Chapter 2

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Eastern towhee

Affected Environment

- Introduction
- Physical Environment
- Geographical Setting and Landscape Context
- Major Historical Influences Shaping Landscape Vegetation
- Land Use History
- Current Conditions
- Refuge Natural Resources
- Climate Change
- Refuge Access and Public Uses
- Refuge Archeological, Historical, or Cultural Resources
- Regional Socioeconomic Setting
- Environmental Justice
- Refuge Administration
- Partnerships and Community Outreach

Introduction

This chapter describes the physical, biological, cultural, and socioeconomic environment of the refuge. In this chapter we describe the regional and refuge settings, current refuge administration, refuge resources, and programs.

Physical Environment

Setting

As previously noted in chapter 1, Massasoit NWR encompasses 209 acres and is comprised of three parcels briefly described below. The refuge has fully met its land acquisition goal within the current acquisition boundary. Under Federal regulations, refuges can acquire lands up to 1 mile from the refuge and up to 10 percent (20.9 acres) of the refuge's original acquisition boundary. The refuge has already maximized this option.

While small, Massasoit NWR is part of the largest contiguous pitch pine-scrub oak habitat north of the Long Island Sound (map 2-1), and is an integral component of the landscape's biodiversity. Together, the three parcels provide habitat that supports a diversity of native flora and fauna including the northern red-bellied cooter, neo-tropical migratory songbirds, rare moths and other native pollinators, and rare plants.

Crooked Pond Parcel

The Crooked Pond parcel is 184 acres and is the original land that was designated as Massasoit NWR in 1983. It is predominantly upland forest consisting of closed canopy mixed oaks and pine, with mixed oaks and pitch pine on the southern part of the parcel and mixed oaks and white pine dominated stands on the eastern part (AECOM 2010). The understory is fairly continuous and is mostly huckleberry and blueberry (both lowbush and highbush). This parcel also includes a 10-acre kettle pond known as Crooked Pond, and two smaller ponds, as well as about 591 feet of shoreline along Gunner's Exchange Pond. This original refuge parcel also abuts the MSSF which lies generally south and west of this refuge parcel and provides principal access routes to this and the Hoyt Pond (see below) parcel. The MSSF is Massachusetts' second largest State forest. Immediately to the north is a residential subdivision situated between this parcel and the Island Pond parcel. A powerline right-of-way (ROW), oriented northeast to southwest, transects the easternmost portion of the Crooked Pond parcel.

Island Pond Parcel

In 2002, an additional 15 acres (including easement) was added to Massasoit NWR on the east side of Island Pond, about 0.62 miles north of the Crooked Pond parcel. This parcel is also predominantly upland forest habitat (mostly white pine with some oak) and also includes about 984 feet of shoreline on the east side of Island Pond, including a small cove. The parcel fronts to the east on Long Pond Road, and its south boundary abuts the same residential subdivision described above for the Crooked Pond parcel.

Hoyt Pond Parcel

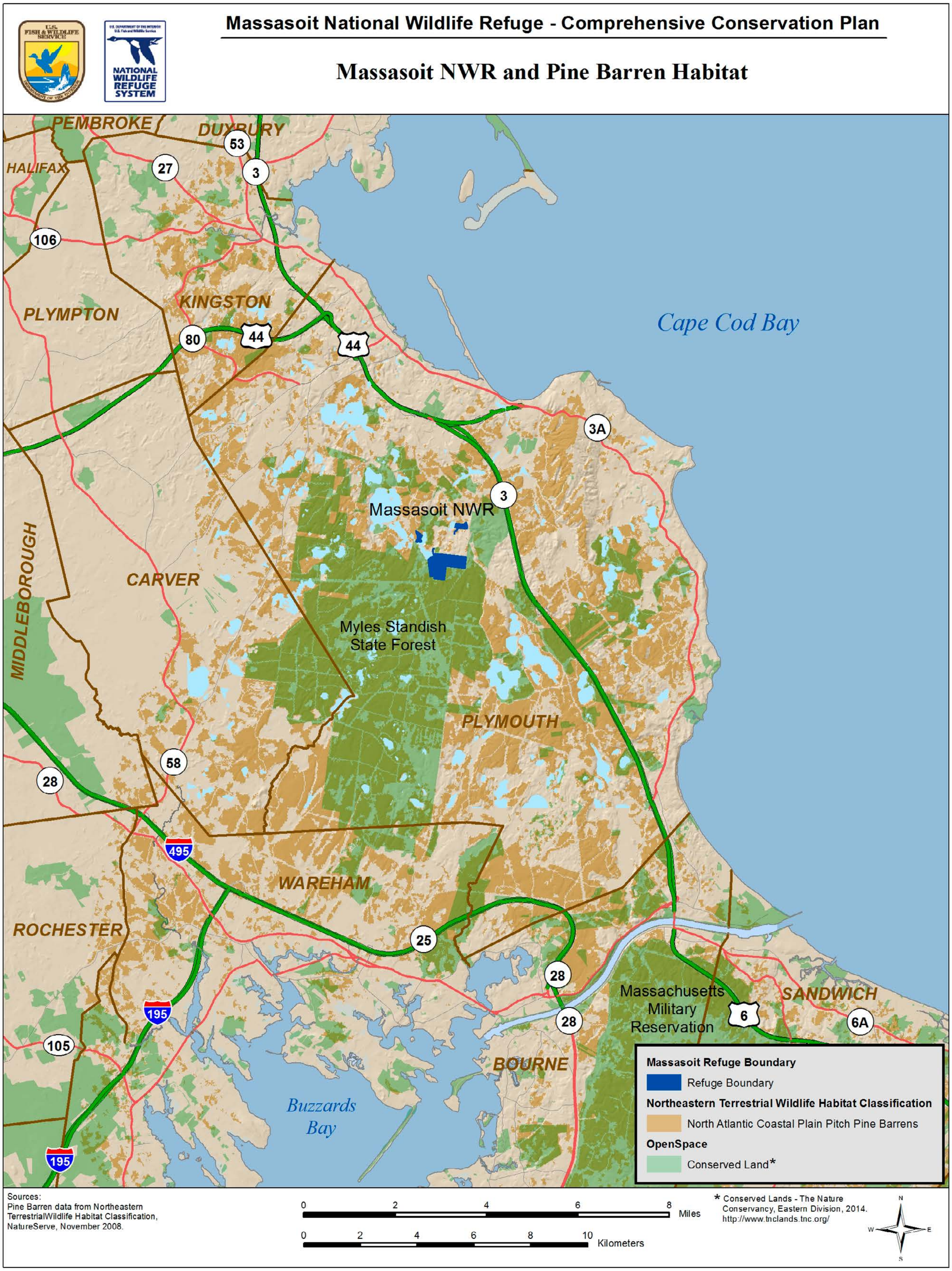
In 2006, an additional 10 acres was added to Massasoit NWR on the west side of Hoyt Pond, about one-half mile northwest of the original designation. This parcel is also predominantly upland habitat (mostly white pine with some oak) and also includes about 1,148 feet of shoreline on the west side of Hoyt Pond, which is connected to Gunner's Exchange Pond at times of high water levels. This parcel fronts to the west on Snake Hill Road, which serves as the primary overland access route to the parcel.

Geographical Setting and Landscape Context

Watershed

The refuge falls within the Plymouth watersheds, part of the regional South Coastal watershed, one of 11 eastern Massachusetts discharging directly into the Atlantic Ocean. The Plymouth watersheds consist of 12 individual watersheds

Map 2-1 Massasoit National Wildlife Refuge and Pine Barren Habitat



that contain 343 ponds including 32 globally rare coastal plain ponds. The Eel River is the most significant river system in the Plymouth area (map 2-2), at approximately 15.4 square miles. Within the Eel River watershed there are shallow glacially formed coastal plain ponds fed primarily by groundwater flowing through the Plymouth-Carver aquifer. The Plymouth-Carver aquifer is the second largest aquifer in Massachusetts, spanning nearly 200 square miles and storing more than 500 billion gallons of water (Town of Plymouth 2009).

The surface water bodies above this aquifer are largely fed by the aquifer itself, rather than from runoff. The Plymouth-Carver aquifer is designated as a sole-source aquifer by the U.S. Environmental Protection Agency (USEPA), to protect the water supply (map 2-3 and *http://www3.epa.gov/region1/eco/drinkwater/plymcarv.html*; accessed October 2015). The surficial geology in the watershed consists of unconsolidated stratified glacial materials deposited during the last glacial retreat approximately 15,000 years ago. Deposits of fine-to-coarse sand and gravel with occasional, limited lenses of silts and clay underlie the Plymouth watersheds. The lower portion of these stratified materials is saturated with water fed by direct infiltration of precipitation. Groundwater table elevations range from sea level to 125 feet above sea level, with the saturated thickness of the aquifer greater than 160 feet in many areas (Watershed Action Alliance 2006).

Geomorphic Region

Geomorphic regions or "physiographic provinces" are broad-scale subdivisions based on terrain texture, rock type, and geologic structure and history. Massasoit NWR lies in the Sea Island Section of the Atlantic Coastal Plain delineated by the USGS (2003). The southeastern part of Massachusetts marks 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.

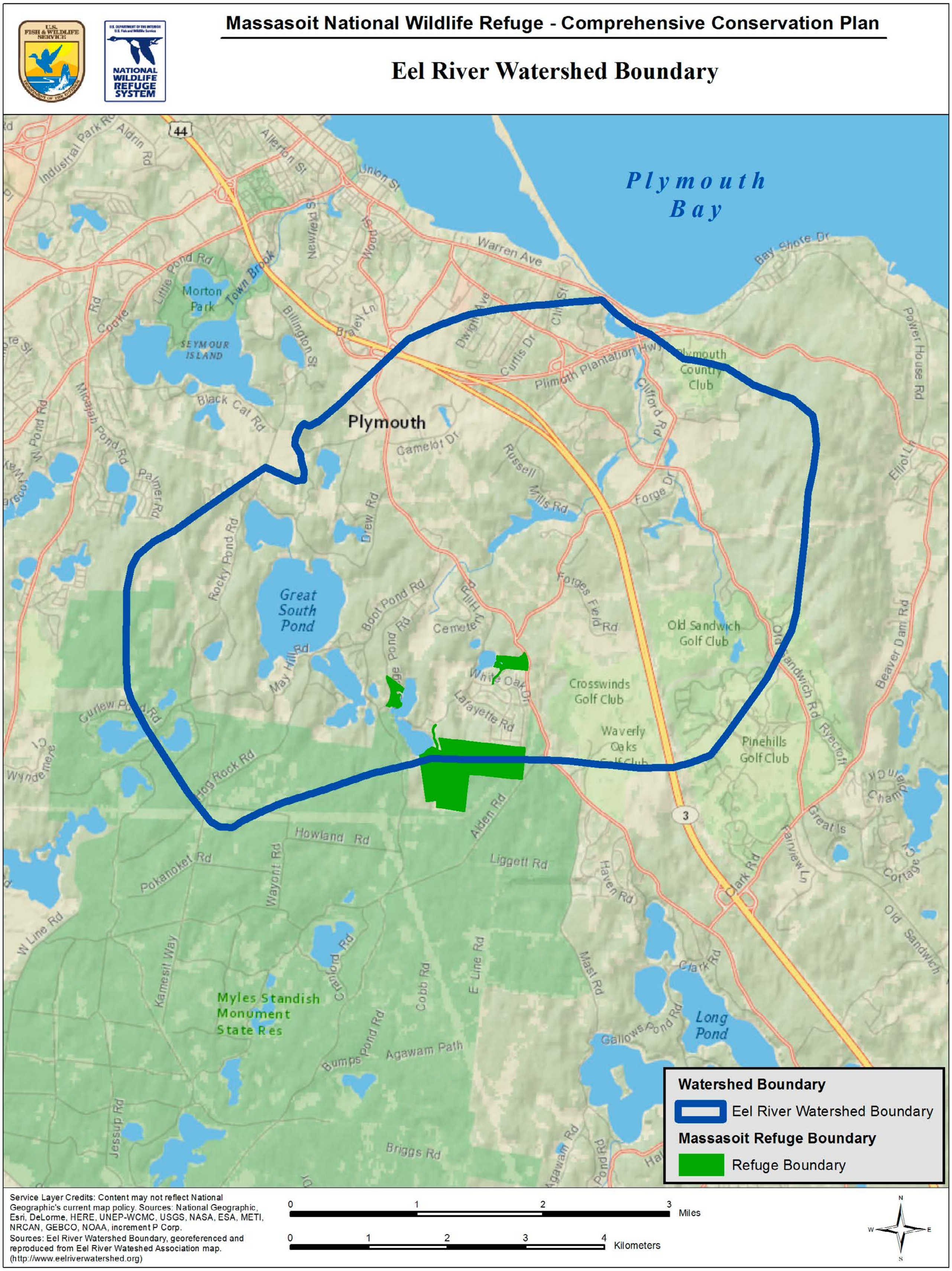
Biophysical Ecoregion 2-3—North Atlantic Coast

TNC has divided the continental United States into 63 ecoregions which are large geographic areas that share similar geologic, topographic, ecological, and climatic characteristics. These ecoregions are modified from the U.S. Forest Service (USFS) "Bailey System" (Bailey 1995). TNC has developed Ecoregional Conservation Plans that identify conservation targets and prioritize conservation actions for each ecoregion.

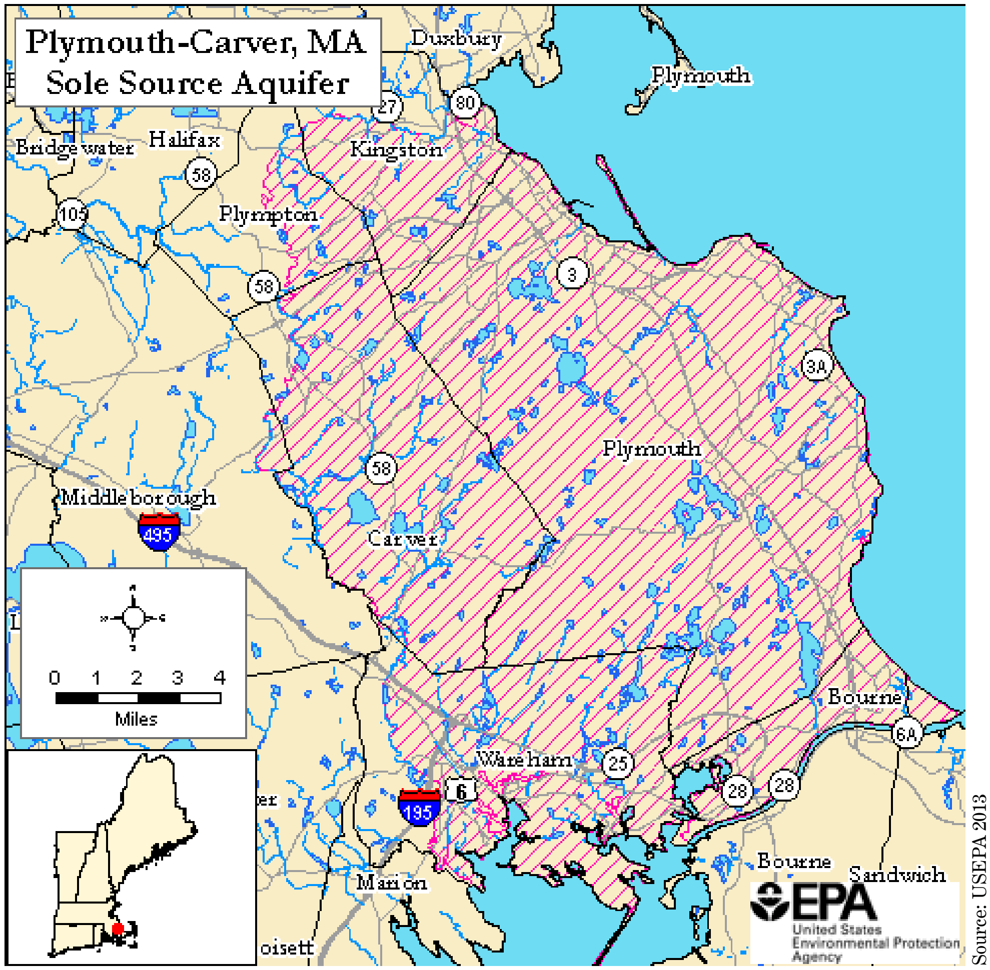
Massasoit NWR is in the North Atlantic Coast ecoregion as described by TNC (map 1-4). This ecoregion extends from Pemaquid Point in Maine south to Delaware Bay. Flat topography, low elevations (less than 600 feet), scattered moraines, large rivers draining into estuaries and bays, and a mild, humid climate characterize this region. Rocky coasts dominate the shore in the north, grading into salt marsh communities to the south. The once extensive forest graded from white pine-oak-hemlock forest in the north, to dry oak-heath forests, to mesic coastal oak forests in the south. Wetlands, beaver meadows, pine barren, and heathlands were embedded in this forested landscape. Hundreds of years of land clearing, agriculture, and widespread development have fragmented the landscape and eliminated large areas of forest. Smaller ecological systems remain, including barrier beaches and dunes, salt marshes, and freshwater wetlands (TNC 2006).

