

## Chapter 2



Tim McCabe/USFWS

*Wood duck*

## Affected Environment

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## Introduction

This chapter describes the ecological, physical, and socioeconomic setting of Great Bay Refuge in a regional and local context. We first describe the regional landscape, including its historical and contemporary influences. We then describe the refuge and its resources.

## Part I. The Regional Setting

In addition to the 1,103-acre Great Bay Refuge, we also administer the 29-acre conservation easement in Concord, New Hampshire, as pine barrens habitat for the federally listed endangered Karner blue butterfly. The easement is approximately 45 miles west of Great Bay and is described separately below.

Great Bay Refuge lies within the Gulf of Maine watershed, an immense area extending from eastern Quebec to Cape Cod in Massachusetts. Along New Hampshire's coast, the Gulf of Maine's tidal waters flow twice daily up the Piscataqua River through Little Bay and then into Great Bay at Furber Strait. Collectively, these water bodies are described as the Great Bay Estuary system. This is one of the most productive ecosystems on the East Coast (Odell et al. 2006). The refuge sits on the eastern shore of Great Bay.

The Great Bay Estuary is approximately 10 miles inland from New Hampshire's seacoast and adds more than 130 miles of tidal shoreline to the 18 miles of shoreline along the State's coast. Seven major rivers flow into the Great Bay Estuary system: the Winnicut, Squamscot, Lamprey, Oyster, Bellamy, Cochecho, and Salmon Falls. Together these rivers drain nearly 1,000 square miles. The major habitats in Great Bay are eelgrass meadows, mudflats, salt marsh, channel bottoms, and rocky intertidal habitat. These habitats support over 16 bird, fish, and plant species, 26 of which are State-listed threatened or endangered (see appendix A) (<http://greatbay.org/about/index.htm>; accessed May 2011). In the estuary, recreational shellfishers harvest oysters and clams; fishing enthusiasts pursue striped bass, bluefish, alewife, and blueback herring; lobstering is a commercial and recreational activity; and American eels are trapped for bait and for export. Birders from all over the world come to view migratory birds on Great Bay (NHEP 2000).

Great Bay Refuge is located on a portion of the former Pease Air Force Base. The rest of the former base is now Pease International Tradeport (Tradeport). The approximately 3,000-acre Tradeport has office and industrial spaces, an active airport, restaurants, hotels, and other amenities. Past land uses, including farming and 30 years of use as an Air Force Base, dramatically changed the upland plant community from an Appalachian oak-pine forest to a mix of transitional pine-hardwood forest, shrubs, fields, and impounded waters. Only some remnants of the historical forest community remain in the area.

*Storage bunker in former Weapons Storage Area*



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## Water Quality and Health of the Great Bay Estuary

Several centers of ecological research and management in the area provide a detailed picture of the historical and current health of the Great Bay Estuary and watershed. These centers, described in more detail in chapter 1, include the PREP, GBNERR, and the NHCP, among others.

In an overview on the restoration of the Great Bay Estuary, Odell et al. (2006) summarized the condition of the estuary system as follows:

“A close look at the history and current condition of the Great Bay estuarine system reveals that although it is relatively intact and remarkably resilient, it has been significantly altered and degraded. Prior to 1900, all of the rivers and many of the tributaries were dammed, extensive logging throughout the watershed brought tons of silt into tidal rivers, the bay bottom was covered in sawdust up to a foot deep and poisoned with industrial wastes, and aquatic resources were over harvested. Since that time, significant human population growth and development throughout the Great Bay watershed have created new stresses—notably habitat loss, and new levels and types of point and non-point source pollution.”

A concerted effort to understand, protect, and restore the Great Bay Estuary is underway among many local, State, and Federal partners. Particular emphasis is placed on land protection, controlling discharges from wastewater treatment plants and other pollution sources, and using best management practices to minimize impacts from development and resource extraction (Odell et al. 2006).

Every 3 years, PREP compiles a report on the “State of the Estuaries.” The report tracks trends in 12 environmental indicators to assess the health of New Hampshire’s estuaries. The report describes each indicator as having an either positive, negative, or cautionary trend. A cautionary trend is a trend or status that demonstrates possibly deteriorating conditions, but more information is needed to fully assess the indicator. In the 2009 report, 11 out of the 12 indicators showed either negative or cautionary trends for Great Bay (table 2.1). In the previous 2006 report, only 7 out of the 12 indicators had either negative or cautionary trends. The report recognizes that although there have been many successful projects to conserve land or restore habitat around Great Bay, these projects have not been able to keep up with continued habitat loss and human development (PREP 2009).

