areas and potentially proposed for designation as a wilderness. Appendix E summarizes the inventory phase of the wilderness review for those portions of Monomoy NWR excluded from the original 1970 wilderness designation. That wilderness inventory (appendix E) determined that none of the current non-wilderness portions of South Monomoy Island excluded from wilderness designation in 1970 yet meet the eligibility criteria for further detailed study as wilderness study areas, as defined by the Wilderness Act, during the 15-year plan period. The refuge will again undergo a wilderness review in 15 years as part of the next planning cycle, at which time wilderness study area designation and the wilderness study and recommendation phases will be reconsidered for the Inward Point and Powder Hole areas. We may also conduct a wilderness review prior to the next planning cycle, should significant new information become available, ecological, or other conditions change, or we identify a need to do so.

Wilderness Character Report

In 2012, Wilderness Fellow Taryn Sudol completed a report, "Wilderness Character Monitoring Report: Monomoy Wilderness" that addresses the five tangible and measurable qualities of wilderness character: untrammeled, natural, undeveloped, solitude or primitive and unconfined recreation, and other features. Since few existing wildernesses actually have the data that extends back to designation for the measurements created at the time of the monitoring report, this initial condition assessment will be the substitute. Baseline conditions must be set as a reference point against which change over time is measured and evaluated. Ideally, all baseline data would have been collected at the time of designation. For the Monomoy Wilderness, the baseline assessment year is FY 2012. With the baseline in place, change can be monitored over time. The discussion below is adapted from Sudol's report (2012). This report can be accessed at the refuge's Web site: *http://www.fws.gov/refuge/Monomoy/what_we_do/conservation.html* (accessed October 2015).

Untrammeled
At present, it seems that nearby developments have not trammeled the wilderness' physical processes. Current management techniques result in minimal trammeling and little effort is needed to restore the wilderness' natural systems and to ensure that the most fragile and endangered wildlife persists; if this management success endures, then even less trammeling would occur in the future.

Natural
The main risks to Monomoy's naturalness are the chances of its being overrun with non-native species or having its existing habitats shift or decline due to climate change. Uncharacteristic alterations in sea level, temperature, precipitation, or soil moisture, and frequency and magnitude of storms may cause a distorted landscape that would not have happened absent mankind's effect on global warming.

Undeveloped
Although considerable artifacts and human debris are left, they appear and disappear with the shifting sands and vegetative regrowth. Today, developments and physical structures on Monomoy are limited to management tools (e.g., nest enclosures), signage, and research equipment. Motorized vehicles, mechanical transport, and motorized equipment are precluded from visitor use, and the administrative use of such is only to be permitted during outstanding occurrences and when deemed the minimum necessary. In fact, such use is generally nonexistent due to access issues and the types of activities conducted.

Solitude or Primitive and Unconfined Recreation
Outside the wilderness boundary, commercial and recreational fishing regularly occur. Boat traffic is heavy at times during the summer; seal tours and fishing boats circulate South Monomoy Island. Commercial, military, Coast Guard, media, and recreational aircraft sometimes fly low over the Monomoy Wilderness, briefly interrupting a feeling of solitude or isolation. Such solitude is also intruded upon by the view of houses and prominent water towers that sustain the mainland communities.

Other Features
The principal exception is the Monomoy Lighthouse. This 40-foot high, cherry-red tower, alongside the wood-shingled light keeper's house and brick oil shed, stands on one of two excluded portions of the wilderness of South Monomoy Island.