Atlantic Flyway

Massasoit NWR is within the Atlantic Flyway (map 1-4).Waterfowl follow distinct, traditional migration corridors, or flyways, in their annual travels between breeding and wintering areas. Flyways have been used for many years in North America as the unit for managing continental waterfowl populations, because they allow land managers to link efforts to conserve migratory bird species and their habitats on breeding, migration, and wintering grounds. The Atlantic Flyway Council is composed of the states of Connecticut, Delaware, *Map 2-2. Eel River Watershed Boundary*



Map 2-3. Plymouth-Carver Sole Source Aquifer



Florida, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Rhode Island, South Carolina, Vermont, Virginia, and West Virginia; the Canadian territory of Nunavut and provinces of Newfoundland, New Brunswick, Nova Scotia, Ontario, Prince Edward Island, and Quebec; plus the U.S. territories of Puerto Rico and U.S. Virgin Islands. The Atlantic Flyway Council contains representatives (usually administrators) from all the agencies with management responsibility for migratory bird resources in the Flyway.

The Council determines actions required for sound migratory game bird management and makes recommendations to the Service. The ACJV (refer to chapter 1—*North American Waterfowl Management Plan* and *Atlantic Coast Joint Venture Implementation Plan*) 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 use this information to help guide the distribution of resources to the needs and issues of highest priority.

Landscape Conservation Cooperatives

The refuge is located in the North Atlantic LCC which combines BCRs 14 (Northern Atlantic Forest) and 30 (New England/Mid-Atlantic Coast), and contains 12 out of 13 northeast states as well as the District of Columbia (map 1-4). It includes a diverse array of ecosystems; from high elevation spruce-fir forests to coastal islands (map 1-4). Many conserved lands exist in southeastern Massachusetts near Massasoit NWR with which the refuge can partner. For more information on the North Atlantic LCC, go to: *http://www.northatlanticlcc.org/* (accessed October 2015).

Major Historical Influences Shaping Landscape Vegetation

Describing the historic natural vegetation types, understanding how they were distributed, and what ecological processes influenced them prior to major, human-induced disturbance can help us evaluate future management options and environmental impacts. However, many ecologists caution against selecting one point in time, and instead recommend evaluating the "historical range of variation" for each habitat type.

The following, briefly summarizes major historic influences on natural vegetation patterns variation across the landscape.

Glaciation

Massachusetts, like all of New England, was covered by the Laurentide ice sheet during the last glacial maximum, approximately 21,000 to 18,000 years before present (BP). The ice sheet lobes occupied large basins in the bedrock surface. 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 (Motzkin and Foster 2002).

During the last glacial maximum, much of what is now the submerged continental shelf along the Massachusetts coast was exposed, with much of the world's water locked up in continental ice sheets. Estimated worldwide sea levels were 279 to 427 feet lower than today (Pielou 1991). By approximately 18,000 BP, the ice sheet began retreating with a warming climate, and by about 14,000 to 15,000 BP reached what is now the northern border of Massachusetts. As ice sheets retreated, sea levels gradually rose and the earth's crust slowly rebounded from the heavy weight of ice, but not as fast as sea levels were rising. This caused flooding along the northern New England coast as far south as present-day Boston (Jorgensen 1971). By about 12,000 BP the coastline between the Bay of Fundy and Cape Cod was much as it is today (Pielou 1991).

The advance and subsequent retreat of the glacier and changing climate had a profound impact on the local biota. With the glacial advance, many northern species were locally displaced and subsisted in southern areas of unaltered habitat. The period of glacial recession was one of highly fluctuating climatic factors (temperature, precipitation, humidity, and atmospheric carbon dioxide). The glacier directly altered the landscape as it retreated by depositing till, boulders, and creating kettle hole ponds. Kettle hole ponds formed when blocks of ice breaking off from a receding glacier became imbedded in or covered by outwash materials (till or sediments deposited from meltwater streams). Upon the melting of the ice, depressions remained that filled with freshwater as ground water levels rose. Typically, kettle ponds lack a surface water inlet or outlet and receive water from precipitation, groundwater from the aquifer below, or a combination of both. The pond levels generally fluctuate in response to the seasonal rise and fall of the water table (USGS 2013). Lakes were also forming as a result of the voluminous meltwater pouring off the retreating glacial front (Prentice et al. 1991, Jackson et al. 2000, Williams 2002). Combined, these factors made for ever-changing conditions as plant and wildlife species recolonized the area.

As the climate warmed and ice retreated northward, continual weathering and erosion of rock released nutrients and created new soils for plant recolonization. Tundra-like vegetation dominated the landscape just south of the glacier, though there may have been places where the ice abutted spruce forests (Pielou 1991, Jackson et al. 2000). The landscape was dominated by sedges and dwarf shrubs for several thousand years. As the climate warmed, these plants and associated animals followed the glacier as it continued to recede (Davis 1983, Marchand 1987).

Regional temperature and moisture levels primarily determined the variability in the post-glacial plant biogeography in southern New England. By 14,600 BP spruce predominated New England landscapes until 11,600 BP when white pine became dominant during a drier, warmer climatic period. By about 8,200 BP, hemlock, beech, and birch had replaced white pine, following a concurrent rise in moisture. Hemlock, a more mesic species, experienced a population crash around 5,400 BP originally attributed to the first-ever recorded occurrence of a pathogen. However, more recent evidence indicates that a drier microclimate may have also been a factor. Deciduous species such as hickory and chestnut were much slower to reach New England, about 6,000 BP and 3,000 BP respectively, likely due to regionally cooler temperatures and lower moisture levels than today (Shuman et al. 2004, Shuman et al. 2005).

The spruce parklands and grassy savanna habitats supported and were influenced by large mammals, including mastodons that disappeared quickly as the glacier receded and humans advanced across the region (Pielou 1991, Askins 2000).

Late Quaternary Water-level Variations and Vegetation History at Crooked Pond

Sediment cores collected along transects in Crooked Pond indicated water level changes between 15,000 BP and the present. The amount of fine-grained, detrital, organic accumulation in the basin suggests low water levels between 11,200 and 8,000 years BP and from 5,300 to 3,200 years BP. This history is consistent with records from the nearby Makepeace Cedar Swamp and other sites in New England and eastern Canada. The similarities in these records indicate that: (1) regional conditions were drier than currently when white pine grew abundantly between 11,200 and 9,500 BP; (2) higher moisture levels existed between 8,000 BP and 5,500 BP as the ice sheet retreated, and; (3) drier conditions possibly contributed to the decline of hemlock at 5,300 BP. Although sensitive to sea level rise, moist climate conditions were the primary reasons for water level rise during the Holocene Period (Shuman et al. 2001) (map 2-4, Figure 2-1; both reprinted from Shuman et al. 2001).

Fire

In contrast to its relatively minor role in the northern forests of Canada and northern New England, fire historically played a major role in shaping the ecosystems of coastal and southern New England, particularly the oak-dominated forests in the south, and the barrens and coastal marsh habitats. Several natural historians have concluded that fires set frequently by native peoples, along with naturally occurring fires, were important ecological factors in New England, especially in oak forests and pine plains (Bromley 1935, Day 1953, Motzkin et al. 1996). In reconstructing pre-European North American fire frequencies[1], Frost (1998) estimated that in PIF Region 9 (previously described in chapter 1) fires occurred approximately every 7 to 12 years in the more fire-prone habitats of the coastal plain, while on plains with hills or low mountains further inland, fire-prone areas burned approximately every 13 to 25 years. In pre-colonial and early colonial periods, the pine barren habitat in Plymouth County was

[1] Frost (1998) used a synthesis of physiographic factors (land surface form and topography), fire compartment size, vegetation records, fire-frequency indicator species, lightning ignition data, composite fire scar chronologies, remnant natural vegetation communities, and published fire history studies.

frequently burned. At that time the region was a mosaic of pitch pine-scrub oak barrens with frequent shrubby openings and grasslands. Pitch pine-scrub oak communities need fire to maintain the community structure and diversity (DeGraaf et al. 2005). The resinous, waxy cutins in the leaves of many of the plant species found in this community are highly flammable and ignite easily during dry periods. Fire-prone areas in New England usually coincide with soils derived from glacial outwash sands and gravels, with fractured or loose rock, or with shallow soils over bedrock (DeGraaf et al. 2005). Davis (1996) reports that fire was the major historic disturbance that shaped the vegetation of coastal Massachusetts, Connecticut, Rhode Island, and New York.

The region has a history of catastrophic wildfires during the 20th century. A 1937 wildfire in the Pine Hills area trapped and killed two firefighters. Humans were considered the cause for that fire as well as additional fires on Island Pond Road and Summer Street in Plymouth. In May of 1957, a wildfire started on the west side of MSSF at Cranberry Road in Carver and swept across what is now Massasoit NWR, jumped Route 3 in Plymouth and, driven by high winds, swept to the coastline at Manomet. This was one of the largest wildfires in the history of this area and burned 15,000 acres, destroyed 6 cottages and forced 150 residents to evacuate. In 1964, a wildfire that started in MSSF under high winds and dry conditions burned over 5,500 acres and destroyed 20 cottages in the area (MADCR 2011). In 1971, a 165-acre fire with 50-foot flames damaged two fire engines and injured seven firefighters. In 1991, a 1,200-acre fire along Route 3 destroyed two cottages and a trailer. And again in 1995, a 95-acre wildfire forced local residents to evacuate the Bourne Road area (Crosby 2001, updated 2007).

Recent improved wildfire protection has resulted in a taller and more closed-canopy pine forest. Pitch pine-scrub oak communities carry one of the highest fuel loads on the North Atlantic Coast (Patterson 1988). Pitch pines have fire resistant bark and serotinous cones, which release stored seeds when subjected to the heat of a surface fire. Taller white oaks and white pines are indications that an area is gradually succeeding towards a closed-canopy forest (NHESP 1990). Natural forest succession proceeded uninterrupted with fire suppression, and this can decrease species diversity. More frequent fires reduce the duff and litter layers and create a more open overstory allowing certain shrubs, grasses, herbs, and forbs with high wildlife value to flourish. Fire suppression can also negatively impact species abundance.

The Service and partners have recently implemented efforts to reduce hazardous fuels within the wildland-urban interface, roughly defined as the zone where natural areas and development meet. The wildland urban interface has gained increasing importance as more Americans build homes in rural settings adjacent to public lands. The Service works closely with neighboring communities to reduce future wildfire risks to homes near national wildlife refuges and other Service lands. Homeowner responsibility for maintaining property according to fire safety standards is essential to effectively protecting communities from catastrophic wildfire (*http://www.fws.gov/fire/living_with_fire/wildland_urban_interface.shtml*; accessed October 2015). Approximately 50 acres of the refuge have been treated with prescribed fires to reduce hazardous fuels (20 of those acres were burned twice since 2007) in the wildland-urban interface (map 2-5). Hazardous fuels were reduced on an additional 12 acres through mechanical treatments along the northern boundary of the Crooked Pond parcel shared with the residential subdivision. Table 2-1 summarizes refuge fuel reduction treatments applied since 2006.

Other Contemporary Influences on Vegetation Patterns

Natural disturbances vary across New England depending on geographic location, forest type, and local conditions. In pre-settlement times coastal regions experienced the highest rates of disturbance because of the prevalence of sandy pine-oak barren, high densities of human (Native American) inhabitants, higher

Map 2-4. Present Bathymetry of Crooked Pond with Transect and Core Sampling Locations

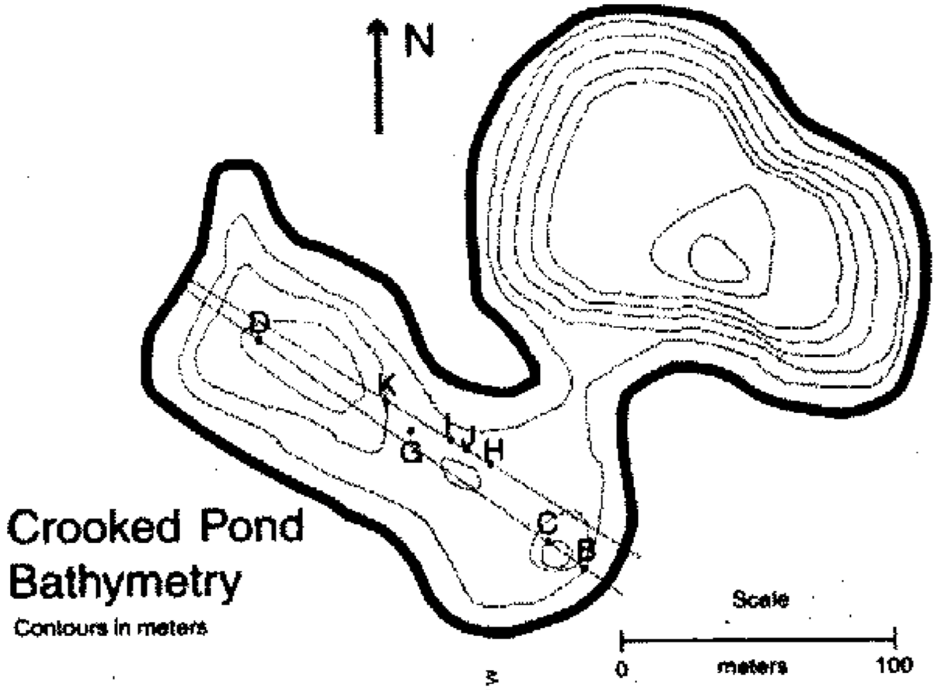
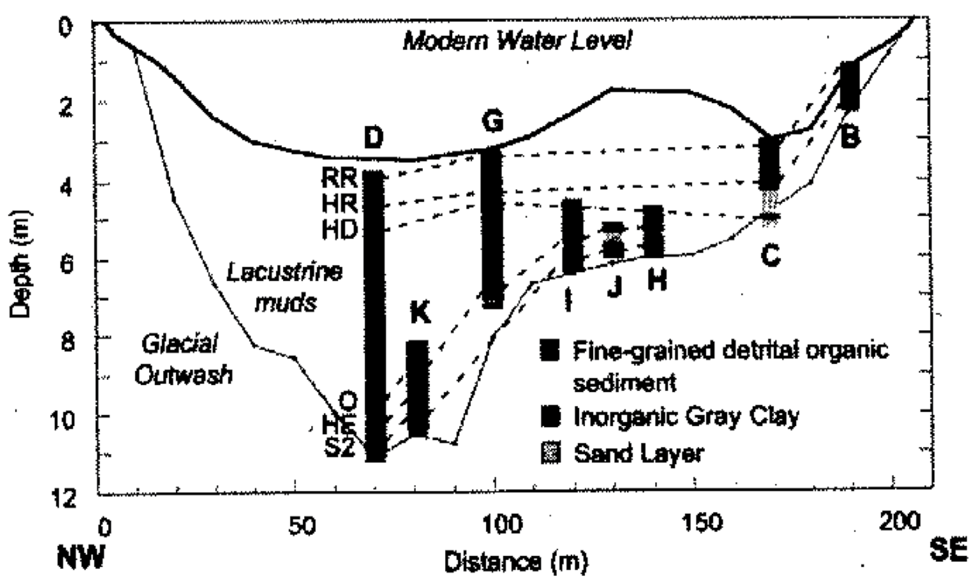