**Table 2.1. Environmental Indicator Trends in the Great Bay Estuary (PREP 2009)**

Indicator	Situation	Trend*
Dry weather bacteria concentrations	Concentrations in Great Bay decreased significantly in the 1990s, but no change in last 10 years.	!
Toxic contaminants in shellfish	Concentrations of a petroleum product have increased by 218 percent in the Piscataqua River over past 16 years.	!
Toxic contaminants in sediments	Toxic contaminants found in 24 percent of estuarine sediment.	!
Nitrogen in Great Bay	Dissolved inorganic nitrogen concentrations increased in Great Bay by 44 percent in past 25 years; the total nitrogen load to Great Bay increased 42 percent in past 5 years.	–
Dissolved oxygen	Levels fall below State standards often in tidal rivers, rarely in the bay.	!
Oysters	Number of adult oysters in Great Bay declined by 95 percent in the 1990s; the population has increased slowly since 2000.	–

Indicator	Situation	Trend*
Eelgrass	Eelgrass cover in Great Bay has declined by 37 percent between 1990 and 2008 and completely disappeared from the tidal rivers, Little Bay, and the Piscataqua River.	–
Anadromous fish	Returning anadromous fish are limited by various factors including water quality, passage around dams, and flooding.	!
Habitat restoration	Yes for salt marsh, but oyster and eelgrass habitats have been restored at a slower rate.	!
Impervious surfaces	In 2005, 7.5 percent of the land area of the watershed was covered by impervious surfaces, and 9 subwatersheds had greater than 10 percent impervious cover. In 2005, the town of Newington, NH had 20.2 percent imperviousness; up from 13.2 percent in 1990.	–
Land conservation	At the end of 2008, 76,269 acres in the Piscataqua watershed are protected, which amounted to 11.3 percent of the land area.	+