The Eastern Massachusetts NWR Complex and Staffing

Since the refuge was established, it has been administered as a satellite of the Eastern Massachusetts NWR Complex located in Sudbury, Massachusetts. We use the term refuge complex (complex) to describe two or more individual refuges, typically in the same region of a state or adjoining states, administratively combined under a single refuge manager's responsibility. Present staffing for the complex includes 15 permanent positions, 11 located at the complex headquarters at Great Meadows NWR in Sudbury and another at the Assabet River NWR, also in Sudbury. Monomoy NWR currently has three permanent full-time staff positions: the refuge manager, a wildlife refuge specialist and a wildlife biologist. Seasonal biological technicians, term staff positions, and summer interns vary each year depending on funding. Oversight of the refuge is provided by the project leader of the complex, and staff from the refuge complex regularly assist Monomoy NWR staff throughout the year with the full range of refuge management activities, including biological surveys and monitoring, visitor services activities, construction and maintenance, outreach, and law enforcement. Appendix G shows the staffing chart for Monomoy NWR.

Refuge Funding

Successful implementation of the CCP for each refuge relies on our ability to secure funding, personnel, infrastructure, and other resources to accomplish the actions identified. This includes staffing, maintenance, major construction projects, and individual resource project management capability, e.g., basic operational expenses such as utilities, office supplies, field supplies, travel, and discretionary biological and visitor services funding that supports shorebird study and management; beach nesting birds' predator and competitor management; northeastern beach tiger beetle research and management, refuge brochures, signage, etc. Most of these projects have been identified as Tier 1 or Tier 2 Projects in the Refuge System's Refuge Operations Needs System database (RONS). Appendix H lists RONS projects and their recurring costs, such as salaries, following the first year, as well as a list of projects in the Service's current Maintenance Management System (MMS) database for the refuge complex. Currently, the MMS database lists $1,195,273 in maintenance needs for Monomoy NWR. This number, however, is outdated and in need of revision.

Monomoy NWR does receive a specific budget allocation annually but, as with staffing, it is insufficient to support the refuge's operations and needs. The complex provides significant support. Funding requests and assistance to Monomoy NWR are addressed in the same fashion as for the other refuges in the complex. Table 2.22 shows the specific allocation for Monomoy NWR and for the entire refuge complex for fiscal years 2007 to 2013.

Table 2.22. Fiscal Year Funding for Monomoy and Eastern Massachusetts NWR Complex.

Fiscal Year	2007	2008	2009	2010	2011	2012	2013
Base Funding (Operations)							
Monomoy NWR	$274,370	$330,706	$346,343	$360,685	$366,545	$364,713	$354,194
Eastern Mass NWR Complex*	$2,070,809	$2,181,898	$1,919,276	$1,949,686	$2,109,679	$2,077,697	$1,545,974
Project, Temporary, Construction, and Other Funds							
Monomoy NWR	$26,200	$76,200	$1,686,633	$137,538	$93,338	$465,493	$92,811
Eastern Mass NWR Complex*	$2,898,619	$497,465	$4,560,000	$2,022,800	$227,302	$470,289	$895,927
Total Fiscal Year Budget							
Monomoy NWR	$300,570	$406,906	$2,032,976	$498,223	$459,883	$830,206	$447,005
Eastern Mass NWR Complex*	$4,969,428	$2,679,363	$6,479,276	$3,972,486	$2,336,981	$2,547,986	$2,441,901

**All complex budget numbers include Monomoy NWR funds. These numbers include one-time construction projects, land acquisition funds, contributed funds, quarters income, etc.*

The allocation for FY 2014 was about the same as previous years due despite budget cuts. These numbers include funding of one-time construction projects, funding from the American Recovery and Reinvestment Act (ARRA) for the Monomoy Point Lighthouse and energy projects, income received from donations, quarters, and grants, as well as base funding for operations and maintenance.

Refuge Facilities, Infrastructure, and Maintenance

All refuge facilities currently in use include the refuge headquarters/visitor contact station, the dormitory/maintenance building, and a public restroom, all located on Morris Island. Periodic maintenance of existing facilities is critical to ensure safety and accessibility for refuge staff and visitors. The headquarters

and dormitory were renovated in 2002, and ongoing energy efficiency improvements completed in 2010 included two 30-tube (approximately 48 square feet) solar-thermal panels installed on the refuge dormitory, providing up to 10 gallons of domestic hot water per hour and connected to a tank-type electrical water heater. The public restroom was constructed in 2004 at the refuge headquarters.