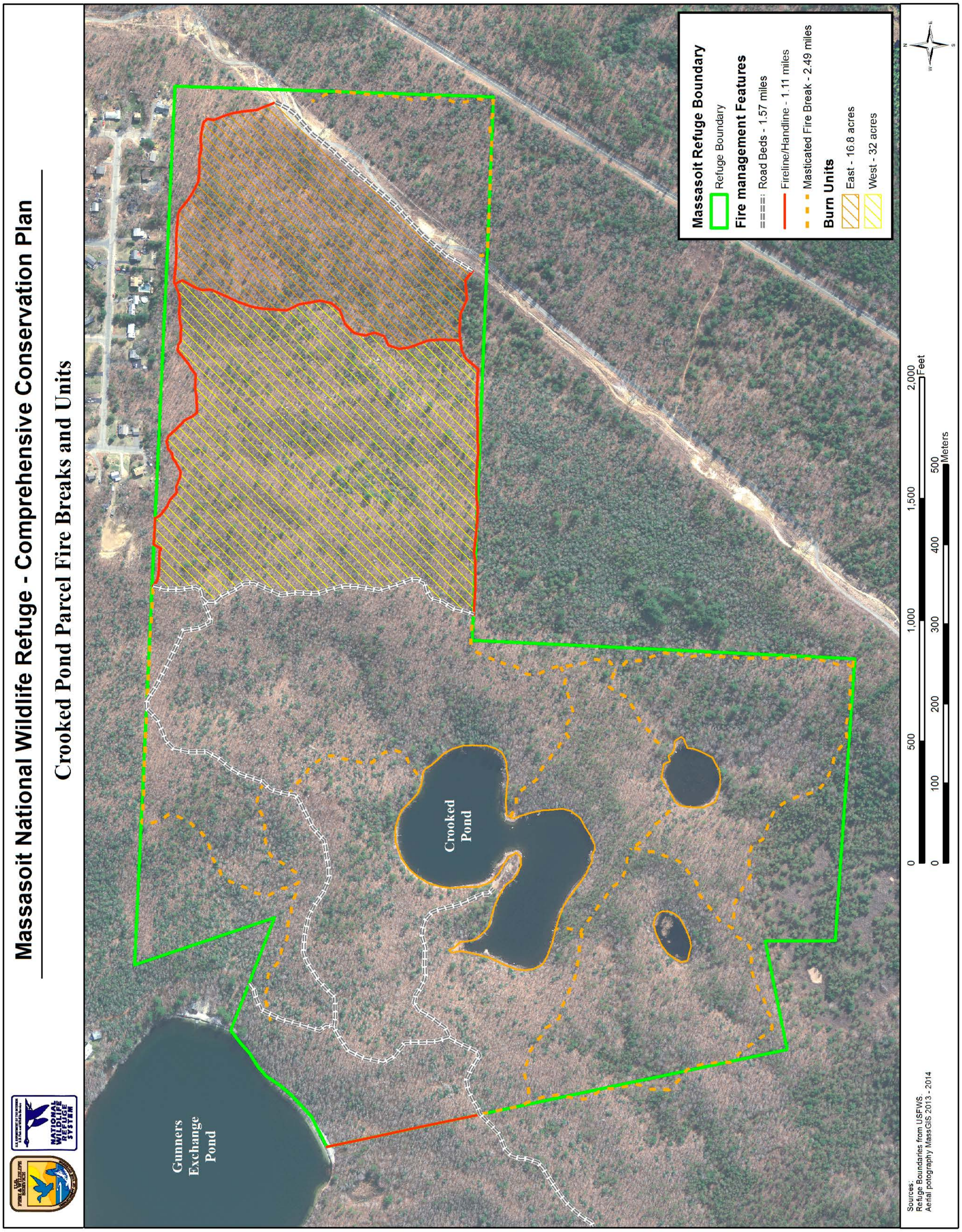
Figure 2-1. Crooked Pond Profile with Core Locations, Sediment Stratigraphy, and Pollen Stratigraphic Correlations.



The dashed lines connect the positions of the second peak in spruce pollen abundance (S2), the peak in heath pollen abundance (HE), the point at which oak pollen first rises above 30 percent (O), the hemlock decline (HD), the late-Holocene hemlock rise (HR), and the ragweed rise (RR). The core stratigraphies are generalized to show three types of sediment: detrital organic sediments, inorganic clay, and sands.

Source: reprinted from Shuman et al. 2001

Map 2-5. Crooked Pond Parcel Fire Breaks and Prescribed Burn Units



frequencies and severity of hurricane and coastal storm impacts, and longer snow-free periods. These disturbance regimes may have maintained about 1 to 3 percent of the inland northern hardwood forests, more than 10 percent of the coastal pine-oak barrens, and perhaps 7 percent of spruce swamps and spruce flats in early successional habitat (Lorimer and White 2003). Native insects and disease, ice storms, droughts, floods, landslides, and avalanches have caused minor and major disturbances across New England. Lorimer and White (2003) depict hurricane frequencies as varying from 85 years in southeastern New England, to 150 years throughout central Massachusetts and the southeast corner of New Hampshire, to 380 years or more in northern New England. Lorimer (1977) estimated catastrophic disturbances from fire and wind-throw at intervals of 800 and 1,150 years, respectively.

Land Use History

Pre-Contact Period-Early Native American Influences

Human occupation of the area around Massasoit NWR began with the arrival of Paleo-Indian hunter-gatherers around 11,000 years ago. Several Paleo-Indian sites are known in the local area, representing the three main periods within the Paleo-Indian era, although none have been found within the refuge boundaries. The well-drained sandy soils would have supported a diverse array of plant and animal food resources typically found along outwash plains and near lakes during the Pleistocene-Holocene transition.

Paleo-Indian people were settling into a developing environment with oak and spruce reemerging as dominant tree species. Oaks provided food for deer and other mast-eating species that could be hunted. During the Early Archaic (9,000 to 7,000 BP), Paleo-Indian people lived in small, widely distributed bands. Although no Early Archaic sites have been found on the refuge, the environment would have been conducive to human settlement during this period. Evidence indicates native people living near what is now Massasoit NWR constructed snail-shaped winter houses as shelter from the cold winter winds. Archeological data indicate that during the summer months, indigenous people exploited riverine environments to gather fish, deer, cattails, and Jerusalem artichokes.

Fishing implements began appearing during the Middle Archaic period when people were primarily settled along drainage systems and around lakes. Native inhabitants made extensive use of newly establishing marshy environments along lake edges and near the coast. Interior lands were used during the winters while the coastal areas were inhabited during the summers.

During the Late Archaic Period, which lasted until approximately 3,000 years ago, fish became very important in Native American diets. People were more settled, establishing seasonal camps from which gatherers and hunters dispersed to harvest nearby food resources (Plymouth Archeological Rediscovery Project (PARP) 2013). Although no recorded Late Archaic sites are located on the refuge, the area would have been conducive to human settlement during this period as well.

The Transitional Archaic overlaps with the Early Woodland (3,000 to 1,650 BP) period, and no diagnostic artifacts distinguish these two periods. Clay pottery began to appear, possibly coinciding with the beginnings of horticulture (PARP 2013). Population densities were low, and the refuge provided an ideal environment to support such populations during this time.

During the Middle Woodland Period (1,650 BP to 1,000 BP), populations increased and became more reliant on agriculture. Plants such as goosefoot, sunflowers, and squashes were domesticated, ceramic manufacture became more widespread, and material cultures emerged which distinguished one group from another. Political structures became more complex and people began to live in village-like communities (PARP 2013).

The Late Woodland began 1,000 years ago and ended with the arrival of Europeans. Maize was introduced from the south. Villages in some areas were fortified, and people lived in larger groups. Social organization was hierarchical with populations organized into sachemships or chiefdoms.

Contact Period-European Influences

Agriculture, logging, fire, wind-throw, exotic pests and diseases, and development have greatly altered the New England landscape since pre-historic times. Agriculture has had the greatest effect on New England's forests, causing major changes in cover types and soils over a wide area. Although most of the region's forests were cut at least once, most logging did not affect succession or impact soils. However, intense fires fueled by logging slash did have a lasting impact on forest vegetation patterns (DeGraaf and Yamasaki 2001).

Table 2-1. Prescribed Fire and Fuel Reduction Management on Massasoit NWR since 2006.

Parcel	Date	Activity	Acreage
Crooked Pond (north side)	Fall 2006	Mechanical methods to reduce fuels and create buffer adjacent to neighborhood. Cleared 100-foot buffer by removing tall white pines and snags, and brush mowed huckleberry understory	12
Crooked Pond (east burn unit)	April 2007	Prescribed burn	20
Crooked Pond (east and west burn unit)	Spring 2011	Prescribed burn	50
Crooked Pond, throughout	January to May 2015	Mechanical methods to reduce fuels through mastication and fire break creation	4

The Proto-Historic and Contact Periods began in 1500 AD and ended around 1650 AD. During this period diseases introduced by Europeans decimated native people groups living around Massasoit NWR. During the early contact period, Native Americans traded with European explorers, trading furs and tobacco for brass kettles, beads, and other European items that were then incorporated into their material culture. No estimates are available of the number of Portuguese, Breton, and Bristol fishermen, Basque whalers, French fur traders, or English codders who established a presence on the North Atlantic coast beginning early in the16th century (Cronon 1983). English traders and fishermen had daily contact with indigenous people but lived on ships or in segregated enclaves around salt-dried codfish stations (favored by the English) built along Massachusetts Bay. In 1620, the Pilgrims migrated to New England and famously settled in Plymouth Colony nearby what is now the refuge.

The Pilgrims were aware that coastal Tribes had been decimated by disease just three to four years before their arrival (1616-1619), when many Native Americans living on the southeastern coast of present-day Massachusetts died from a mysterious pandemic disease. The Patuxet (Plimouth) Native American village was severely depopulated. Classic explanations include yellow fever, smallpox, and plague, and more recently chickenpox, trichinosis, and leptospirosis complicated by Weil syndrome (Marr and Cathey 2010). In New England, Smith noted "three plagues in three years successively neere two hundred miles along the coast" of southern Massachusetts to Cape Cod and inland for 15 miles (Smith 1622). Bennett suggested a 50- to 60-mile interior extension, corresponding with the area of corn horticulture (Bennett 1955). Native American influence on the local landscape subsequently declined following this pandemic, and was replaced by European influence.

By 1616, several subtribes of the Wampanoag (Pokanoket) Nation were living between the present-day borders of eastern Rhode Island and southeastern Maine. The Patuxet village was localized to an area in and around Plymouth harbor. Salisbury (1982) estimated the size of the Patuxet Tribe before the epidemic at 2,000. Demographers and historians disagree about the total size of the Wampanoag Nation, but Salisbury (1982) considers an estimate of 21,000 to 24,000 as reasonable. Gookin (1972) also estimated 3,000 men living in Massachusetts before the epidemic which when extrapolated for family size is consistent with Salisbury's overall estimate.

The Pilgrims chose a settlement location near an abandoned indigenous village that provided plant and animal foods, and land with drainage patterns suitable for agriculture. Massasoit NWR is located very close to the Plymouth settlement area, and it is likely that these early English settlers used and impacted resources located on the refuge.

As time progressed, Plymouth changed and declined as the political or economic center of the colony, shifting north to Boston, the new regional center. The region around the refuge became important as a source of agricultural products for markets in Boston. The refuge area would have likely also provided valuable timber for ship building. During the Federal Period (1750 to 1830), maritime commerce increased, further depleting timber around the refuge. Also, a shift from an agricultural to an industrially based economy began with improvements in water power technology and the subsequent development of new mills. Villages housing millworkers began growing around rural mills, and road networks and turnpikes emerged linking rural villages to larger markets.

During the Early Industrial Period (1830 to 1870), the introduction of railroads revolutionized transportation. Agriculture declined as the frontier and settlement extended westward. The Civil War generated major expansions in textile, metal working, machinery manufacturing, and shoe and boot industries. Whaling declined with the advent of petroleum products, and this in turn lowered the demand for ship timbers.

Plymouth remained the largest agriculture and fishing community throughout the 19th century. Shipbuilding and shipping developed leading to its principal industry, rope-making. The Plymouth Cordage Company founded in 1824 produced rope and cords into the 20th century. During the Late Industrial Period (1870 to 1915), technological advances altered the development of rural areas. Electricity, gas lighting, and motorized vehicles allowed people to live farther from cities, and there was also an influx of immigrants.

In 1856, Plymouth County became the central cranberry production area in Massachusetts as many areas previously mined for bog iron were reused as cranberry bogs. East Head Pond in the MSSF was dammed in 1868 to provide a water source for cranberry production, a use still remaining today. By 1890, extensive wetlands located southwest of the refuge were developed for cranberry production (MADNR 1971).

Human Influences over the past 100 years

The Modern Period (1915 to present) witnessed the decline of the mill industries during the Great Depression, and agriculture became the most important economic base around the refuge. In the 1960s, the Plymouth Cordage Company failed and the factory was converted to retail and commercial use.


Matt Poole

Cranberries

Highway development in the 1970s led to increased population growth in Plymouth as it became more accessible to Boston. Plymouth's population increased more than fourfold in the past 50 years. The inexpensive land costs and a low tax rate are cited as factors in this rise in population. The downtown area and North Plymouth have become commercial centers (Town of Plymouth 2009). In 2007, a large industrial center was completed with one of the largest retail malls along the South Shore. Throughout the region, rural areas continue to be altered by large-scale residential developments, most often in the form of large lot single-family homes. Additional large tracts of rural land, often outside of the established village centers, remain attractive and are constantly being evaluated for additional development (Town of Plymouth 2013). The continuing availability of large tracts of developable land, the region's rural character, the high quality community services, transportation improvements, and proximity to Boston will continue to promote a high growth rate.

Current Conditions

Climate

Influenced by its proximity to the Atlantic Ocean, the refuge climate is characterized by warmer temperatures in the winter and cooler temperatures in the summer compared to more interior locations. The frost-free growing season for Plymouth ranges from 146 to 174 days (U.S. Climate Data 2011). The average annual temperature for Plymouth is 51 degrees Fahrenheit (°F). The July average high temperature is 82°F and the average low temperature is 60.3 °F. The coldest month is January with an average high temperature of 36.8 °F and an average low temperature of 16.2 °F.

The refuge, like other coastal areas, is vulnerable to nor'easters as well as to Atlantic hurricanes and tropical storms. The average annual precipitation is approximately 49 inches spread evenly throughout the year. Annual snowfall averages approximately 20 inches. The wettest month is normally January and the driest months are June, July, and August. Variations in precipitation from year to year can cause drought or flooding with as much as a 5-foot variation in water table levels (Epsilon 2000).

Also see the Climate Change discussion later in this chapter.

Air Quality

Under the CAA, the USEPA regulates six criteria pollutants—ozone, carbon monoxide, nitrogen dioxide, particulate matter, sulfur dioxide, and lead, as well as hazardous and other toxic air pollutants, including mercury. A maximum concentration is established for each criteria pollutant, 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 (MADEP) monitors levels of ozone, particle pollution (also known as particulate matter; $PM_{2.5}$ or PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). These pollutants are measured from several stations in Massachusetts for attainment or exceedance above the limit of the NAAQS set by the USEPA to protect public health. These standards are reviewed every 5 years by the USEPA and may be changed in response to new scientific information. Each state must ensure that 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 compliance in a way that incorporates future economic and emissions growth. 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 (MADEP 2008).

In 1997, USEPA set a new 8-hour ozone standard designed to be more representative of exposure over time. Massachusetts is designated as nonattainment of this 8-hour standard. Ozone monitors currently show that the State is meeting the 1997 0.08 parts per million (ppm) standard (MADEP 2008). In January 2008, Massachusetts submitted a *State Implementation Plan* to the USEPA, describing strategies to attain the 8-hour ozone standard by 2010 (MADEP 2008). However, the 8-hour standard was revised in 2008 to 0.075 ppm. In March 2009, Massachusetts recommended to USEPA that the entire State be designated as nonattainment for the 2008 standard. In January 2010, USEPA proposed to further revise the primary 8-hour ozone standard to a level with a range of 0.06 to 0.07 ppm, but postponed the new ozone standards in September 2011.

There are a total of 29 air quality monitoring stations across Massachusetts, and one additional Tribal site on Martha's Vineyard. Fifteen of these sites are designated as part of the ozone monitoring network. Exceedances at a station, averaged over 3 years, can lead to a NAAQS violation. Based on data from these sites, there were a total of 36 exceedances (above the standard) of NAAQS Statewide for ozone on 14 days in 2010. One of the closest monitoring stations to the refuge in Brockton, Massachusetts (MADEP 2012) had no exceedances. Based on data from 2009 to 2012, the results from the Brockton station, air quality did not violate the primary 8-hour ozone standard (MADEP 2012).

Water Quality

Long-Term Trends and Status of Water Quality for Massasoit NWR

Municipal and private wells tap the groundwater throughout the town of Plymouth, primarily for residential and irrigation uses. This water is largely returned to the aquifer through ground discharge to the ground from septic systems or infiltration of irrigation waters. In areas served by public sewer, primarily North Plymouth and downtown Plymouth, wastewater is redirected to a new sewage treatment plant, and treated water is discharged into the Eel River headwaters. Groundwater recharge is important in Plymouth because the numerous kettle ponds and freshwater wetlands depend on groundwater for their existence. However, intensive development can result in the nitrification of groundwater, a serious public health concern (Town of Plymouth 2009).

State-reported Impaired Waters

The goals of the State's water quality assessment program are to determine whether water quality standards are met and to design and implement a plan to restore waters with impaired quality.

In 2012, the DEP released the 305(b)/303(d) *Integrated List of Waters* (MADEP 2012a). It combines both the 305(b) Water Quality Assessment and the 303(d) Report on Impaired Waters for each river basin. The DEP compiled those reports and submitted them to the EPA and Congress, satisfying reporting requirements under section 305(b) of the Clean Water Act.

Water quality standards designate six uses for surface waters:

(1) Aquatic life
(2) Fish consumption
(3) Drinking water
(4) Shell-fishing
(5) Primary and secondary contact recreation
(6) Aesthetics

The standards define the water quality needed to support each of these designated uses, and if a water body is more contaminated than allowed under existing water quality standards and so will not support one or more of its designated uses, it has "impaired" water quality. In most cases, a cleanup plan [called a "Total Maximum Daily Load" (TMDL)] must be developed and implemented to restore impaired waters.