\* + is a positive trend; - is a negative trend; ! is a cautionary trend

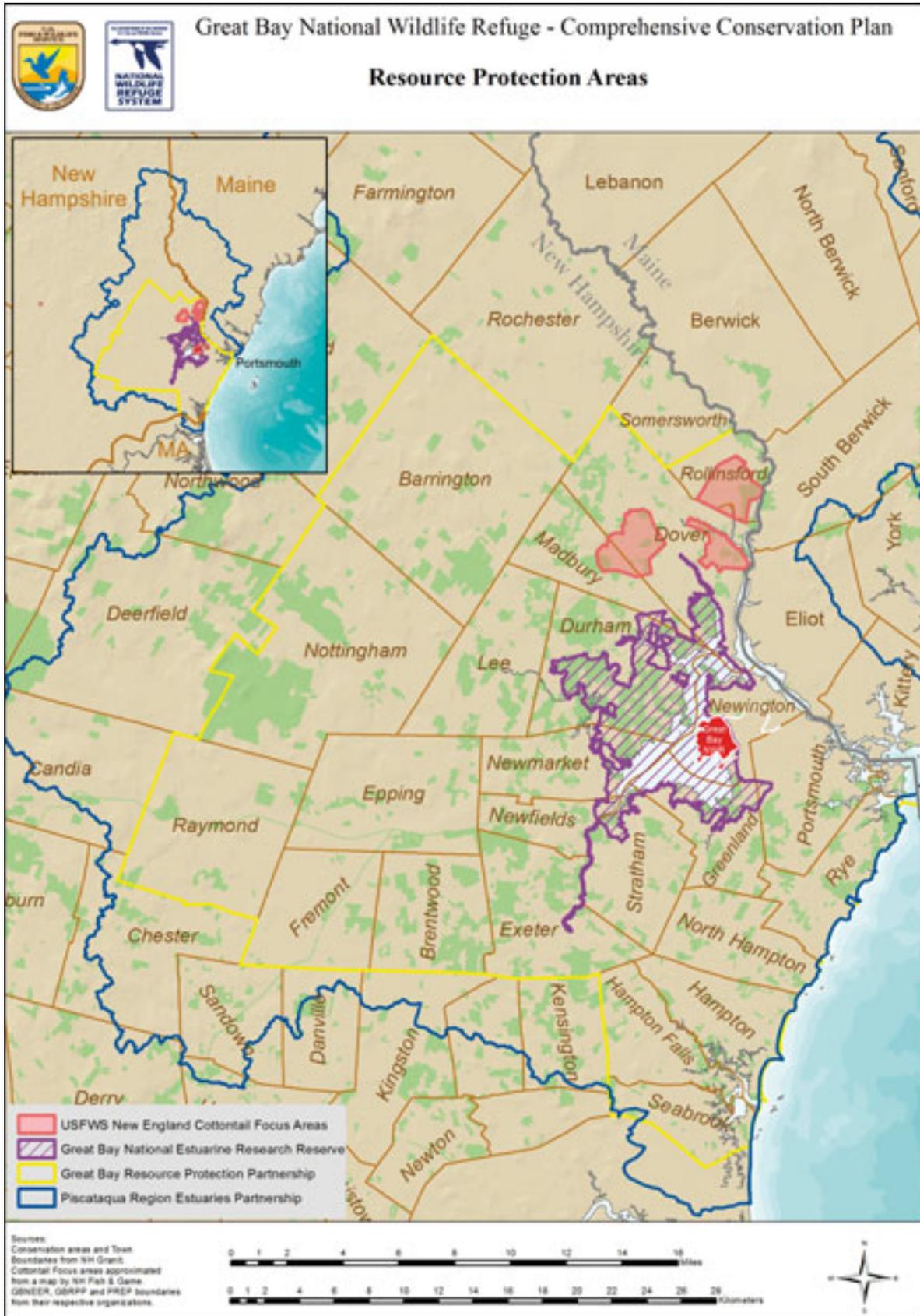
## Conserved Lands Network

Great Bay Refuge is within the boundaries of the GBNERR (map 2.1). The reserve was designated in 1989, encompassing 4,500 acres of tidal waters and wetlands and 3,000 acres of surrounding upland. The refuge and the reserve are part of the Great Bay Resource Protection Partnership (GBRPP), a coalition working to permanently protect land in 24 towns around Great Bay, including those within the boundaries of the reserve (map 1.1). The partnership funded the protection of 5,098 acres in the Great Bay region from 1996 to 2008, and an additional 3,052 acres were protected as a match to the partnership-funded lands (<http://www.greatbaypartnership.org/index.html>; accessed May 2011).

Great Bay Refuge is the largest block of protected land on Great Bay. Table 2.2 lists other key conserved lands around the Great Bay Estuary.

**Table 2.2. Conservation Lands Bordering Great Bay Estuary**

Name	Town	Acres	Ownership
Great Bay National Wildlife Refuge	Newington	1,103	U.S. Fish and Wildlife Service
Fox Point	Newington	119	Town of Newington
Wagon Hill Farm	Durham	130	Town of Durham
Adams Point	Durham	70	NH Fish and Game
Wilcox Point	Durham	38	NH Fish and Game
Lubberland Creek	Newmarket	70	The Nature Conservancy
Shackford Point	Newmarket	34	NH Fish and Game
Sandy Point (Great Bay Discovery Center)	Greenland	46	NH Fish and Game
Great Bay Wildlife Management Area	Greenland	32	NH Fish and Game



## Land Use Trends

Despite the network of conservation lands in the Great Bay watershed, future growth is a concern, especially in the northern portion of the watershed on those lands not protected. As the population of the region increases, there is an associated increase in sources of pollution. Developed lands also reduce or fragment wildlife habitat. Development creates more impervious surfaces, such as paved roads, parking lots, and buildings. Impervious surfaces increase the volume and velocity of stormwater runoff and the sediment and pollutant load flowing into the estuary. Because of this, the amount of impervious surface in a watershed is a good indicator of stream and water quality (PREP 2009). Generally, water quality deterioration is expected in watersheds with greater than 10 percent impervious surface. According to PREP, 7.5 percent of the land area of the Piscataqua watershed was covered with impervious surface in 2005. Impervious surfaces continue to be added to the watershed at a rate of approximately 1,500 acres a year (PREP 2009). The town of Newington, where the refuge is located, has one of the highest levels of impervious surfaces in the watershed; increasing from 18 percent in 2000 to over 20 percent in 2005 (PREP 2009).

## Climate

Along the coastal lowlands, winter temperatures average about 30°F and summer temperatures average about 80°F. At higher elevations and further inland, winter temperatures are often 10 to 12°F cooler. Afternoon sea breezes affect the refuge in spring and summer, with noticeable wind shifts at about 11 a.m. and again just before sunset. Further inland, low elevation areas can be 5 to 10°F warmer during summer, but cooler as elevation rises. Annual precipitation is uniform throughout the year with the wettest month being November (greater than 5 inches on average). Total annual precipitation Statewide is about 45 inches. Annual snowfall for coastal areas is 50 inches and higher elevations can receive 150 inches. Much of the precipitation is the result of cooler air from the polar region meeting a warmer, moist southerly air mass riding the Atlantic seaboard northward (Schroeder 1970). The resulting storms can be quite severe and can occur year-round.

## Air Quality

The Clean Air Act requires the EPA to set National Ambient Air Quality Standards for pollutants considered harmful to public health and the environment. The Clean Air Act established two types of national air quality standards: primary and secondary standards. Primary standards set limits to protect public health, including the health of sensitive populations such as people with asthma, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility, and damage to animals, crops, vegetation, and buildings. The EPA has set standards for six principal pollutants: carbon monoxide, nitrogen dioxide, ozone, lead, particulates, and sulfur dioxide (<http://www.airmap.sr.unh.edu/background/naaqs2.html>; accessed May 2011).

During summer, most of southern New Hampshire and coastal Maine experiences ozone events that are considered “very unhealthy” for humans and the environment. Acid rain also impacts the region. These and other air quality issues in the region are largely the result of the influx of airborne pollutants originating from industrial regions, metropolitan centers, and transportation corridors located upwind, and primarily from the Midwest and Mid-Atlantic regions. Industrial and transportation sources within New England also contribute to air quality issues (Wake et al. 2004).