The National Weather Service (NWS), an agency within the Department of Commerce's NOAA had been co-located with the refuge at the Morris Island administrative complex since 1971; this joint tenancy is expected to continue at least through the plan period. The NWS has two buildings and a parking area in which they conduct their work. A MOU guides the dual-use of the Morris Island facilities. The current refuge headquarters and visitor contact station building were actually constructed and occupied as an administrative office for the Environmental Science Services Administration, forerunner to the National Weather Service.

On South Monomoy Island, refuge structures currently listed on the NRHP include a lighthouse, keeper's house, and small oil house built in the early 1800s for the Monomoy Point Light Station. These buildings are currently closed to the public, but it is our intention to open these facilities to local historical tour groups. These buildings require regular maintenance and received major repairs in 2011, but additional repairs can be expected in order to meet safety standards.

This CCP will explore the expansion of current infrastructure or establishing an alternative visitor contact station in the local community to help alleviate the overcrowding that would occur with increased staff.

Right-of-Way

The refuge has right-of-ways on Tisquantum Road, Wikis Way, and Stage Island Road to access its properties for refuge resource management, public use, and visitor access. Encroachments on the Wikis Way right-of-way will be resolved separately from this planning process.

Findings of Appropriateness and Compatibility Determinations

Chapter 1 describes these two decision processes in detail. When the refuge manager publishes a CD, it stipulates the required maximum reevaluation dates: 15 years for wildlife-dependent recreational uses and 10 years for other uses. However, the refuge manager may reevaluate the compatibility of any use at any time, in some cases sooner than its mandatory date, or even before the CCP process is complete, if new information reveals unacceptable impacts or incompatibility with refuge purposes. Refer to appendix D for an updated list of CDs and associated findings of appropriateness for refuge activities for our preferred alternative.

Partnerships

Monomoy NWR has been involved in many partnerships since its establishment in 1944. These would not have been possible without the cooperation of conservation organizations, Town and county community leaders, State and Federal agencies, universities, and local elected officials. Those partners continue to be active in land conservation for the common goal of maintaining the aesthetic, cultural, economic, and ecological values of the region for future generations.

Our partnerships continue to expand to include not only groups and individuals interested in land conservation, but also those interested in habitat and species management, recreation and visitor services, and education and public outreach.

These partners include Mass Audubon, with whom we have a cooperative agreement that enables us to combine resources to facilitate monitoring, management, and habitat restoration efforts for piping plovers, least terns, American oystercatchers, and northeastern beach tiger beetles on Nauset/South Beach. For the last 3 years, we have been working with the Conserve Wildlife Foundation of New Jersey to study red knot migration and its regional significance. The American Oystercatcher Working Group assists us with banding oystercatchers on the refuge and we participate in meetings. We have also worked well with the Town, which, in particular, has allowed access to Nauset/South Beach and other lands for red knot research, has engaged us in shellfishing discussions, and has shared aerial photography.

Conservation Organizations:
- American Oystercatcher Working Group
- Cape Cod Stranding Network (International Fund for Animal Welfare)
- Conserve Wildlife Foundation of New Jersey
- Friends of Monomoy NWR
- Gulf of Maine Seabird Working Group (GOMSWG)
- Manomet Center for Conservation Sciences
- Mass Audubon
- Northeastern Beach Tiger Beetle Working Group
- Red Knot Working Group
- Seabird Ecological Assessment Network (SEANET)
- Wildcare Rehabilitation Center
- Cape Cod Museum of Natural History
- Student Conservation Association
- Americorps-Cape Cod
- Senior Americorps

Town and County Governments:
- Chatham Department of Health and Environment–Coastal Resources Program
- Chatham Public Schools

Chatham Department of Public Works
- Chatham Department of Community Development.