The report on impaired waters in the State describes segments of streams, lakes, and estuaries that exhibit violations of water quality standards. It also

Crooked Pond at Massasoit National Wildlife Refuge

Jared_Green

identifies the pollutant responsible for the violation(s) and the cause and source of the pollutant, if known. In this report there was no mention of the level of contamination for the ponds within the refuge boundaries. The Eel River showed impairment due to nonnative vegetation (MADEP 2012a).

Refuge Natural Resources

Terrain and Soil

Refuge topography is primarily flat glacial till plains and elevated moraines. Evidence of the Wisconsin glaciation is readily observed in the deposits of sediments and other materials that shaped the local landscape. The ponds located on the refuge are kettle ponds created by glaciation. Crooked Pond is a typical coastal plain pond occupying a depression connected hydrologically to an underground aquifer; hence, the water level of the pond fluctuates with the water table. The water level is usually high in winter and spring and generally much lower by late summer when the shoreline is exposed. Three other ponds, Island, Gunner's Exchange, and Hoyt, are within 0.62 miles of Crooked Pond. The southeastern corner of Gunner's Exchange Pond and parcels with frontage on Hoyt Pond and Island Pond are part of the refuge. Surficial geology at Massasoit NWR is mostly composed of excessively drained soils from the Merrimac, Plymouth, and Plymouth-Carver series (table 2-2, map 2-6, Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database *http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm*; accessed October 2015).

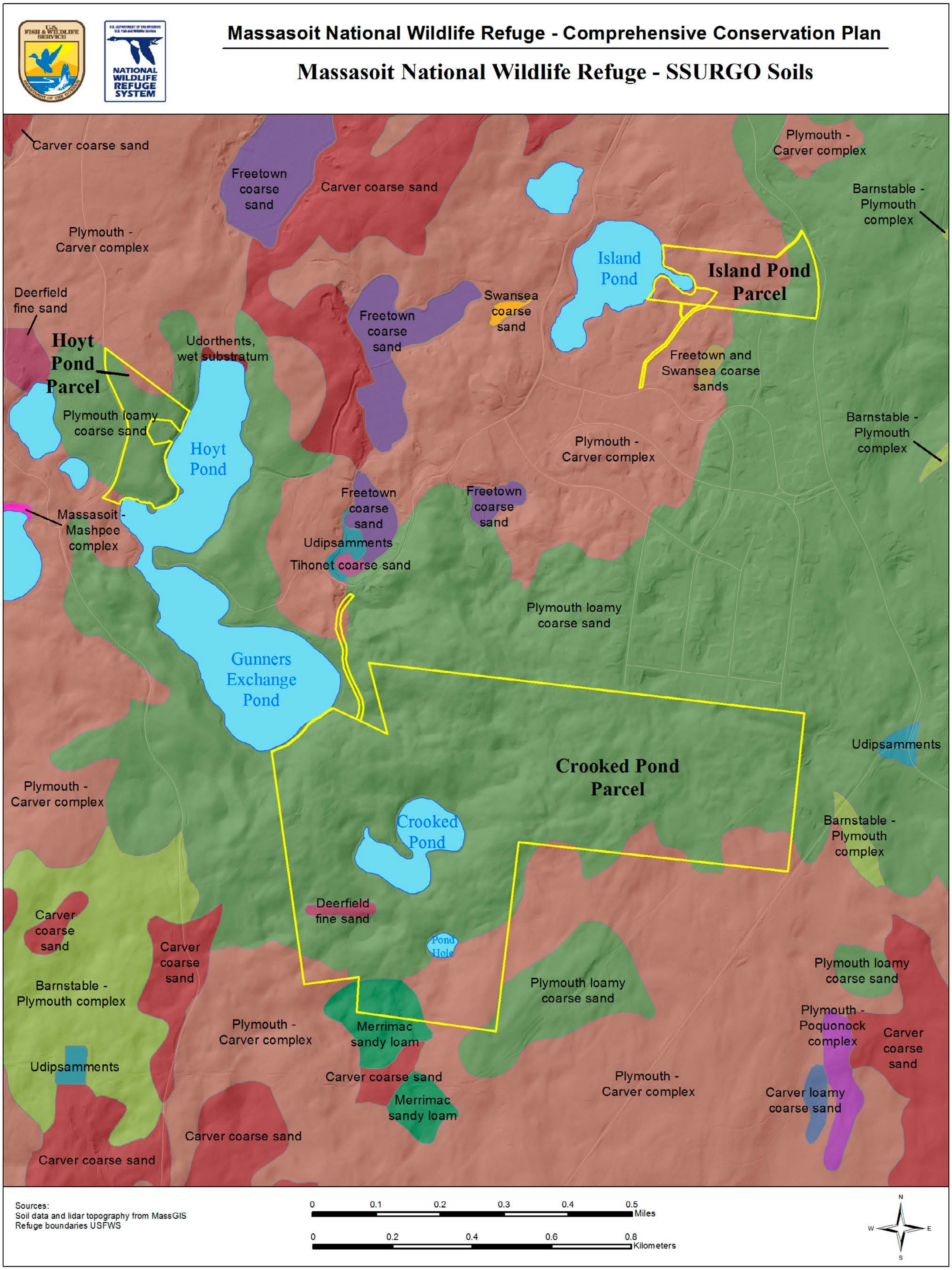
Refuge Habitats

Natural Community Types and Vegetation

In 2010, AECOM® was contracted to conduct vegetation cover type mapping on the refuge. Infrared aerial imagery was acquired in July and used to classify vegetation on the entire refuge using a minimum mapping unit of 1 acre. The vegetation cover types are based upon the National Vegetation Classification System (NVCS) developed by USGS and NPS. However, because the NVCS classifications for Massachusetts are incomplete, other sources were also used to classify habitat types (AECOM 2010; refer to the report for more details). Nine community types were identified for Massasoit NWR. Table 2-3 below lists the NVCS Associations as determined by AECOM (2010), the comparable Massachusetts Community Types identified by AECOM (2010), the description of those Community Types from Swain and Kearsley (2001) in the Classification of Natural Communities in Massachusetts, and the acreage for each. Map 2-7 shows habitat type locations.

In addition to the vegetation cover type mapping effort, a comprehensive survey of plant species was conducted on the refuge by volunteer botanists in 2012, and 183 plant species were documented (Zinovjev and Kadis, 2012 unpublished report). The species list is included in appendix A. Among the species documented are two Massachusetts State-listed as Special Concern species and five Watch List species (see table 2-4; Zinovjev and Kadis, 2012 unpublished report). On adjacent MSSF lands, 15 plant species have been documented (Myles Standish State Forest 2011) that are listed as Endangered, Threatened, or Special Concern in Massachusetts (Dow Cullina et al. 2011), including the two Special Concern species found on the refuge. It is possible that other rare species found on the State forest also occur on the refuge. The volunteer botanists also documented 21 nonnative species, 10 of which are classified as invasive in Massachusetts, or for which invasive status is pending. Two additional non-native species (spotted knapweed and rabbit-foot clover) were recorded during vegetation cover type mapping work (AECOM 2010), and all 23 nonnative species are listed in table 2-5. Additional botanical work will likely result in more species being added to the refuge species list.

Map 2-6. Massasoit National Wildlife Refuge - SSURGO Soils



Map 2-7. Massasoit National Wildlife Refuge Habitat Types

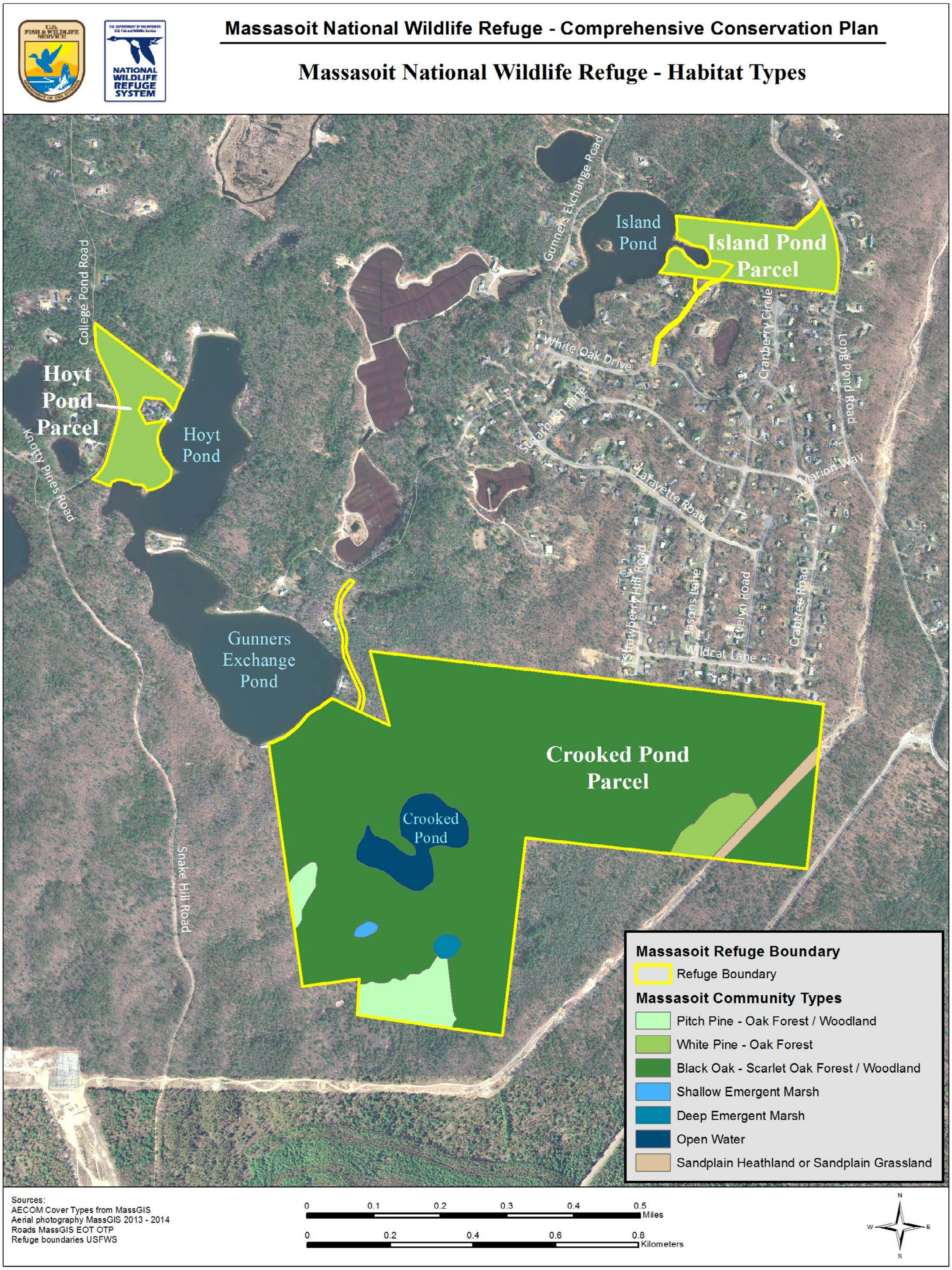


Table 2-2. Massasoit NWR Soils.

Soil Type	Percent Slope	Drainage Class	Parent Material	Landform
254C Merrimac sandy loam	8 to 15 percent	Somewhat excessively drained	Coarse loamy Aeolian deposits over sandy and gravelly glaciofluvial deposits	Outwash plains, terraces, kames
437B Plymouth loamy coarse sand bouldery	3 to 8 percent	Excessively drained	Sandy and gravelly supraglacial meltout till over sandy and gravelly glaciofluvial deposits	Outwash plains, moraines
437C Plymouth loamy coarse sand bouldery	8 to 15 percent	Excessively drained	Sandy and gravelly supraglacial meltout till over sandy and gravelly glaciofluvial deposits	Outwash plains, moraines
437E Plymouth loamy coarse sand bouldery	15 to 35 percent	Excessively drained	Sandy and gravelly supraglacial meltout till over sandy and gravelly glaciofluvial deposits	Outwash plains, moraines
438B Plymouth loamy coarse sand extremely bouldery	3 to 8 percent	Excessively drained	Sandy and gravelly supraglacial meltout till over sandy and gravelly glaciofluvial deposits	Outwash plains, moraines
438E Plymouth loamy coarse sand extremely bouldery	8 to 15 percent	Excessively drained	Sandy and gravelly supraglacial meltout till over sandy and gravelly glaciofluvial deposits	Outwash plains, moraines
480E Plymouth-Carver complex	15 to 35 percent	Excessively drained	Sandy and gravelly supraglacial meltout till over sandy and gravelly glaciofluvial deposits	Outwash plains, moraines
481B Plymouth-Carver complex bouldery	3 to 8 percent	Excessively drained	Sandy and gravelly supraglacial meltout till over sandy and gravelly glaciofluvial deposits	Outwash plains, moraines

Source: USDA-NRCS Soil Survey Online

Table 2-3. Vegetation Types at Massasoit NWR.

NVCS Association as identified by AECOM (2010)[1]	Comparable Massachusetts Community Types as identified by AECOM (2010)	Acres: Crooked Pond	Acres: Island Pond	Acres: Hoyt Pond	Total	Vegetation Description for Massachusetts Community Types (from Swain and Kearsley 2001)
Pitch Pine–Oak (scarlet, black, white) Forest	Pitch Pine–Oak Forest / Woodland	8.0	0	0	8.0	Pitch pine–oak forests have a canopy of pitch pine and tree oaks (black, scarlet, chestnut, and white), with blueberries (lowbush and blue ridge), black huckleberry and other ericaceous shrubs forming an often continuous low shrub layer. Scattered patches of scrub oak and bear oak can be dense. Catbriar and other briars (*Smilax* **spp.**) often make dense barriers around low, damp openings. The herb layer is generally sparse, with bracken fern, wild sarsaparilla, wintergreen, Pennsylvania sedge, and, less commonly, pink lady's slipper. Occasional white pine and red maple contribute to the canopy.
White Pine–Oak (scarlet, black, white) Forest	White Pine–Oak Forest	4.3	15.0	10.0	29.3	White pine and oak species (northern red, black, white, scarlet, or chestnut) dominate the canopy layer in a variety of proportions. Pitch pine, red maple, white birch, and black birch, occur regularly but in low numbers. Southern areas also have pignut hickory and sassafras. American chestnut is frequently present as a shrubby tree. Usually has a prominent heath shrub layer, with blueberries (lowbush and blue ridge), black huckleberry, mountain laurel, and sheep laurel. Other shrubs include maple-leaf viburnum. Characteristic species of the sparse herb layer include bracken fern, wild sarsaparilla, Canada mayflower, wintergreen, partridge-berry, pink lady's slipper, cow-wheat, and whorled loosestrife.
Oak (scarlet, black, white)–Pine (pitch, white) Forest	Black Oak–Scarlet Oak Forest/ Woodland	159.0	0	0	159	Black and scarlet oaks are the dominant canopy species. White oak and red maple are common associates. A sparse subcanopy may have species of recent disturbance such as grey birch, black cherry, and sassafras, as well as species less tolerant of fire such as flowering dogwood or shadbush. Blueberries (lowbush and blue ridge), black huckleberry, and scrub oak form a fairly dense, but clumped low shrub layer, with scattered maple-leaf viburnum and American hazelnut. Sedges (such as Pennsylvania sedge), bracken fern, and pink lady's slipper are often scattered in the open herbaceous layer.
Swamp Loosestrife Semipermanently Flooded Shrubland White Water Lily–Cow-lily Permanently Flooded Temperate Herbaceous Highbush Blueberry Saturated Shrubland	Shallow Emergent Marsh or Deep Emergent Marsh	1.2	0	0	1.2	Vegetation composition is similar to deep emergent marshes except that shorter grasses, sedges, and rushes dominate. Cattails, *Phragmites*, and wool-grass, the dominants of deep emergent marshes, can occur but are never dominant. Tussock forming species, like tussock sedge and Canada bluejoint, often cover broad areas and form a hummock hollow topography. Reed canary grass can also occur. It is common to see tussock sedge-dominated marshes in old beaver flowages mixed with scattered shrubs like alder and *Spiraea*. The shallow water typically has a mixture of bur-reeds, sedges, and rice cut-grass. Floating leaved plants, like American white water lily and cow lily, and submergents, like pondweeds, occur in open areas, and duckweed is abundant in still water. Tall graminoids, like broad-leaved cattail and *Phragmites*, often form extensive dense stands. Narrow-leaved cattail occurs in more alkaline sites or in saline areas along roads. Other characteristic graminoids include woolgrass, common threesquare, Canada bluejoint, rice cut-grass, and tussock-sedge. Herbaceous associates include arrow-leaf, tearthumb, bulblet, water-hemlock, swamp-candles, beggar-ticks, bedstraw, common arrowhead, slender-leaved goldenrod, and marsh-fern.