Ozone at ground-level is a pollutant that forms in the atmosphere as a by-product caused by the release of volatile organic compounds and nitrogen oxides emitted from automobiles, diesel trucks, and industrial sources. Several areas, including the Dover-Portsmouth-Rochester region, are designated as “serious

non-attainment zones” for ozone by the EPA. Very high ozone levels occur in the seacoast regions of Maine, New Hampshire, and Massachusetts during the summer due to a combination of factors (e.g., dense population, local pollution sources, and being downwind of sources outside the region). On average, southern New Hampshire and coastal Maine experience 3 to 5 days per year of very unhealthy ozone levels, with some years (e.g., 1988) that are much worse. Many unknowns still exist about air quality in New England, including the specific sources of pollution, and effects of weather patterns and climate changes (Wake et al. 2004).

Every year, Public Service of New Hampshire (PSNH) uses 400,000 tons of low-sulfur coal to fuel their Newington, New Hampshire Schiller Station’s three 50-megawatt steam boilers. In 2006, they converted one of the coal boilers to a wood burning boiler, reducing coal burning by about 130,000 tons a year. The new boiler is expected to annually consume more than 400,000 tons of wood, most of which will come from suppliers in the New Hampshire area. According to PSNH, the wood-burning boiler emits 70 percent less nitrogen oxide, 90 percent less mercury, and 95 percent less sulfur dioxide than the coal plant (<http://www.psnh.com/RenewableEnergy/About-PSNH/Northern-Wood-Power.aspx>; accessed May 2011).

## The Historical Picture

### After the Ice Age

New England emerged from an ice age 12,000 years ago. A 1-mile thick glacier scraped and molded the valleys, slopes, and mountain tops, leaving behind a landscape bare of vegetation. At the southern edge of the glacier, however, plants survived and immediately began to recolonize the newly exposed soils (Marchand 1987). Large mammals, including mastodons, wandered the spruce parkland and grassy savanna, but disappeared quickly at the same time the glacier receded and humans advanced across the region.

Continual weathering and erosion of rock over time released nutrients and created new soils for plants to grow. Hardwood and softwood tree species advanced independently of one another creating different forest communities through time (Davis 1983). The sequence of plant species’ arrivals as the glacier receded was also different at different sites (Davis 1981). In a relatively short time period (about 2,000 years), the land cover changed from tundra to woodland with scattered trees, and then to closed canopy forest. Pine and oak arrived around 11,500 years ago with a warmer and drier climate. Eastern hemlock became more prevalent around 10,000 years ago with a wetter climate (Manomet Center 2010). Graham (1992) reported similar species-specific responses by mammals to post-glacier climate changes.

### Native People

Prior to European arrival, coastal southern New England likely supported a “shifting mosaic” of open land habitat within a mostly forested landscape. The open lands were a result of native heathlands, grasslands and shrublands, extensive beaver meadows, periodic fires, shifting agriculture by Native Americans, and occasional hurricanes (Cronin 1983, DeGraaf and Yamasaki 2001). DeGraaf and Yamasaki (2001) and Askins (2000) reported broad evidence for the presence of extensive grasslands along the coast and major rivers in pre-European New England.

Native Americans in southern New England fished and shellfished for much of their food, as well as hunting birds and trapping and hunting small game. When colonists landed on Massachusetts shores in the early 1600s, they saw large clearings and open woodlands. Waterfowl, deer, ruffed grouse, wild turkey, and wild pigeons were abundant (Marchand 1987, Foss 1992, DeGraaf and Yamasaki 2001). Colonists found old growth forests not far inland, including old stands of

mixed hardwoods, white pine, and hemlock at low elevations, and spruce and fir in the mountains (Marchand 1987).

### **European Settlement**

European contact (e.g., explorers and traders) with native people began during the 16th century in New England. Foster and Motzkin (2003) suggested that European arrival prompted such rapid and profound changes to the lifestyle and land use practices of indigenous people that by the time colonists began to settle here, the landscape was already altered. Foster and Motzkin (2003) suggested that expansive clearing for agriculture and semi-permanent (rather than mobile) villages were a new phenomenon and resulted from European influence.

European colonists brought new land use concepts such as permanent settlements and political boundaries. They shifted land use from primarily subsistence farming and gathering to harvesting and export of natural resources (Foss 1992). Just 100 years after the colonists arrived, the forests were rapidly being logged. By 1830, central New England was 80 percent cleared (Marchand 1987).

However, shortly after this, many people began leaving the rough, rocky New England landscape for other opportunities. The abandonment was due to a variety of factors, including the California Gold Rush, the Industrial Revolution, new railroads, richer midwestern soils, and the Civil War. Abandoned farm fields began reverting back to forest. White pine seeded into the fields and pastures and by 1900 was ready for harvest. An understory of hardwoods, released from the shade of white pine, emerged as the new dominant vegetation. This is a legacy that remains today (Marchand 1987, DeGraaf and Yamasaki 2001).