Federal and State Agencies:
- Massachusetts Department of Conservation and Recreation, Division of State Parks and Recreation
- Massachusetts Division of Fisheries and Wildlife (MassWildlife)
- Massachusetts Division of Marine Fisheries (MA DMF)
- National Marine Fisheries Service (NMFS)
- NPS, Cape Cod National Seashore
- USGS Patuxent Wildlife Research Center
- Federal Highway Administration
- National Weather Service

Universities and Other Educational Institutions and Organizations:
- Antioch University New England
- Tufts University School of Veterinary Medicine
- University of Rhode Island
- Clemson University
- University of Massachusetts
- University of Maine
- Provincetown Center for Coastal Studies
- Woods Hole Oceanographic Institute

Friends Group
The Friends of Monomoy NWR support visitor services and biological activities on the refuge. They have assisted in developing and implementing interpretive programs and tours on the refuge in the past, written grant proposals, and are invaluable in supporting those priority programs and helping respond to the requests for programs that far exceed the refuge's ability to meet them.

Volunteer Programs
Our active volunteer program involves student interns from all over the country, as well as local residents, clubs, and organizations. Every summer, the refuge hosts volunteer student interns, who are generally college-aged students or recent graduates. Interns spend time assisting with various refuge projects including collecting biological data, monitoring public use, leading nature walks and interpretive programs, designing educational displays, writing monitoring plans and grant proposals, greeting the public, and conducting maintenance on refuge equipment and facilities.

Special Use Permits, including Research

SUP's are issued to individuals, organizations, and agencies requesting the use of refuge facilities or resources beyond what is available to the public; this includes conducting research projects in the refuge. In order to ensure that wildlife disturbance is minimized, special conditions and restrictions are identified for each request. On average, the refuge issues about 12 permits each year, with project periods ranging from 1 day to 1 year, depending on the scope of the request. The refuge manager issues SUP's on a case-by-case basis after determining whether the use is compatible with refuge purposes.

Refuge staff, graduate students, conservation organizations, and others have conducted numerous surveys and studies on the refuge, each covered by a special permit. A sampling of those research efforts is provided in table 2.23. Additional information on these studies can be obtained from refuge headquarters.

Table 2.23. Sample of Special Use Permits for Monomoy NWR Since 2000.

Year(s) Issued	Organization/Permittee	Purpose
2000	Virginia Polytechnic Institute and State University/Jim Fraser	Piping plover study
2000 to 2001	NPS, University of Rhode Island, and Massachusetts Audubon Society	Population demographics and spawning densities of the horseshoe crab
Annually	Blair Nikula	International shorebird surveys
2007	University of Massachusetts—Amherst, Entomology Department	Brown-tail moth survey
2007	Cornell University	Nitrogen disposition study
2001 to 2002	Manomet Center for Conservation Sciences	Study of organophosphate levels in night herons
2001 – 2012	National Marine Fisheries Service	Gray seal population and diet studies
2003 to 2005	I.C.T. Nisbet and Company Scientific Consulting	Follow-up studies to investigate effects of Buzzard's Bay oil spill on common terns nesting on Monomoy NWR
2008	Provincetown Center for Coastal Studies	Photo identification of individual gray seals and harbor seals on South Monomoy
2007	Antioch University	Roseate and common tern use of staging sites during the post-breeding period
2005	Town of Chatham	Investigation on impacts of commercial shellfishing within refuge boundary on shorebirds

Mosquito Management

The refuge lies within the jurisdiction of the Cape Cod Mosquito Control Project. The CCMCP has conducted mosquito control activities on Morris Island (both on and off-refuge) since the CCMCP was organized in 1930. Mosquito and arbovirus surveillance, monitoring, and treatment within the refuge historically focused on several small saltwater wetland areas on Morris Island harboring *Ochlerotatus cantator* and *O. sollicitans*, "bridge vectors" for West Nile virus (WNV) transmission to humans. The CCMCP controlled larval mosquitoes in these small pools from at least 1983 until August 2001, when the practice was suspended pending review of the Service's new compatibility process. In July 2003, the Service found mosquito surveillance and limited mosquito control to be compatible, and the CCMCP resumed surveillance and larvicidal mosquito control of select mosquito species.