NVCS Association as identified by AECOM (2010)[1]	Comparable Massachusetts Community Types as identified by AECOM (2010)	Acres: Crooked Pond	Acres: Island Pond	Acres: Hoyt Pond	Acres: Total	Vegetation Description for Massachusetts Community Types (from Swain and Kearsley 2001)
Open Water (non-vegetated lacustrine unconsolidated bottom)	NA	8.2	0	0	8.2	NA
Pitch Pine–Scrub Oak Shrubland						
Little Bluestem Herbaceous	Sandplain Heathland or Sandplain Grassland[2]	2.3	0	0	2.3	Many of the dominant species in heathlands are woody: scrub oak, black huckleberry, bearberry, and lowbush blueberry. Other characteristic species include hairgrass, Pennsylvania sedge, little blue stem, stiff aster, bayberry, golden heather, chokeberry, dwarf chinquapin oak, sweetfern. Heathlands are less species rich than grasslands and appear taller. The tall shrublands association particularly includes non-ericaceous tall shrubs such as beaked hazelnut, beach plum, and dewberry. The species overlap with grasslands is great: it is the proportion of the species and the resultant structure that separates the communities. The communities are not distinct at some sites. Grasslands are dominated by graminoids, usually little blue stem grass, Pennsylvania sedge, and poverty grass, with bearberry, scrub oak, stiff aster, bayberry, lowbush blueberry, and black huckleberry. Shrub clones often form patches. There is great species overlap with sandplain heathlands, but sandplain grasslands are much richer in vascular species. As a group, Goat's rue, yellow wild indigo, butterfly weed, and bird's foot violet are good indicators of the community.

[1] *AECOM (2010) referenced a Draft NVCS report from 1994 which was used to determine the appropriate NVCS Association. Up-to-date NVCS information can be found at http://usnvc.org/explore-*classification/ *(last accessed October 2015). Slight changes in the NVCS Associations identified by AECOM may be evident in the NVCS Website.*

[2] *This is actually habitat along a power line right-of-way, and the habitat classification may not be accurate.*

Source: AECOM 2010

Table 2-4. State-Listed Species Documented on Massasoit NWR during Botanical Surveys in 2012.

Species	Status in Massachusetts*	General Locations**
Pink Tickseed	Watch List	Crooked Pond; Island Pond; Gunner's Exchange Pond
Plymouth Gentian	Special Concern	Island Pond
Sessile Water-horehound	Watch List	Island Pond
Pondshore or Terete Arrowhead	Special Concern	Crooked Pond; Island Pond;, Gunner's Exchange Pond; Hoyt Pond
Black-fruited Spike-rush	Watch List	Island Pond, Crooked Pond, Hoyt Pond
Annual Umbrella Sedge	Watch List	Island Pond
Black Oatgrass	Watch List	Crooked Pond Parcel

Source: Zinovjev and Kadis, unpublished report

** Dow Cullina et al. 2011.*

***Locations were tied to a parcel (Crooked Pond Parcel, Island Pond Parcel, and Hoyt Pond Parcel). Each of the four ponds was also recognized as a separate location (Crooked Pond, Island Pond, Hoyt Pond, and Gunner's Exchange Pond).*

No comprehensive surveys of aquatic plants have been conducted on the refuge, but Eurasian water-milfoil (also a nonnative invasive species) and arrowhead have been documented in Crooked Pond (USFWS 1985). Both fanwort and hydrilla are increasingly detected in Massachusetts coastal plain ponds; control of these species is very difficult. The control of nuisance aquatic plants, particularly submerged aquatic vegetation, often requires the use of herbicides at concentrations that can harm local populations of rare native plants and animals if present, or labor intensive hand or mechanical removal. An exotic invasive species that has recently invaded a number of Massachusetts coastal plain ponds is gray willow.

Coastal Plain Pondshore Community

The kettle ponds on the refuge, having no inlet or outlet, are recharged from groundwater so water levels within these ponds are influenced by seasonal and year-to-year groundwater table fluctuations in the. The ease with which water moves through the sandy glacial till substrates causes the water levels of the ponds to fluctuate directly with the water table, partially or completely exposing the pond shorelines during late summer and early fall. Fluctuating pond water levels are key to a globally rare plant and animal community known as the Coastal Plain Pondshore (Swain and Kearsely, 2001). Plants and animals of this community type are adapted to the nutrient-poor, changing pond water levels, and many occur almost exclusively on coastal plain ponds. The Massachusetts SWAP (MassWildlife 2015) identifies buffer areas around aquatic (including coastal pond) Core Habitats as Critical Natural Landscapes to help ensure their long-term (biological) integrity. The periodic inundations of the shore help deter shrubs and upland plants, and the periodic drying deters the obligate aquatic plants. Dominant plants on the exposed shore as the water levels drop are herbaceous and graminoid species. During leaf-out in the spring, trees increase transpiration, evaporation increases from leaves and pond surfaces, and pond water levels fall. McHorney and Neill (2007) demonstrated a distinct connection between some coastal plain ponds and groundwater. Groundwater connections provide cool, normally low-nutrient water to coastal ponds. In areas with polluted groundwater however, ponds can acquire the pollutants. In the winter, when there is little evaporation and much precipitation, the groundwater and pond levels rise, and are recharged.

Sudden alterations to natural hydrologic regimes pose the greatest threats to these systems. Many coastal plain ponds are in a fragile balance. ORV use on and around pond shorelines destroys herbaceous vegetation, dragonfly and damselfly habitat, and turtle nesting habitat (NHESP 2007). Nutrient input into naturally low-nutrient Coastal Plain Ponds allows more weedy plant species to grow, changing the habitat for plants and animals alike. Increased nutrient input can come from improperly maintained septic systems, large numbers of swimmers, over-wintering populations of Canada geese, fertilizer use in the watershed, and soil erosion. Heavy recreational use of pond shorelines removes plants and deters animals from using the habitat. Concentrating recreation at particular ponds effectively protects the other ponds (NHESP 2007). Although Island, Gunner's Exchange, and Hoyt Pond have shoreline residential development which affect the habitat through septic use and recreational activities, these threats do not occur at Crooked Pond where the Service owns and controls access to the entire pond and shoreline.

Alexey Zinovjev_and Irina Kadis

Slender arrowhead (Sagittaria teres)

Several Massachusetts plant species occur only in coastal plain ponds, including the globally rare species Plymouth gentian, rose coreopsis, terete arrowhead, and creeping St. John's wort (MassWildlife 2015). Many of the rare plant species associated with coastal plain ponds are regionally rare species as well, as indicated by Brumback and Gerke (2013). The plants of the community appear to form zones dependent on the magnitude, duration, frequency, and timing of flooding and exposure events between the water and the shrubs around the pond. Of the Massachusetts SGCN plants, New England boneset, Maryland meadow-beauty, and pondshore and swamp smartweeds occur in the driest zone, inundated only during high-water periods. An intermediate area of beach provides habitat for most of the species of the coastal plain pondshore community; the globally restricted but locally abundant Plymouth gentian and rose coreopsis grow in this zone. In the submerged or water-saturated areas, terete arrowhead, subulate bladderwort, and the horned- and bald-sedges may occur.

Coastal plain pond shorelines are important habitat for dragonflies and damselflies (over 45 odonate species are known to occur on coastal plain ponds and several of those species are rare). Further, coastal plain ponds have been listed by others as the most vulnerable odonate habitats in the northeastern United States (White et al. 2014). Near-shore emergent plants are important sites for dragonflies and damselflies. Many live amongst the submerged vegetation as larvae and climb onto the emergent vegetation to undergo metamorphosis to adults. Eggs and larvae may survive for a time either in the stalks of vegetation (where many species lay their eggs) or in the mud of drying ponds.

Larger ponds are used by migrating and wintering waterfowl. Some of these ponds support warm-water fish and freshwater mussels, and others can function as vernal pools when fish populations are absent. Freshwater mussel species likely to occur include the MESA-listed eastern pondmussel and tidewater mucket, and the unlisted eastern lampmussel and triangle floater.

An exotic invasive species that has recently invaded a number of Massachusetts coastal plain ponds is gray willow, actually a species complex that includes *Salix cinerea*, *S. atrocinerea,* and probable hybrids (MassWildlife 2015). This species complex is not as averse to seasonally high water as native shrubs are, and seems to thrive along these pond shores, particularly where soil disturbance has occurred. Both fanwort and hydrilla are increasingly detected in Massachusetts coastal plain ponds and control of these species is very difficult.

Recent research indicates that the last two decades have been the wettest years in the Northeast in 500 years (Pederson et al. 2013, Newby et al. 2014, Weider and Boutt 2010). Pond shorelines not under the influence of water withdrawals did not experience pondshore exposure for 10 years, which has led to the loss of several native plant populations from several ponds. The Sustainable Water Management Initiative, administered by the MADEP, with input from multiple state agencies, is supporting research by the USGS into the degree of hydrological alterations imposed by water supply withdrawals and climate change (MassWildlife 2015).

The coastal plain pondshore community consists largely of plant species adapted to the special shoreline environment, able to thrive in the nutrient-poor, acidic conditions and out-compete more common plant species. Some species' seeds germinate early in the growing season when the shore is still covered with water, and other seeds germinate as water levels drop and the shores dry.

Table 2-5. Nonnative species documented on Massasoit NWR during vegetation cover type mapping and during 2012 botanical surveys.

Species	Status in Massachusetts*	General Locations**
Bull Thistle	Nonnative	Crooked Pond Parcel
Smooth Hawkweed	Nonnative	Crooked Pond Parcel; Crooked Pond
King Devil	Nonnative, Invasive Status Outside MA	Gunner's Exchange Pond
Spotted Cat's Ear	Nonnative, Invasive Status Outside MA	Island Pond Parcel; Gunner's Exchange Pond
Spotted Knapweed	Nonnative, Likely Invasive	Right of Way
Butterfly-bush	Nonnative, Invasive Status Outside MA	Crooked Pond Parcel
Morrow Honeysuckle	Nonnative, Invasive	Crooked Pond Parcel
Mouse-ear Chickweed	Nonnative	Crooked Pond Parcel
Oriental Bittersweet	Nonnative, Invasive	Island Pond
Black Locust	Nonnative, Invasive	Island Pond Parcel
Rabbit-foot Clover	Nonnative	Right of Way
Palmate Hop-clover	Nonnative	Crooked Pond Parcel
Carpetweed	Nonnative	Crooked Pond; Island Pond
White Mulberry	Nonnative	Island Pond
Lady's Thumb	Nonnative	Crooked Pond; Island Pond
Bitter Dock	Nonnative	Island Pond
Glossy Alder-buckthorn	Nonnative, Invasive	Crooked Pond Parcel; Crooked Pond; Island Pond Parcel

Species	Status in Massachusetts*	General Locations**
Gray Willow	Nonnative, Invasive	Crooked Pond Parcel; Island Pond Parcel; Island Pond; Gunner's Exchange Pond; Hoyt Pond
Common Mullein	Nonnative, Invasive Status Outside MA	Crooked Pond Parcel
Barnyard-grass	Nonnative	Island Pond
Sheep Fescue	Nonnative	Crooked Pond Parcel; Crooked Pond; Island Pond Parcel
Common Reed	Nonnative, Invasive	Island Pond
Norway Spruce	Nonnative, Invasive Status Outside MA	Crooked Pond Parcel

Sources: AECOM 2010; Zinovjev and Kadis, unpublished report

** Dow Cullina et al. 2011.*

***Locations were tied to a parcel (Crooked Pond Parcel, Island Pond Parcel, and Hoyt Pond Parcel). Each of the four ponds were also recognized as separate locations (Crooked Pond, Island Pond, Hoyt Pond, and Gunner's Exchange Pond).*

Plant Pests and Insects

Plymouth County has seen a greatly increased number of winter moth adults, a member of the Geometridae family, that typically emerge around Thanksgiving and continue throughout December. The following spring, the caterpillars emerge in large numbers, defoliating maples, oaks, and other deciduous trees (*https://ag.umass.edu/fact-sheets/winter-moth-overview* accessed March 2016). Initially introduced in Nova Scotia from Europe in the 1950s, this species became a problem causing tree foliage damage. Deciduous plants on the refuge susceptible to winter moth damage include oaks, blueberries, and maples. In Plymouth County, oaks primarily are showing signs of decline after consecutive years of winter moth defoliation.

Oaks in Plymouth County have also been impacted by outbreaks of gypsy moths. Leaf defoliation from gypsy moths frequently occurs in forests with greater than 50 percent oak presence (Schweitzer 2004). Pitch pine and scrub oak are more resistant and are at a lower risk level to defoliation than other trees, whereas white pine is defoliated much more often than other pines (U.S. Forest Service 2007). In June 1981, heavy defoliation occurred in oak and mixed oak forests from southern Maine to coastal Connecticut. Defoliation maps published by the Forest Service show no major defoliation in the Plymouth area in recent years.

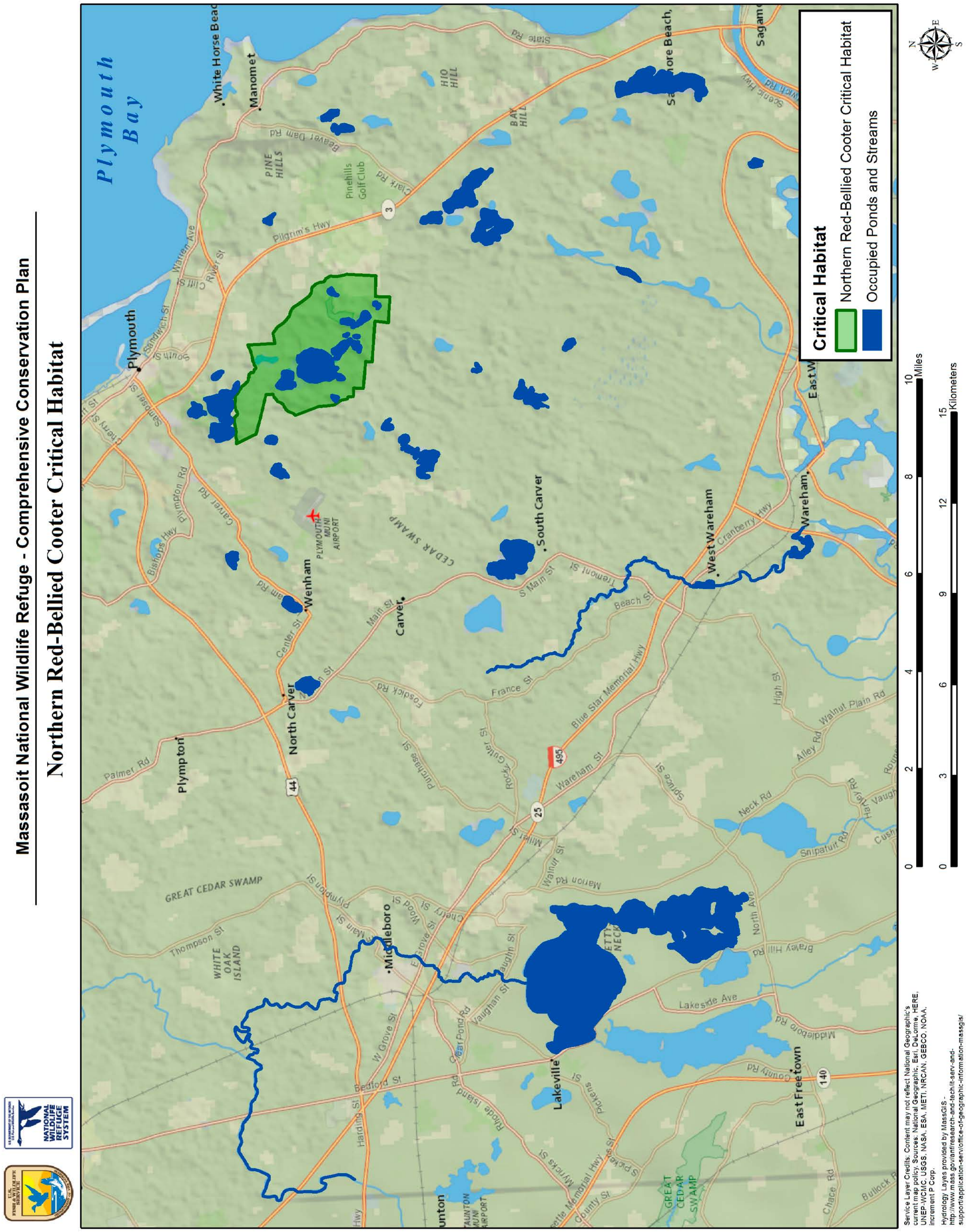
There is limited information about specific pest outbreaks in or near the refuge. Neighboring MSSF has had several pest outbreaks in past years including the outbreak of the pine looper that killed many pitch pines in the 1970s and 1980s. The black turpentine beetle has also impacted trees there. Outbreaks of gypsy moths have defoliated scrub oaks in past summers, but have since recovered (MADCR 2011).