The Great Bay Estuary was long a center of commerce for natural resource based industries including fishing and logging. Early settlers exploited the region's extensive forests and abundant populations of salmon, shad, sturgeon, alewife, blueback herring, and shellfish. Flat-bottomed gundalows, a type of sailing barge, were used to transport cargo up and down the swift-current and shallow waters of the Piscataqua River to and from the towns on Little Bay and Great Bay. Shoe and textile mills were built on the water's edge of the towns within the estuary (Jones 2000). By 1790, Portsmouth, New Hampshire was the 14th largest city in the country, known for its shipping and fishing industries (Bolster 2002). Growing human populations, accompanied by unchecked sewage disposal and dumping of industrial wastes degraded the water quality in the estuary, led to population declines of fish and shellfish. Beginning in the 1940s, pollution controls began to improve water quality and habitats in Great Bay (Jones 2000).

### **Climatic Effects and Natural and Human Disturbances**

The Northeastern United States is particularly cold, given its latitude (Marchand 1987). The reason for the region's cold climate is partly a result of the pattern of atmospheric circulation in this hemisphere. Low pressure systems all converge on New England, regardless of their origin, and pull cold Canadian air in behind as they pass over the Northeast (Marchand, 1987). New England weather conditions are influenced more by the North American landmass than by the Atlantic Ocean except along the coastline (Taylor et al. 1996). Forty to 45 inches of precipitation fall about evenly throughout the year, although drought periods occur in some years (Patterson and Sassaman 1988).

Natural disturbances vary across New England, depending on geographic location, forest type, and local conditions. In presettlement times, coastal regions experienced the highest rates of disturbance because of the prevalence of fire-dependent sandy pine-oak barrens, higher densities of Native Americans, higher frequencies of hurricanes, and longer snow-free periods. These disturbance regimes may have maintained about 1 to 3 percent of the inland northern

hardwoods forests and greater than 10 percent of the coastal pine-oak barrens, in early successional habitat (Lorimer and White 2003).

Native insects and disease, ice storms, droughts, and floods have caused both minor and major disturbances. Lorimer and White (2003) depicted hurricane frequencies as varying from 85 years in southeastern New England, 150 years through 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 at intervals of 800 and 1,150 years, respectively.

Agriculture, logging, fire, wind, exotic pests and diseases, and development have significantly altered the New England landscape. Agriculture had the greatest effect on New England's forests, causing major changes in cover types and soils over a vast area. Although most of the region's forests were cut at least once, most logging did not affect succession or impact soils (DeGraaf and Yamasaki 2001). Human settlements are emerging as the major cause of permanent habitat loss compared to previous impacts from agriculture and logging.

### **Climate Change**

Climate changes are predicted to affect climate patterns over time (Lorimer 2001). The greatest effects of climate change will be on regional air and water temperatures, precipitation patterns, storm intensity, and sea levels. In the Northeastern United States, the average air temperature is expected to rise by 8°F by 2100, with the greatest increase during winter months (Frumhoff et al. 2007). New Hampshire's summers are anticipated to be similar to those currently experienced in Virginia (Frumhoff et al. 2007). Climate change is anticipated to influence natural disturbances patterns and result in a decrease in freeze periods, decreased snow cover, increased storm intensities and frequencies, increased intensity and frequency of summer droughts, damaging ozone, and an increase in the spread of invasive species and disease (NHFG 2005, Manomet Center 2010). The resulting effects on wildlife and habitats are expected to be variable and species-specific, with a predicted general trend of ranges shifting northward by 350 to 500 miles (Frumhoff et al. 2007).

Tidal marshes are among the most susceptible ecosystems to climate change, especially rapid sea level rise. In an effort to address these potential effects on national wildlife refuges, the Service ran Sea Levels Affecting Marshes Model (SLAMM) 5.0 analyses to estimate the impacts of sea level rise for all coastal refuges, including Great Bay Refuge. The model predicted that the salt marshes at Great Bay Refuge would be resilient to the effects of sea level rise, with very little conversion of upland to wetland (Clough and Larson 2009). The majority of the refuge is dominated by oak-hickory forest, which is at the northern edge of its range. Under climate change scenarios, this forest type is expected to persist and expand northwards. Increasing summer droughts and disease is expected to increase the likelihood of forest fires, which the oak-hickory habitat is adapted to. Two habitats on the refuge that are vulnerable to climate change are hemlock communities and forested wetlands. The hemlock woolly adelgid, an invasive pest, is currently at the northern edge of its range in southern New Hampshire, and is expected to expand northwards with increasing winter temperatures. Earlier flooding and prolonged summer drought may result in a reduction of forested wetlands on the refuge and decrease both the quantity and quality of these habitats for wetland-dependent species, such as northern leopard frog and willow flycatcher. The main guiding principal of the Service's climate change adaptation planning is to maintain or increase resiliency of the refuge's habitats and ecological process. The uncertainty about the future effects of climate change also requires refuge managers to use adaptive management to maintain healthy ecosystems in light of the unpredictability (Inkley et al. 2004).

### Wildlife Changes

Wildlife populations ebb and flow as habitat conditions vary in space and time. Natural and human disturbances intervene, shifting species abundance and diversity. Some species, such as alpine plants, have been here for 10,000 years or more. Others, like the coyote, arrived in the last 75 years. Change is inevitable and natural, although human activities in the last 400 years have significantly altered the landscape compared to the previous 10,000 years when humans first colonized the northeast (Foss 1992).