The refuge has worked with the CCMCP to reduce the quantity of insecticides used on refuge lands and ensure activities are consistent with the Service's policies. Mosquito management is a complicated issue for the refuge. Monomoy NWR is adjacent to residential beach communities where nuisance issues are amplified. The control of mosquitoes is a State priority and a reality of management of salt marshes in Massachusetts, and on the refuge as well. Pesticide treatment is not be used on Monomoy NWR solely for nuisance mosquito relief, and is only considered when there is a demonstrated human or wildlife health risk. Only pesticides identified in the SUP and for which a pesticide use proposal has been submitted and approved are used on the refuge. Two types of treatment historically employed to control refuge mosquito populations within salt marsh habitats are larvicide (*Bacillus thuringiensis* var. *israelensis* (Bti) and Aquabac) and pupacide (Agnique). No adulticides have been used in recent decades.

WNV was first detected in birds, mosquitoes, and humans in Barnstable County in 2003. West Nile virus was detected in mosquito pools in 2003 to 2006 (Towns of Falmouth and Barnstable) and 2008 to 2009 (Towns of Barnstable and Bourne). WNV was detected in dead birds (primarily corvids) in Barnstable County in 2005 (three positive samples, including one from Harwich) and 2006 (nine positive samples, including two each from Dennis and Brewster) before testing of dead birds was discontinued in 2009. Two human WNV cases were documented in the Town of Barnstable, one case in 2003 and another in 2007. There have been no human WNV cases documented for Chatham or surrounding communities (Harwich, Dennis, Brewster, or Orleans). WNV has not yet been detected in humans, dead birds, or mosquito pools in Chatham.

Periodic outbreaks of the eastern equine encephalitis virus (EEE), with an epicenter in southeastern Massachusetts just west of Cape Cod, are also documented. The majority of human EEE virus cases have occurred in Norfolk, Bristol, and Plymouth counties, although some cases are documented for Middlesex County, Essex County, and as far west as Worcester County. Although the historic EEE virus epicenter lies just to the north and west, Cape Cod and the islands (Martha's Vineyard and Nantucket) have no documented human eastern equine encephalitis cases or deaths. During 2012, EEE virus was isolated for the first time in the mid- to lower-Cape region from mosquitos captured adjacent to Nickerson State Park in Brewster, but there are no EEE virus occurrence records yet from Chatham or Harwich.

Larvicide treatments to reduce the threat of human transmission of WNV were applied annually to select Morris Island wetland areas along the refuge boundary from May to October, after monitoring indicated *O. cantator* and *O. sollicitans* larval counts exceeded an average of 5 larvae per standard (350 ml) dipper.

Pupacides are only used when large numbers of mosquitoes are considered an immediate threat to human health and thresholds developed by the appropriate public health authority are exceeded, such as when there is active transmission of mosquito-borne disease from refuge-based mosquitos or within flight range of vector mosquito species present on the refuge.

Adulticide treatments have not been applied on or near Monomoy NWR in recent decades, but were applied just west of Cape Cod during 2006, 2010, and 2012. In August 2006, an EEE virus outbreak prompted the Governor to declare a public health emergency for Plymouth and Bristol Counties, well west of Chatham. Aerial spraying of adulticides was used for the first time in 16 years. In August 2010, the Massachusetts Commissioner of Public Health issued a certificate of public health hazard due to the high risk of EEE virus transmissions to humans for this same area; this again prompted aerial spraying of the adulticide sumithrin. In 2012 the same general area was treated with adulticides due to a high risk of EEE virus transmission. For additional details on the refuge's mosquito management program, refer to the mosquito control compatibility determination in appendix D.