Federally Listed Northern Red-bellied Cooter

Ecology and Rangewide Status

The northern red-bellied cooter is a large, freshwater basking turtle with a carapace (shell) length of 10 to 12 inches when mature. They subsist primarily on submergent vegetation, and require good water quality and suitable basking, nesting, and overwintering sites free from disturbance. Northern red-bellied cooters spend most of their lives in freshwater coastal ponds in Plymouth and Carver counties, coming on land to bask and breed in sandy soils. Typically, they reach sexual maturity at 14 to 15 years of age. In 1979, the total number of breeding-age individuals was estimated to be approximately 300, and on April 2, 1980, the species was listed as federally endangered and 3,269 acres were designated as critical habitat (map 2-8; USFWS 1994). Massasoit NWR was

Map 2-8. Northern Red-bellied Cooter Critical Habitat



established for the protection of northern red-bellied cooters and lies entirely within the critical habitat designation.

In 1981 the first recovery plan was written for the northern red-bellied cooter (USFWS 1981), and in 1994 the recovery plan was updated (USFWS 1994). At that time, this population was considered a subspecies (*P. r. bangsii*) of the more broadly distributed red-bellied cooter; however, taxonomic revision removed the subspecific status. The Service has determined that the population qualifies as a distinct population segment, and formally revised the listing. The northern red-bellied cooter is found only in southeastern Massachusetts, disjunct from the remainder of the species distribution, with the next closest population being located in New Jersey. Northern red-bellied cooters in Massachusetts were known from just 12 ponds in Plymouth County, with an estimated population of approximately 200 individuals when first listed. The 1994 Recovery Plan states that downlisting to "Threatened" status will be considered when the populations collectively include 600 breeding-age northern red-bellied cooters, among at least 15 self-sustaining populations. In addition, the species will be considered for delisting when the populations collectively include at least 1,000 breeding-age individuals among 20 self-sustaining populations, along with certain requirements for habitat protection and increased life history information to protect and manage the species and its habitat (USFWS 2007).


Bill Byrne MDFW

A young northern red-bellied cooter

Many factors have contributed to the current endangered status. The northern red-bellied cooter's small population size and restricted range are foremost among factors limiting its long-term viability. As a small, isolated population, the northern red-bellied cooter may be subject to inbreeding and genetic drift, which can reduce genetic variability and potentially decrease survivorship. Limiting factors include: adverse modification of water quality due to siltation from land clearing adjacent to ponds; pollution and excess nutrients in ponds; and pollution of groundwater or reduction in the water levels of ponds from groundwater withdrawals (pumping). These disturbances can adversely affect aquatic invertebrates and vegetation which provide food and shelter. Other factors include draining or filling of wetlands adjacent to occupied ponds and shoreline modifications such as filling, dredging for beaches, dikes, real estate development, or similar activities. The northern red-bellied cooter has also been subject to environmental pressures in more recent times. The Plymouth County area, particularly along pond shores, has undergone rapid residential and commercial development. Long-term changes to land use practices (such as those associated with development and recreation) may cause loss of needed undisturbed nesting and basking sites. Closure of the forest canopy also plays an important role in diminishing habitat suitability. In pre-colonial and early colonial periods, the pine barren habitat was burned often. Today, the area has been largely protected from fire, and most remaining undeveloped areas are closed-canopy pine forest. The closed-canopy forest surrounds most ponds; hence, suitable nesting habitat that receives adequate solar heating (sunlight) for nest incubation is scarce (USFWS 1994).

Habitat alteration as a result of agricultural development and practices may affect the status of the northern red-bellied cooter population. It is unknown to what extent northern red-bellied cooters have been affected by the growth of the cranberry industry in the region. Cranberry bog acreage increased greatly during the last century, and the industry owns and manages more than 14,000 acres in Massachusetts (Cranberry Growers Association 2014). The immediate and long-term effects of chemicals used by cranberry growers have not been studied. While the bogs themselves are a monoculture of cranberry plants, and considered low value northern red-bellied cooter habitat, many of the reservoirs and upland watershed areas managed by the industry provide high quality habitat. Some of these areas have become increasingly important to the species conservation as surrounding habitat is lost to residential development or becomes over-shaded through forest succession. Due to the changing markets and socioeconomic pressures, the potential decrease in acreage owned and managed by these growers could pose new threats of development and disturbance to northern red-bellied cooters.

Limiting factors for hatchling and juvenile northern red-bellied cooters include predation, low nesting success, and high juvenile mortality. Less than one percent of newly hatched turtles survive their first winter (USFWS 2007), although protecting nests and releasing head-started turtles may be effective short-term measures to improve first winter survival rates. Available data indicate that non-headstart hatchlings released directly into ponds may experience nearly 100 percent mortality. Predation by bullfrogs, herons, and snapping turtles is suspected but poorly documented. Predation of unprotected nests by raccoons and striped skunks, whose populations tend to increase with residential development and habitat fragmentation, has been documented to be relatively high (Graham Annual reports 1984-1999, USFWS 1994). The widespread introduction and translocation of several predatory sport fish including smallmouth bass, largemouth bass, chain pickerel, brown bullhead, and white perch, may also play a key role in the low hatchling turtles survivorship, although no studies have been undertaken to address this possibility (USFWS 1985, USFWS 2007).

To increase survival and recruitment by reducing predation rates, in 1985 MassWildlife, in partnership with the Service, began a headstart program that continues today. Headstarting involves raising northern red-bellied cooter hatchlings in captivity for nine months (through their first fall and winter) and then releasing them back to the wild in the following spring/summer. Since 1985, over 3,500 wild-born individuals have been headstarted and released at 28 sites, including two large river systems and 13 new ponds. This is the longest and most intensive freshwater turtle headstart program in existence. Anecdotal observations and some preliminary field work suggest that the headstart program has provided an important contribution to species recovery, but the population increase and landscape occupancy remains uncertain. It is estimated that the population increased from 400 to 600 breeding-age individuals, in more than 20 ponds (USFWS 2007).This breeding-age population estimate is likely conservative because it is based on a demographic model that incorporates known survival rates of headstarted individuals, but not reproduction by the headstarted or wild cooters (both of which are now documented). Additionally, very little field work has been conducted to validate other model assumptions (i.e., no increased annual survival with age, most likely an untrue assumption), or determine the current distribution of northern red-bellied cooters across the landscape.

From the late 1960s through 2001, researchers working with the Service and MassWildlife studied northern red-bellied cooters throughout their range. Some of this work occured at the refuge (USFWS unpublished reports). Research focused primarily on determining the species biology and identifying factors adversely affecting population size, and secondarily assessing taxonomic status. Data for determining age- and sex-distribution, population size, and growth and survival rates were collected at several ponds. However, information needs remain (Haskel 1993). Although focused, on-the-ground research ceased in the early 2000's, Massachusetts Division of Fisheries and Wildlife has continued monitoring at priority nesting sites. In 2013, the Division re-initiated field research, focusing on refining methods for (1) capture and processing of adult and juvenile cooters, (2) documentation of nesting, and (3) visual surveys. This preliminary field work also provided evidence of the improved population status of this species. Through this effort over 100 adult and subadult individuals (released as headstarts from 1987 to 2006) were captured and implanted with passive integrated transponder tags at two primary study sites where northern red-bellied cooter populations were established through the release of individually marked, headstarted turtles in the late 1980's and early 1990's. Over 40 nesting attempts by adult headstarts and evidence of juvenile recruitment were documented (MassWildlife unpublished data).

Northern Red-bellied Cooters at Crooked Pond

Headstarted northern red-bellied cooters (81 total) were released annually into Crooked Pond from 1985 to 1991 (USFWS 1994), and mark-recapture surveys were conducted. Population size of these head-started turtles is estimated at 40, and annual survival rates are high, averaging over 85 percent (Haskell 1993). Surveys conducted from 1985 to 2001 show the Crooked Pond northern red-bellied cooter population was almost entirely headstarted individuals, with a disproportionate sex ratio favoring males. Limited movement, primarily of male cooters, was documented (T. Graham, personal communication, undated).

Refuge staff conducted habitat management work on the Crooked Pond shore to improve and create additional cooter nesting habitat since 2001. Management actions include girdling trees to decrease canopy cover and increase sunlight, rototilling and loosening of soil, and thinning low shrubby vegetation. Management was conducted at three sites: (1) on the western peninsula; (2) on the southwestern cove, and; (3) on the eastern peninsula. Monitoring of nesting habitat has been inconsistent in some years because of the travel distance to the refuge from our Sudbury headquarters, and varying levels of funding and staff. Beginning in 2013, refuge staff used trail cameras to monitor nesting areas at Crooked Pond and monitoring efforts have been thorough and consistent. Management actions and known nesting activity are summarized below in table 2-6.

Migratory Birds

Breeding landbird surveys were conducted on the refuge twice each year from 2001 through 2010. Over 60 species were detected during the surveys, and 2,401 individual birds were recorded. The most commonly recorded species was ovenbird (16 percent of all landbirds recorded), followed by eastern towhee (9 percent of all landbirds recorded). The 9 most commonly recorded species comprised more than 60 percent of all landbirds recorded (See table 2-7). These species also tended to be widespread and were generally detected at all (or most) of the 11 survey points during the 10 years of surveys. For a complete list of birds documented during breeding bird surveys, and recorded opportunistically on the refuge, see appendix A. Breeding landbird surveys were recently re-initiated, but data have not been yet analyzed.

Mammals

Few mammal surveys have been conducted on the refuge. Acoustic monitoring was conducted in 2012 at the Crooked Pond parcel to determine presence of bat species, and in 2013 the survey effort was expanded to include the Island Pond parcel. Preliminary analysis of 2012 acoustic survey data indicates the presence of big brown, Eastern red, silver-haired, tri-colored, and Eastern small footed bats, but data verification from 2012, as well as preliminary analysis and data verification from 2014, are still ongoing. No bats calls were recorded in 2013 (USFWS unpublished data).

Limited live trapping was also done at the refuge in January 2012 to survey for New England cottontail, but the only mammal caught was a fisher. Mammals observed opportunistically on the refuge include red squirrel, white-tailed deer, raccoon, striped skunk, red fox, grey fox, and coyote (USFWS unpublished data).

It is uncertain as to whether white-tailed deer on the refuge are overabundant due to the large scale at which regional deer population studies are conducted. A study of deer survivorship in the MSSF indicated the deer density was 15 to 20 deer per square mile (Epsilon 2001 as referenced in MADCR 2011). This suggests deer abundance in the vicinity of the refuge is currently well above the MassWildlife 2014 "target" of 6 to 8 deer per square mile average density for Wildlife Management Zone 11(MassWildlife 2015; *http://www.mass.gov/eea/agencies/dfg/dfw/publications/masswildlife-annual-reports.html*; accessed November 2015).

Appendix A lists mammal species present on the refuge.

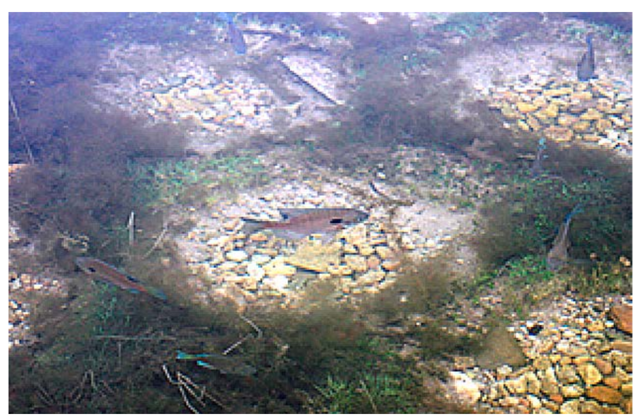
Reptiles and Amphibians (other than Northern Red-bellied Cooters)

Standardized anuran surveys were conducted on the Crooked Pond parcel of the refuge in 2001 and 2002 and several species of frogs and toads were recorded: bullfrog, green frog, northern spring peeper, American toad, and gray treefrog (USFWS unpublished data). Several other reptile and amphibian species have been recorded by Service staff and volunteers while conducting other work including Fowler's toad, northern leopard frog, wood frog, red-spotted newt, red-backed salamander, milk snake, eastern ribbon snake, and eastern hognose snake. Turtles recorded by staff while conducting cooter surveys included musk (stinkpot) turtle, snapping turtle, and painted turtle (USFWS unpublished data). Appendix A lists reptile and amphibian species present on the refuge.

One amphibian and two reptiles identified as SGCN in the Massachusetts SWAP (MassWildlife 2015) inhabit lake and pond environments. Northern leopard frog can be found in damp, heavily vegetated areas of lake margins or swampy areas, as well as adjacent terrestrial habitats, which provide foraging, refuge, and breeding habitats.

Fish

No formal fish surveys have been conducted by the Service on refuge property; however, largemouth and smallmouth bass, chain pickerel, yellow perch, white perch, black crappie, and pumpkinseed have all been documented in Crooked Pond (Graham Annual Reports, 1987-2000). Additionally, redbreast sunfish are frequently seen in Crooked Pond (USFWS unpublished data). Appendix A lists fish species present on the refuge.



Brian Bastarache

Redbreast sunfish and their nests in Crooked Pond at Massasoit National Wildlife Refuge

Invertebrates, Including Pollinators

No formal surveys of invertebrates have been conducted on the refuge, but several species have been documented by Service staff and volunteers while conducting other work. Those species are listed in appendix A.

Coastal plain ponds and pine barren supports several rare invertebrates, including moths and other native pollinators. Rare species have been documented on neighboring MSSF (2011) and are listed in appendix A.

Seven dragonfly and damselfly species (odonates) identified in the 2015 Massachusetts SWAP are also found within and around lake and pond environments. Further, coastal plain ponds have been listed by others as the most vulnerable odonate habitats in the northeastern U.S. (White et al. 2014). Odonates display three distinct life stages: aquatic egg and larval stages, and an adult flying stage. Near-shore emergent plants are important dragonfly and damselfly sites. Many larval odonates live amongst the submerged vegetation and climb onto the emergent vegetation to undergo metamorphosis to adults within littoral lake habitats. Upon emergence, dragonfly and damselfly adults move briefly to upland habitats to feed and mature before returning to vegetated lake and pond margins to mate. Eggs and larvae may survive short-duration water level drawdowns for a time either in the stalks of vegetation or in the mud of drying ponds. The scarlet bluet, attenuated bluet, and Pine Barrens bluet are known from only a limited number of locations primarily in coastal plain ponds of southeastern Massachusetts and the Cape.

The water-willow stem borer, a Noctuid moth, another Massachusetts SGNC (MassWildlife 2015), inhabits shallow portions of coastal plain ponds, swamps, and abandoned cranberry bogs. Larvae of this moth species bore into and feed internally upon water-willow, requiring management and conservation strategies are undertaken on a broader, landscape, ecosystem-based scale.

Table 2-6. Summary of Management Activities for the Northern Red-bellied Cooter at Crooked Pond.

Year	Summary of Habitat Management	Northern red-bellied cooter Nesting Activity
2001	• Cleared vegetation from eastern peninsula in March and April.	• None.
2002	• Cleared vegetation and loosened soil in western cove. • Cleared vegetation from eastern peninsula in March.	• None.
2003	• None.	• None found by staff, but volunteer found one nest on eastern peninsula that was depredated by a canid.
2004	• Rototilled soil and removed vegetation in western cove. • Removed trees, raked vegetation, and rototilled soil on western peninsula. • Turned soil manually and removed shrubs on eastern peninsula in June.	• None found in 2004, however, evidence of nesting in 2004 was confirmed when one nest was discovered on May 17, 2005, during habitat work on eastern peninsula. Volunteer found four eggshells and one shell with a cooter still inside.
2005	• Turned soil manually on eastern peninsula. • Rototilled soil on western cove and western peninsula. • Removed high bush blueberry along edges and around 15 trees on western peninsula in May.	• None.
2006	• Removed old cabin on western peninsula in spring and filled foundation with sand in fall.	• None.
2007	• Cut vegetation and girdled trees on western peninsula in March and April. • Rototilled soil on western peninsula and western cove in May.	• Two nests (around 14 eggs each) successfully hatched from western peninsula near old cabin site. Evidence of nest hatches were found on October 4 and had likely hatched within a week prior.
2008	• Rototilled soil on western peninsula and western cove; trimmed vegetation on western peninsula edges in May.	• None.