During the 1800s, many wildlife species declined because of habitat loss (e.g., forest clearing), bounty and market hunting, millinery trade (for feathers to use in hats), and natural history specimen collecting (Foster et al. 2002). The millinery trade in the late 1800s, and hunting and egg collecting (for food and bait) decimated Arctic, common, and roseate tern populations in the Gulf of Maine (Drury 1973). Mountain lion, gray wolf, elk, and caribou were extirpated from the area by the mid-1800s or early 1900s and have not recolonized the region. Heath hen, passenger pigeon, great auk, Labrador duck, and sea mink became extinct at the hand of humans during the same period (DeGraaf and Yamasaki 2001, Foster et al. 2002).

The historical record is unclear on the abundance and distribution of open land plant and animal species in the Northeast prior to European settlement (Foster and Motzkin 2003). Scattered large grasslands occurred in coastal areas including the approximately 59,300-acre Hempstead Plain on Long Island and the blueberry barrens along the Maine coast (Askins 1997, Winne 1997). Smaller, more temporary grasslands were created when beavers abandoned their dams, or by fires set by lightning or humans (Askins 1997). Some grassland bird species, such as horned lark and dickcissel, likely spread eastward from the Midwest as lands here were cleared for agriculture. However, some grassland birds, including bobolink, eastern meadowlark, and upland sandpiper, may have existed here long before European settlement in these coastal barrens, heathlands, and grasslands (Askins 1997). Populations of grassland birds have declined significantly across their range in the last 40 years (Askins 1997, Norment 2002). After farm abandonment escalated in the early 1900s, wildlife species that prefer thickets, brush lands, and young forests increased (Litvaitis 2003).

The young hardwood forests that emerged in the 1920s and 1930s provided premier habitat for ruffed grouse (DeGraaf and Yamasaki 2001). The succession of that forest into mature hardwood forests in the late 1900s caused a decline in the grouse population but an increase in other species that prefer more mature forests. Abundances of early successional species declined to levels approaching presettlement levels (Litvaitis 2003).

### *Opossum*



Tim Williams.

Eastern coyotes were first sighted in New Hampshire and Vermont in the 1940s, in northern Maine in the 1930s, and in Massachusetts in the 1950s. DeGraaf and Yamasaki (2001) reported three major trends in New England's wildlife: forest species are increasing (e.g., American black bear, beaver, deer, wild turkey, pileated woodpecker), grassland and shrubland species are declining (e.g., grasshopper sparrow, bobolink, upland sandpiper, whip-poor-will), and many southern species are expanding their ranges northward (e.g., glossy ibis, willet, Carolina wren, northern cardinal, northern mockingbird, Virginia opossum). A few species, such as common raven, fisher, and moose are expanding southward. A group of species remains regionally extirpated, including wolverine and mountain lion, although Canada lynx have returned to northern Maine and New Hampshire (DeGraaf and Yamasaki 2001).

## Regional Demographics and Economic Setting

### Population and Demographics

Great Bay Refuge is located in southern New Hampshire in the town of Newington in Rockingham County. Its close proximity to metropolitan areas, including Boston, Massachusetts, and Manchester, New Hampshire, expose the refuge to the effects of urban sprawl. As real estate in cities and their outskirts becomes scarce and more expensive, city residents look outward for more affordable housing. In addition, New Hampshire offers numerous scenic and natural areas, and opportunities for outdoor recreation.

An analysis of population data by the New Hampshire Office of Energy and Planning (NHOEP) shows the State divided into the slow-growing north and the fast-growing south. Since 1960, New Hampshire’s population has increased by about 703,000 people. More than 60 percent of that growth occurred in Rockingham and Hillsborough Counties. This growth is expected to shift away from Rockingham County because of the decreasing availability and increasing cost of land, and the greater freedom to reside in and commute from more remote communities. In contrast, Merrimack County is expected to gain in the State’s future share of growth (NHOEP 2006).

Rockingham County’s 695 square miles of land area contained 426 persons per square mile in 2007. The estimated 2007 population of Rockingham County is 296,543, an increase of 19,184 people since 2000. Rockingham County was the second most populated county in the State in 2007, accounting for about 23 percent of New Hampshire’s total population. From 2005 to 2007, the median age in Rockingham County was 40.2 years. Persons under 18 years accounted for 24 percent of the population, while 11 percent were 65 years or older (USDOC 2007). Table 2.3 presents the population trends for Rockingham County and the communities surrounding the refuge.