Year	Summary of Habitat Management	Northern red-bellied cooter Nesting Activity
2009	• Rototilled soil on western peninsula and western cove. Trimmed vegetation on western peninsula edges and in some swaths to pond edge in May.	• One nest (at least 10 eggs) was found on July 6 in western cove and protected with a predator exclosure.
2010	• Rototilled soil and removed vegetation on western peninsula and western cove in May.	• None.
2011	• None.	• None.
2012	• None.	• No nests found, but three females trapped in Crooked Pond are known to have nested (caught while gravid, and again post-laying) and likely nested on the Crooked Pond shoreline.
2013	• None.	• One nest (10 eggs) was found and protected with a predator exclosure. • Ten hatchlings collected from 1 nest.
2014	• Removed shrubs and small trees crowding the nesting areas with power and hand tools. • Turned over soil and removed small grasses with rakes and hoes.	• Five nests were found; 3 were predated and 2 were protected with a predator exclosure (11 eggs and 14 eggs). • Twenty-four hatchlings total collected from 2 nests.
2015	• None.	• Eight nests were found; 7 were predated and 1 protected with a predator exclosure. (15 eggs). • Thirteen hatchlings total collected from one nest.

Table 2-7. Bird Species Detected at Most Survey Points during 10 Years of Breeding Surveys.

Species	Total Individuals Recorded	Percentage of Total Recorded	Percentage of Points Detected
Ovenbird	384	16	100
Eastern Towhee	201	9	91
Baltimore Oriole	163	7	100
Pine Warbler	140	6	100
Hermit Thrush	126	5	100
Tufted Titmouse	123	5	100
Black-capped Chickadee	109	5	100
Eastern Wood-Pewee	100	4	100
Scarlet Tanager	92	4	91

Climate Change

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. In its 2007 assessment report on climate change, the International Panel on Climate Change (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 2008).

Climate change is a serious concern to the Service and our conservation community partners. Scientists are predicting dramatic changes in temperature, precipitation, soil moisture, sea level, and 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 2008). Species' ranges are expected to continue shifting northward or to higher elevations as temperatures rise; however, responses will 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 (Inkley et al. 2013, NABCI 2010, IPCC 2007). 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. For example, plants, mussels, and amphibians are more vulnerable to shifts in temperature that may affect their ability to survive, grow, and reproduce. Climate change impacts in coastal regions also 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).

Climate Change as it Relates to Massachusetts

Predictions

Massachusetts' climate is already changing and will continue to do so over the course of this century. Ambient temperature has increased by approximately 1.8 °F since 1970, and sea surface temperature has increased, on average, by 2.3 °F between 1970 and 2002. These warming trends have been associated with other observed changes, including a rise in sea level of 0.72 feet between 1921 and 2006, more frequent days with temperatures above 90 °F, reduced snowpack, and earlier snow melt and spring peak flows (Frumhoff et al. 2006, 2007; Hayhoe et al. 2006). By the end of the century, under the IPCC high emissions scenario, Massachusetts is predicted to experience a 5 to 10 °F average ambient temperature increase, with several more days of extreme heat during the summer months. The annual number of days with temperatures greater than 90 °F is predicted to increase from 5 to 20 days currently to 30 to 60 days annually. At the same time, the number of days with temperatures above 100 °F is expected to rise from 2 days currently to as many as 28 days annually (Frumhoff et al. 2006, 2007). Sea surface temperatures are also predicted to increase by 8 °F (Dutil and Brander 2003, Frumhoff et al. 2007, Nixon et al. 2004), while winter precipitation—mostly as rain—is expected to increase by 12 to 30 percent. The number of snow events is predicted to decrease from five each month to one to three each month (Hayhoe et al. 2006).

Ecological changes in response to climatic change have been observed in the northeastern United States as plants leaf out and bloom earlier (Wolfe et al. 2005), amphibian breeding seasons start earlier (Gibbs and Breisch 2001), and Atlantic salmon spring migrations begin sooner (Juanes et al. 2004). In addition to these direct impacts, species and ecosystems face a broad range of indirect climate-related threats. For example, rising temperatures cause decoupling of bird migration and food source timing and provide a competitive advantage to nonnative insects and plants.

It is also important to recognize that the observed ecological changes in North America and elsewhere have occurred under a relatively modest average global temperature increase of only 1.3 °F; the additional increase of 5 to 10 °F predicted for the Northeast is likely to have considerably greater impacts on ecosystems.

Coastal Plain Ponds (Kettle ponds)
Changes in climate and local weather patterns will likely affect aquatic systems by exacerbating or accelerating habitat degradation due to other identified threats (MassWildlife 2015). Warmer temperatures will warm coastal plain pond waters faster. Additionally, increases in severe rain and snowfall events will increase runoff of pollutants from agricultural and urban areas into waterbodies that combined with increased surface water temperatures will allow longer growing seasons for nuisance aquatic plants and harmful algal blooms (MassWildlife 2015). Increases in rain will also increase atmospheric deposition of pollutants, including nitrogen deposition. Extended periods of drought could result in lowered water levels and the loss of littoral habitat.

Recent research indicates that the last two decades have been the wettest years in the Northeast in 500 years (Pederson et al. 2013, Newby et al. 2014, Weider and Boutt 2010). The Sustainable Water Management Initiative, administered by the MADEP, with input from multiple state agencies, is supporting research by the USGS into the degree of hydrological alterations imposed by water supply withdrawals and climate change (MassWildlife 2015).


USFWS

Forest habitat on Massasoit National Wildlife Refuge

Upland Forests
Upland forests provide important functions including support for a variety of habitats and wide-ranging biological diversity, purification of air and water, moderation of subsurface and overland water flow, and the sequestration of carbon in both the above-ground vegetation and in the organic components of forest soils. In addition, forests provide scenic, recreational, and tourism benefits and a rural quality of life desired by many citizens.

Upland forests provide important filters along wetlands, rivers, and streams and stabilize soils and sediments in high-gradient streams, thus minimizing erosion. They also help to moderate temperature by shading small streams. They provide important habitat for wildlife species that occupy vernal pools and offer both direct or indirect habitat benefits to forest-dependent wildlife species. In conjunction with other stressors, climate change will alter forest structure and function and change species composition and the ability of forests to provide wildlife habitat. Climate change could also reduce the ability of forests to provide ecological services such as air and water cleansing (Executive Office of Energy and Environmental Affairs (EOEEA) 2011).

Under the most commonly accepted climate change scenarios, Massachusetts could experience a greater intensity and frequency of forest-disturbing weather events, including ice storms, localized or regional wind events such as microbursts or hurricanes, and more frequent and longer droughts and associated wildfire. Any of these conditions or events has the potential to kill or alter the vigor of native trees, thereby opening the forest to new species. The same climate change phenomena that affect trees could also impact forest-dependent species such as song birds, forest floor plants, and invertebrates, as well as disrupt predator-prey relationships and alter phenological patterns and other complex ecological processes. Some changes may be slow while others may proceed quickly once critical thresholds are met (e.g., forest pests). Changes in species composition are predicted as the result of increased ambient temperatures that will extend the northern limits of species with limited cold tolerance. Corresponding changes in habitat suitability are also likely. Range shifts in tree distribution (historically, forest types have shifted at the rate of 12 to 15 miles every 100 years) will change the relative proportions of forest tree species. However, the migration of tree species in response to habitat changes is likely to be much slower than the predicted changes in habitat due to climate change. It is also important to note that differing movement is likely to occur at the individual species level and not by groups of species. These changes could happen quickly or take place over decades (EOEEA 2011).

Changing climate factors and forest types will also likely alter the composition and role of myriad other forest species including vertebrates, invertebrates, shrubs, herbs, non-vascular plants, fungi, and bacteria. Invasive insects and diseases will also respond to climate change. For example the hemlock woolly adelgid is likely to expand northward while the response of other species, such as the emerald ash borer, the Asian longhorned beetle (currently attacking hardwoods in Worcester), or the widespread beech bark disease, is uncertain. Overall, the negative impacts of invasive species may increase as native forests are increasingly stressed and become more vulnerable to changes in mean and maximum air temperatures and subsequent changes in the water cycle (EOEEA 2011).

The 2015 Massachusetts SWAP states that Massachusetts forestlands are being impacted by elements of human-accelerated climate change (Rustad et al. 2012) such as increasing growing season length, more extreme summer temperatures, and increased periods of summer drought, as well as by more frequent freeze-thaw cycles in winter (*http://nsrcforest.org/sites/default/files/uploads/templer09full.pdf*, accessed November 2015). Climate change appears at least partially responsible for the recent and rapid spread of native insect pests such as the Southern pine beetle into more northern climes (Gan 2004). Southern pine beetle very recently caused extensive mortality of pitch pine on Long Island, and could soon cause similar mortality in southeastern Massachusetts' pitch pine forests.

The *Climate Change and Massachusetts Fisheries and Wildlife* report was written to address the climate change stressors to habitats and wildlife mentioned in the Massachusetts SWAP (MassWildlife 2006). The overall objective of this three volume report is to advance the adaptation planning to climate change (Manomet and MassWildlife 2010). Volume 2 addressed the vulnerabilities to habitats and wildlife and specifically addressed twenty habitats most likely to be impacted by climate change. Vulnerability scores were assigned to each habitat based on both low and high emissions scenarios and are delineated from "critically vulnerable" to "greatly benefit" from climate change. This report indicates a *medium* vulnerability score (four) for pitch-pine-scrub oak habitats, suggesting these forests are *less vulnerable* to climate change and unlikely to change in their extent, or to experience only moderate losses under both the lower and higher emissions scenarios. The confidence score assigned to this habitat is *Medium* because of the potentially confounding effects of drought. While it is likely that an increased frequency and severity of drought could adversely affect these habitats in Massachusetts, given the uncertainty of modeling precipitation change the scientists were unable to project future changes with more confidence (Manomet and MassWildlife 2010). Other forest types represented on the refuge were not listed in the vulnerability assessment. Because pitch pine is prevalent on the refuge, it is less vulnerable to climate change due in part to its ability to tolerate wildfire (Manomet and MassWildlife 2010) with the removal of excess hazardous fuel through prescribed burning.

Climate change may cause a shift in species composition in young forest and shrubland habitats in Massachusetts, but these habitats will be able to be maintained on the landscape with active management (MassWildlife 2015). Some rare plant species, such as chestnut-colored sedge, currently near their southern extent in Massachusetts, may disappear from our landscape as a result of climate change.

This report may be viewed online at: *http://www.mass.gov/eea/agencies/dfg/dfw/wildlife-habitat-conservation/climate-change-and-massachusetts-fish-and-wildlife.html* accessed October 2015.

Precipitation, Drought, and Streamflow

The Northeast is forecasted to experience a greater frequency of high precipitation events. Scientists predict an 8 percent increase in extreme precipitation events in the northeastern U.S. by mid-century, and up to a 13 percent rise by 2100. In the case of coastal storms, the frequency and timing of winter storms or "nor'easters" could change. Under the low-emissions scenario, little change is predicted in the number of "nor'easters" striking the Northeast, but it could experience approximately 5 to 15 percent more late-winter storms under the high-emissions scenario (Frumhoff et al. 2007).

Changes in temperature, as well as in the amount, timing, and type of precipitation, affect streamflows and drought characteristics. With more winter precipitation as rain and less as snow, there is likely to be more runoff during the winter and less during the spring. This phenomenon along with the increased temperatures would cause streamflow to peak earlier in the year and to be lower in the spring, which is typically when flows are highest. Changes in precipitation and runoff can have a substantial impact on fisheries, agriculture, and other natural systems. Drought is related to soil moisture, which in turn is related to evapotranspiration, rainfall, temperature, drainage, and climatic changes. By the end of the century, under the high emissions scenario, the occurrence of droughts lasting 1 to 3 months could rise by as much as 75 percent over historic conditions (Hayhoe et al. 2006). Streamflows would be lower in the summer months, especially under the high emissions scenario, as a result of higher evapotranspiration.

Aquatic Resources

Aquatic ecosystems are also vulnerable to climate change. Predicted changes in timing, frequency, and duration of precipitation events, more intense storms, a shift from winter snow to rain, more frequent and longer summer droughts, and increases in temperature trends as well as extreme high temperatures will affect both lotic (flowing water) and lentic (still water) habitats (EOEEA 2011).

Predicted increases in temperature, drought, and the number of extreme heat days, combined with a decrease in summer precipitation, are expected to adversely impact water quality and quantity. Higher temperatures along with changes in stream flow will degrade water quality. Warmer, drier conditions will lead to deeper and stronger thermal stratification in lakes which will decrease the volume of the deeper, cooler, well oxygenated water that is critical summer habitat to a number of species. This habitat may be eliminated altogether from many shallower lakes and ponds. Under warmer conditions, nonnative species will likely become a bigger problem in lake and stream ecosystems (Ramsar 2002). In general, climate change can influence the establishment and spread of invasive species and reduce resilience of native habitats to these species (USEPA 2008). Increased mobilization of non-point source nutrients and suspended solids from more intense winter rain storms, followed by higher summer temperatures, will result in more frequent algal blooms (e.g., blue-green algae) and the vigorous growth of aquatic vegetation leading to nutrient rich and dissolved oxygen depleted lakes and impounded rivers (EOEEA 2011).

A projected increase in average winter temperatures will decrease the amount of snowpack and ice and negatively impact aquatic ecosystems. Reduced ice cover on lakes and ponds will result in more winter sunlight penetrating below the surface and more abundant aquatic vegetation, while less melting snowpack will reduce spring groundwater recharge. A shift from snow to rain during the winter will potentially lead to more runoff, more flooding, and greater storm damage, and scour and erosion during a time when there is reduced vegetative cover and low evapotranspiration (the combination of evaporation from the ground and transpiration from plants). In waterways and water bodies, increased temperatures are likely to cause loss of thermal refuges for coldwater species, decreases in dissolved oxygen, changes to hydrologic mixing regimes, and changes in biogeochemical cycling (Ramsar 2002).

The *Climate Change and Massachusetts Fisheries and Wildlife* report indicates that kettle ponds have a *medium vulnerability* rate (score of five) for impacts from climate change under both the low and high emissions scenarios. This score means that these ponds are *vulnerable* to climate change and at risk of being reduced or greatly reduced in extent under either emissions scenario. The factor most influencing this score is the vulnerability to aquatic invasive species (Manomet and MassWildlife 2010). These ponds are also potentially vulnerable to drought which is projected to increase in intensity and frequency under both scenarios (Manomet and MassWildlife 2010).

Andrew MacLachlan

Female eastern towhee

The 2015 Massachusetts SWAP states that changes in climate and local weather patterns will likely affect aquatic systems by exacerbating or accelerating habitat degradation due to other identified threats. Extended periods of drought could result in lowered water levels and loss of littoral habitat. Littoral areas are used for foraging, rearing, reproduction, and refuge by a myriad of species including mussel, odonate, fish, and invertebrate species. Thus extended periods of drought and the loss of these areas has the potential to reduce the abundance of these species. Additionally, increases in severe rain and snowfall events will increase runoff of pollutants from agricultural and urban areas into waterbodies. Increases in rain will also increase atmospheric deposition of pollutants, including nitrogen deposition. In addition to increased nutrient pollution from runoff and atmospheric deposition, increased surface water temperatures will allow longer growing seasons for nuisance aquatic plants and harmful algal blooms.

Climate change and severe weather may threaten coastal plain pond and pond shore habitats (MassWildlife 2015). While much uncertainty remains as to exactly how climate change impacts will manifest themselves, it is reasonable to expect that warmer temperatures will warm water in coastal plain ponds faster than normal, and may make some ponds inhospitable to their suite of current species. Warming of surface and groundwater in coastal plain ponds may create conditions that favor invasive species, and increase growing seasons for harmful algal blooms. Additionally, increases in severe rain and snowfall events will increase runoff of pollutants from agricultural and urban areas into waterbodies. Increases in rain will also increase atmospheric deposition of pollutants, including nitrogen deposition. In addition to increased nutrient pollution from runoff and atmospheric deposition, increased surface water temperatures will allow longer growing seasons for nuisance aquatic plants and harmful algal blooms.

Although total precipitation is expected to increase for southeastern Massachusetts, other common predictions include warmer temperatures, longer and more severe summer droughts, shorter but more intense winter/spring floods, and reduced extent and duration of winter snow cover. Taken together, such changes could alter the hydrological regimes of many coastal pondshore habitats in the region. Expected outcomes include seasonal drying of wetland soils, which could facilitate changes in dominant vegetation.

Lake Depth
In 2009, researchers collected surface and deep core sediment samples from Crooked Pond as part of a study to establish a relationship between chironomids and lake depth, with the goal of using chironomid remains as an indicator of moisture levels, and thus climate change (map 2-4). Although precipitation is a major climatic variable, there are almost no proxies available to quantitatively reconstruct lake depth, which is a major problem for establishing natural variations in precipitation, but also for validating climate models used to predict future climate changes. This project aims to develop a new tool for reconstructing past changes in precipitation using fossil chironomid remains as indicators (Cwynar 2009). The deep sediment core was used to reconstruct changes in depth over the last 8,000 years, and results can be found in Engels et al. (2012).