**Table 2.3. Population Trends for Communities and the County Around Great Bay Refuge**

	Population in 2007			Percent Population Change	Projected Population
	Residents	Persons per Square Mile	Median Age	1990 to 2000	2020
<b>New Hampshire</b>	1,315,828	146.7	39.3	+11.4	1,470,010
<b>Rockingham County, NH</b>	296,543	426.7	40.2	+12.8	331,190
<b>Newington, NH</b>	803	96.0	42.6	-21.7	900
<b>Greenland, NH</b>	3,395	322.2	38.1	+15.9	3,880
<b>Portsmouth, NH</b>	20,495	1,312.7	36.6	-19.8	22,730

*Source: U.S. Census Bureau (2007), New Hampshire Office of State Planning (based on 2000 US Census data), and New Hampshire Office of Energy and Planning (projections compiled Jan 2007 based on past trends).*

### Environmental Justice

Executive Order #12898, “Federal Actions to Address Environmental Justice in Minority Populations and Low-income Populations,” (dated February 11, 1994) requires Federal agencies to identify and address any potential disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations. The Presidential Memorandum accompanying this order further

directs Federal agencies to improve opportunities for community input and the accessibility of meetings, documents, and notices (CEQ 1997). To facilitate this, Federal agencies should also consider if a significant portion of the affected community is linguistically isolated, and as warranted, provide translated documents and other appropriate outreach materials.

In creating table 2.4 below, we used the following definitions:

- **Minority population** includes persons who are members of the following groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic.
- **Low-income population** includes persons living below the poverty line.
- **Linguistically isolated population** includes persons who speak English less than “very well.”

**Table 2.4. Regional Environmental Justice Characteristics.**

	<b>Rockingham County, NH</b>	<b>Town of Newington, NH</b>
<b>Minority Population</b> (as percent of total population)	4.8 percent	4.0 percent
<b>Low-income Population</b> (as percent of total population)	4.8 percent	4.6 percent
<b>Linguistically Isolated Population</b> (as percent of total population)	1.6 percent	3.4 percent

**Business and Economic Climate**

New Hampshire has made several economic transitions in the past. Historically, the area was agriculturally based. The economy later shifted to textile and leather goods manufacturing during the industrial era and then shifted again to the manufacturing of higher valued goods such as fabricated metal and electrical goods. Currently, the State is in transition to a post-manufacturing, service-based economy (NHOEP 2006).

New Hampshire has a 70 percent “labor force participation rate.” This means that 70 percent of the population age 16 and older is either employed or unemployed but able to work and looking for a job. In 2007, retail was the largest employing industry in the State, providing jobs for 97,700 workers (NHES 2009). New Hampshire does not tax personal income, sales, inventory, capital gains, personal property, machinery, or equipment. This contributes to its competitive status in the retail industry. In 2007, the State median income was \$67,576 (NHES 2009).

In 2007, 38 percent of the workforce in Rockingham County was employed in management, professional, and related occupations, while 27 percent filled sales and office occupations. The remaining workforce was divided among service occupations including production, transportation, and material moving; and construction, extraction, maintenance and repair occupations. The primary industries in the county are educational services, health care, and social assistance, and retail. The Great Bay Estuary is important to local and regional recreational and commercial fisheries (Jones 2000). In 2007, the median household income in Rockingham County was \$72,600 in 2007 (USDOC 2007).

In the region around Great Bay Refuge, the major economic participant is the Pease International Tradeport. The Tradeport is a 3,000-acre business and aviation industrial park located at the former Air Force Base that was developed by the Pease Development Authority (PDA) after the closure of the base in 1991. It has more than 200 tenants, 5,100 employees, and 3.9 million square feet of new construction and renovated space for businesses (Greater Portsmouth Chamber of Commerce 2006). The Tradeport also includes the Portsmouth International Airport at Pease which is used both for military aviation by the New Hampshire Air National Guard and for civilian aviation.

The PDA has marketed the Tradeport as an ideal location for businesses interested in global trade because of its proximity to major highways, an international airport, and the marine Port of New Hampshire. Companies located at the Tradeport also benefit from the State's lack of a broad-based tax system. Some of the amenities provided by the Tradeport include hotels, restaurants and banquet facilities, golfing, personal and commercial banking, copy and printing services, job training and continuing education (PDA 2006).

The expanding business center of the city of Portsmouth is less than 1 mile away from the Tradeport. Portsmouth is a significant commerce center in New England (GPCC 2006). In addition to being accessible by five major highways, Portsmouth is served by the Boston and Maine Railroad. It is New Hampshire's only ice-free deep-water port with a Foreign Trade Zone, and lumber, fuel oils, salt, gypsum, scrap metal, and other materials are shipped from here.

PSNH's wood burner along the Piscataqua River in Portsmouth is another major part of the economy. As mentioned before, it uses over 400,000 tons of wood chips annually to run, most of which comes from suppliers in New Hampshire (<http://www.psnh.com>; accessed May 2011).

Portsmouth is also home to many shops, businesses, galleries, museums, restaurants, and the Portsmouth Naval Shipyard, which has been in operation since 1800. As the second oldest city in the State, Portsmouth has a prominent cultural heritage that attracts many visitors to historic sites such as Strawberry Banke. In nearby Durham, UNH adds to the vitality of the area's social and cultural resources.