Specific Climate Change Impacts on the Northern red-bellied cooter
The northern red-bellied cooter population is geographically separate and distinct from the more southern species and an increasingly warmer climate could have several effects on this northern population. Warmer weather in spring and summer may provide more favorable conditions for basking, feeding, and nesting. Hatching success (absent predation) may increase, and a more equal sex ratio of hatchlings could result. However, shifts in other species' ranges could affect this population as well, introducing new competitors, pathogens, and invasive species (USFWS 2007). Drought conditions could reduce groundwater levels and subsequently lower water levels within the kettle ponds, streams, rivers, and other important wetlands. Warmer winters could result in ponds not icing over and therefore change the winter hibernation pattern of the cooter. More research is needed to determine the impact of climate change on the northern red-bellied cooter and other species of conservation concern.

Potential Contributions of Refuges to Climate Change Mitigation and Adaptation
Table 2-8 below demonstrates potential impacts from climate change and offers specific examples of how those impacts can be addressed at Massasoit NWR:

Table 2-8. Potential Contributions of Refuges to Climate Change Mitigation and Adaptation.

Problems Associated with Climate Change	Refuge Mitigation Potential
Rising ambient air temperature caused by increasing greenhouse gases. Increased water temperatures.	Sequester carbon in vegetative biomass that also serves as "sinks" for greenhouse gasses.
Modified fire frequency and intensity.	Use controlled burn programs to reduce fuel loads and forest canopy shading on refuge and train fire professionals for other areas in need.
Loss of species and their required habitat.	Protect lands with a diversity of habitats for declining species and spearhead efforts to protect species of concern. Protect genetic diversity and serve as a source for repopulation efforts.
Geographical shifts in biomes and species' ranges.	Serve as ecological hub in a greater network of conservation lands, allowing for species migration.
Altered species phenologies and interaction (competition, predation, parasitism, and disease).	Provide natural, minimally altered (i.e., minimal building structures) settings for the evolutionary process and wildlife interaction.
Advancement of exotic invasive species, pest species, pathogens, and contaminants.	Manage to control and eradicate invasive species on refuge lands. Focus efforts to reduce species susceptibility to disease, pathogens, pests, and contaminants.
Limited scientific understanding of long-term climate change implications.	Develop inventory and monitoring sites for ecological and climate variables. Conduct direct research to address climate change topics. Continue to build scientific capacities and expertise in the agency. Foster collaboration among conservation science community.

Source: Excerpt from table in Crane Meadows Refuge CCP (USFWS 2010)

Refuge Access and Public Uses

Priority Wildlife-Dependent Recreational Uses

The refuge is currently closed to all public uses including the six priority, wildlife-dependent recreational uses: hunting, fishing, wildlife observation and photography, environmental education and interpretation. The refuge has not been open to the public since its establishment due to both staffing limitations and the presence of a federally endangered species that is disturbance sensitive. Exceptions have been made for occasional interpretive and environmental education programs under a special use permit (SUP) or special staff-led programs.

Activities Not Allowed

Unauthorized activities that occur on the refuge include: horseback riding; ORV use, including all-terrain vehicles (ATVs) and motorized dirt bike use; mountain biking; fishing in Crooked Pond; dog walking; swimming; boating; and hiking.

Law Enforcement Concerns

Law enforcement on the refuge is conducted:

- To enhance the management and protection of fish and wildlife resources on refuges.
- To ensure legal and equitable utilization of fish and wildlife resources on refuges, as prescribed by law.
- To obtain compliance with laws and regulations necessary for proper administration, management, and protection of the Refuge System.
- To protect refuge visitors and their possessions from disturbance or harm by other visitors or themselves.
- To assist visitors in understanding refuge laws and regulations and the reasons for them.

Massasoit NWR is patrolled by Federal wildlife officers from the Refuge Complex, along with officers from the Massachusetts Environmental Police. In addition to general public safety, these officers focus on the prevention of, and investigation into resource violations such as disturbance of the northern red-bellied cooter and its habitat, and trespass of horses, dogs, and ORVs.

Special Use Permits, Including Research

SUPs are issued to individuals, organizations, and agencies that request the use of refuge facilities or resources beyond those generally available to the public. To ensure that wildlife disturbance is minimized, special conditions and restrictions are identified for each request. We generally support research activities on the refuge that are compatible with the refuge purposes and help us gain knowledge and understanding to benefit our management goals and objectives. Further details on SUPs are available from the Refuge Complex.

Refuge Archeological, Historical, or Cultural Resources

No specific archeological surveys have been conducted on the refuge. The Massachusetts Historical Commission (MHC) and Service files indicate no known sites within the current refuge boundaries. The refuge has the potential to yield important information that could contribute to our knowledge about the original inhabitants of this area, and efforts must be made to protect the resources there. The area around the refuge has been significant for humans for the past 11,000 years. It is the ancestral homeland of the Wampanoag Nation, comprised of 69 Tribes from Provincetown to Narrangassett Bay. The Paktuksut Wampanoags were instrumental to the survival of the English colonists who landed in the Plymouth area in 1620 *http://www.mashpeewampanoagtribe.com/historyculture* (accessed August 2016). Today, many members of the Mashpee Wampanoag Tribe and the Gay Wampanoag Tribe of Gay Head (Aquinnah), both federally recognized Tribes, live in or maintain ties to the area. Refuge staff actively coordinate with Tribal members in the management of Mashpee and Nomans Land Island refuges. Systematic archaeological testing could help identify more pre-historic sites in this area, as well as further evidence of historical settlement.

Regional Socioeconomic Setting

Population Demographics

Massasoit NWR lies in Plymouth County, which consists of 660.85 square miles of land and in 2010 had a population density of 748.9 people per square mile (State density of 835.2 people per square mile). The population of Plymouth County, at the time of the 2010 Census, was 494,919, or about 7 ½ percent of Massachusetts' population (6,547,629). Between 2000 and 2010, Plymouth County's population grew by 4.7 percent, compared to a Statewide 3.1 percent growth rate *http://quickfacts.census.gov/qfd/states/25/25001.html* (last accessed October 2015). Table 2-9 below illustrates the population changes over the last 100 years.

Table 2-9. Population Change in Plymouth County.

Year	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
Population	144,337	156,968	162,311	168,824	189,468	248,449	333,314	405,437	435,276	472,822	494,919
Percent Change		+8.8	+3.4	+4.0	+12.2	+31.1	+25.5	+21.6	+7.4	+8.6	+4.7

Source: http://www.census.gov/population/cencounts/ma190090.txt (accessed October 2015)

As of 2010, there were 174,288 households in Plymouth County with an average of 2.73 persons per household. There were a total of 194,237 (2009) housing units within the county at an average density of 294 per square mile. The population distribution included 24.2 percent children under age 18 and 13.4 percent adults age 65 years or older. Fifty-one percent of the population was female (2009). The racial makeup of the county is depicted in table 2-11. While periodic updates do occur between the decennial censuses, we include only the official decennial census data here for simplicity's sake. Please visit: *http://www.census.gov/quickfacts/table/PST045216/25023,00* for more recent Plymouth County population and demographic estimates.

The town of Plymouth is a coastal community in southeastern Massachusetts, approximately 5 miles north of the Cape Cod Canal. It is the seat of Plymouth County, and has the largest land area of any town in the Commonwealth. For most of its existence, Plymouth was an isolated seacoast community, where economic fortunes were linked to the sea and shipping. The site of the original 1620 settlement is now a portion of today's Downtown-Harbor District.

The South Shore's accessibility to the Boston metropolitan area has greatly influenced the growth rates of its communities. Desirability in terms of land prices, tax rates, and residential amenities further influenced community growth, and Plymouth's population mushroomed from 18,606 in 1970 to 45,608 in 1990, a 145 percent increase in just 20 years. Also of significance during this period was the development of a healthy industrial and commercial base. In 2000, Plymouth's population was 51,701; in 2010, it had grown to 56,468. The rate of growth declined from 13.3 percent in 1990 to 2000 to 9.2 percent in 2000 to 2010 and much of this new growth has occurred in the rural residential areas of South Plymouth. The town and surrounding areas continue to out-pace state averages for development (Town of Plymouth 2009). Plymouth has an overall population density of 501 people per square mile. The town of Plymouth is committed to controlling its residential growth while welcoming industrial and commercial expansion.

One of the largest threats to the federally endangered northern red-bellied cooter is the increase in both residential and business development. Privately owned, unprotected open space is being converted into residential homes and the number of residential housing developments found near the refuge is increasing. The possible sale and development of thousands of acres, currently owned and managed as cranberry bogs, has the potential to greatly increase demand for housing development, increase pressure on open areas for recreation, decrease high quality wildlife habitat and wildlife corridors, and increase human-wildlife conflicts.

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Signs of trespass on the refuge

The median household income for Plymouth County in 2010 was $70,447, and this income level was among the highest compared to neighboring counties. Nantucket County had a median household income of $68,746; Barnstable County's and Bristol County's median household incomes were $64,057 and $54,048, respectively. The 2007 county business patterns for Plymouth County are listed below (table 2-10).

Plymouth's primary economic base is tourism and the different types of businesses that support that activity including hotel, restaurant, and retail industries. The major industry is tourism, with healthcare, technical and scientific research, real estate, and telecommunications also being primary industries. The largest employer in the town is Jordan Hospital (Town of Plymouth 2013).

Cranberry bogs have long been an important part of Massachusetts' culture, economy, and history. Plymouth County is one of the two biggest producers (Cape Cod being the other), with the nearby town of Carver hosting the Ocean Spray Corporation. The town of Plymouth has a small agricultural base (Town of Plymouth 2013) and hosts a current cranberry bog belonging to A.D. Makepeace Company, one of the largest cranberry companies in the world.

Environmental Justice

EO 12898, "Federal Actions to Address Environmental Justice in Minority and Low Income Populations," requires Federal agencies to identify and address potential disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations (EO 12898, February 11, 1994; *http://www.archives.gov/federal-register/executive-orders/pdf/12898.pdf*, accessed October 2015). The Presidential Memorandum accompanying this EO further directs Federal agencies to improve opportunities for community input and the accessibility of meetings, documents, and notices (Presidential Memorandum, February 11, 1994; *http://govinfo.library.unt.edu/npr/library/direct/memos/21a6.html*, accessed October 2015).

In creating table 2-11 below, we used the definitions provided by the United States Census Bureau for race, ethnicity, income, and poverty.

Table 2-10. Industry in Plymouth County.

Industry	Number of Employees	Annual Payroll ($1,000)
Forestry, Fishing, Hunting, Agriculture	67	3,772
Mining	145	11,174
Utilities	1,440	148,741
Construction	13,599	657,152
Manufacturing	11,869	567,468

Industry	Number of Employees	Annual Payroll ($1,000)
Wholesale Trade	6,893	414,032
Retail Trade	28,889	742,089
Transportation and Warehousing	5,026	189,209
Information	2,409	147,689
Finance and Insurance	7,120	379,100
Real Estate and Rental Leasing	1,834	70,984
Professional, Scientific, and Technical Services	7,370	418,185
Management of Companies and Enterprises	3,836	391,004
Admin, Support, Waste Management, Remediation Services	11,721	449,792
Educational Services	2,958	84,849
Health Care and Social Assistance	27,111	1,061,526
Arts, Entertainment, and Recreation	3,553	77,396
Accommodation and Food Services	16,873	252,674
Other Services (Except Public Administration)	7,940	251,941

Source: U.S. Census Bureau, 2008 Economic Census

Table 2-11. Regional Environmental Justice Detailed Characteristics.

	Plymouth County, Massachusetts (percent)	State of Massachusetts
Race and Ethnicity (from year 2010)		
White persons	85.5	80.4
Black Persons	7.2	6.6
American Indian and Alaska Native persons	0.2	0.3
Asian persons	1.2	5.3
Native Hawaiian and Other Pacific Islander	0.0	0.0
Persons reporting two or more races	2.6	2.6
Persons of Hispanic and Latino origin	3.2	9.6
White persons not Hispanic	83.9	76.1
Income and Poverty (from years 2005 to 2009)		
Median household income	$ 70,447	$ 64,057
Per capita income	$32,686	$33,460
Percent Persons below poverty level (from year 2009)	7.6	10.3

Source: United States Census Bureau, 2010

Refuge Administration

Refuge Funding

Successful implementation of the CCPs for each refuge in the Refuge Complex relies on our ability to secure funding, personnel, infrastructure, and other resources to accomplish the actions identified. The funding for Massasoit NWR is embedded in the larger Refuge Complex budget. Operational funding includes salaries, supplies, travel, and all other operational activities (wildlife and habitat surveys and management) that are not funded by special projects. Annual funding fluctuates according to the number and size of the projects funded that year (e.g. vehicle or equipment replacement, visitor service enhancements, and facility improvements). Table 2-12 summarizes the funding levels of levels for the larger Refuge Complex, including Massasoit NWR, for fiscal years 2008 through 2015.

Refuge Revenue Sharing Payments

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 of Plymouth since 2001 (table 2-13). 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 from year to year because Congress may or may not appropriate sufficient funds to make full payment. Payments are based on one of several different formulas, whichever results in the highest payment to the local taxing authority. In Massachusetts, the payments are based on ¾ 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.

Table 2-12. Fiscal Year Funding for the Eastern Massachusetts Refuge Complex from 2008 to 2015.

	2008	2009	2010	2011	2012	2013	2014	2015
Operations	$2,181,898	$1,919,276	$1,949,686	$2,109,679	$2,077,697	$1,545,974	$2,068,493	$2,317,269
Project, Construction, Temporary, and Other Funds	$497,465	$4,560,000*	$2,022,800*	$227,302	$470,289	$895,927	$1,013,199	$574,438
Total Fiscal Year Budget	$2,679,363	$6,479,276*	$3,972,486*	$2,336,981	$2,547,986	$2,441,901	$3,081,692	$2,891,707

**Includes American Recovery and Reinvestment Act funded projects, road work and construction of a new visitor center at Assabet River NWR.*

Table 2-13. Refuge Revenue Sharing Payments to Town of Plymouth in Dollars ($) for Massasoit NWR from 2001 to 2015.

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Payment	4,927	5,299	5,093	4,505	5,088	1,735	1,678	1,302	1,223	862	923	4,380	5,140	4,811	5,058

Refuge Facilities and Maintenance

There are no buildings on the refuge. Two old cabins present on the refuge were demolished due to degradation and vandalism. There is no public parking at the refuge and no place to construct a parking lot.

Staff and equipment that provide support for operations and management on Massasoit NWR come primarily from the Refuge Complex headquarters located on Great Meadows NWR in Sudbury, Massachusetts.

Rights-of-Way and Access

Refuge staff generally access the Crooked Pond parcel through the MSSF on a dirt road located off of Snake Hill Road. A formal ROW off of Gunner's Exchange Road is rarely used by Service staff and is closed to public use. Access to the Island Pond parcel is from a legal ROW off Cannon Road. While all the refuge parcels have some road frontage, it is extremely limited. Construction of parking areas on these parcels is not feasible for safety reasons, lack of suitable location, or the negative impact a parking area would have on refuge neighbors. Because the refuge has been closed to public use since its establishment, the lack of suitable parking and access has not been a problem.

Partnerships and Community Outreach

The NHESP works collaboratively with the refuge in the protection and enhancement of the northern red-bellied cooter population. Prior to 1993, the refuge was managed by a partnering agency, the Massachusetts Division of Fisheries and Wildlife. Massasoit NWR was originally associated with the Parker River NWR Complex. When the Service reorganized, refuge oversight shifted to the Refuge Complex. At that time, the Memorandum of Agreement with MassWildlife was not renewed and the Service assumed management (T. French, 2012 personal communication).

Due to staffing limitations and given the refuge is closed to public use, very little community outreach has occurred by refuge staff. Past outreach included the collaborative efforts of the northern red-bellied cooter headstart program and this CCP process, including using volunteers for inventorying and monitoring, outreach to landowners surrounding the refuge primarily regarding wildland-urban interface and fire management, and conservation opportunities with organizations such as TNC (who recently closed their Plymouth Office), the Wildland Trust, MassWildlife, University of Massachusetts Cooperative Research Unit, Bristol County Agricultural High School, and others.

The MSSF abuts the refuge to the south and west. This forest is managed by the MADCR and falls within the designated critical habitat area for the northern red-bellied cooter. MSSF consists of more than 12,000 acres of both wildlife habitat and recreational areas. The staff and Friends of MSSF have contributed to the refuge by offering species data, volunteer botanists for plant inventory, and some shared environmental education opportunities. The Service has also agreed to collaborate in prescribed burning efforts for the benefit of wildlife habitat and for fuel reduction

Volunteer Programs

Although the refuge volunteer program at Massasoit NWR is currently small, volunteers have made important contributions towards habitat management and inventory and monitoring program by conducting vegetation surveys (including rare and nonnative species), assisting with efforts to improve northern red-bellied cooter nesting habitat, and monitoring nesting activity and hatchling emergence.

Northern red-bellied cooter (on right) and painted turtle

Bill Byrne