### **Resource-based Recreation and Tourism**

The natural beauty of New Hampshire has attracted many visitors to its mountains, forests, lakes, and seashore. Visitors to the State have cited visiting beaches, State parks or national forests, and opportunities for hiking, skiing, wildlife watching, and outdoor recreation as reasons for visiting New Hampshire (INHS 2009a). Tourism is an important economic contributor in New Hampshire, as 10 percent of private sector employees work in the "accommodation and food services" sector (NHES 2009). The tourism industry has seen a recent slowing due to the larger economic slowing of the country, however, meals and rooms taxes paid by tourists grew 2.3 percent in 2008, totaling \$132.9 million (INHS 2009b).

The conservation of open spaces and their associated wildlife recreation activities provide economic benefits to the local and regional community. A report by the Trust for Public Land (TPL) titled "The Economic Benefit of Parks and Open Spaces" found that throughout the nation, parks, protected rivers, scenic lands, wildlife habitat, and recreational open space help support a \$502-billion tourism industry (Trust for Public Land 1999). Another report by the Service found that national wildlife refuges in the lower 48 States attracted 34.8 million visitors in 2006 and generated \$1.7 billion of sales in regional economies (Carver and Caudill 2007). In New Hampshire, the estimated annual value of open space

to the economy totaled \$8 billion, representing 25 percent of the State’s local economy and contributing \$891 million in State and local taxes (Trust for Public Land 1999). Wildlife refuges, such as Great Bay Refuge, provide an opportunity to generate revenue through recreational activities. In 2006, the combined total revenues from wildlife watching, fishing, and hunting in New Hampshire was \$520 million (USFWS and USDOC 2007) (table 2.5).

**Table 2.5. Revenues from Wildlife-associated Recreation by Residents and Non-residents in New Hampshire**

Activity	Total Participants	Total Expenditures	Total Participants	Total Expenditures
	2001		2006	
Wildlife watching	450,000	\$200,010,000	710,000	\$273,769,000
Fishing	164,000	\$186,436,000	230,000	\$172,413,000
Hunting	53,000	\$55,775,000	61,000	\$74,467,000
<b>Totals</b>	<b>667,000</b>	<b>\$442,221,000</b>	<b>1,001,000</b>	<b>\$520,649,000</b>

*From the U.S. Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau. 2001 and 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.*

Woodman Point



USFWS

## Part II. The Refuge and its Resources

### Refuge Administration

#### Staffing and Budget

When the refuge first opened in 1992, its staff consisted of a refuge manager, assistant manager, and an office administrative assistant. A biological technician was also on staff for a few years. In 2006, the Service implemented a Regional Workforce Plan which included a decision to de-staff Great Bay Refuge. Since 2008, Great Bay Refuge has been administered by Parker River Refuge in Newburyport, Massachusetts, (see table 2.6).

**Table 2.6. Refuge Staffing and Budget, 2005 to 2010**

Fiscal Year	Total Budget (Including Salaries)	Full-Time Staff
2005	\$135,800	1
2006	\$159,410	1
2007	\$264,336	1
2008	\$124,857	0.33
2009	\$61,108	0*
2010	\$67,740	0*

*\*Note: Staff from Parker River Refuge administers Great Bay Refuge.*

#### Refuge Facilities

From 1992 through the summer of 2001, the refuge headquarters was located on the second floor of the former Newington Town Hall on Nimble Hill Road in Newington. The current headquarters was built in 2001, and is located past the electronic gate at the refuge entrance on Merrimack Drive, next to the former Weapons Storage Area. The automated entrance gate is timed to be open from dawn to dusk. The headquarters building houses staff space, a reception area, and a small meeting room. This office also provides office space for two regional Service staff: the regional wildlife biologist and a regional Geographic Information Systems (GIS) specialist. Map 2.2 displays the existing location of facilities.

Other refuge facilities include a house, maintenance building, and a visitor parking lot with adjacent interpretive kiosk, public restroom facility, and bicycle rack. Two pedestrian trails leave from the parking lot. These trails are described in more detail under the subheading “Public Use Programs” below.

#### Refuge Revenue Sharing

National wildlife refuges contribute to local economies through shared revenue payments. Federally owned land is not taxable; but, under the provisions of the Refuge Revenue Sharing Act, the Service pays annual refuge revenue sharing payments to municipalities or other local units of government where there are national wildlife refuges. Land in public ownership requires little in the way of services from municipalities, yet it provides valuable recreational opportunities for local residents. Table 2.7 lists the payments made to the town of Newington since 2000.



**Table 2.7. Great Bay Refuge’s Refuge Revenue Sharing Payments to the Town of Newington, 2000 to 2009**

Fiscal Year	Newington, NH
2000	\$36,277
2001	\$37,028
2002	\$41,550
2003	\$39,935
2004	\$35,323
2005	\$39,892
2006	\$36,922
2007	\$35,702
2008	\$27,699
2009	\$26,028

**Special Use Permits**

The refuge manager issues special use permits on a case-by-case basis after determining whether a use is compatible with refuge purposes. All special use permits have a 1-year term. The refuge has issued special use permits for the following types of activities:

- Wildlife Inventories and Research
  - \* Christmas Bird Counts (NH Audubon)
  - \* Wood wasp trapping (U.S. Forest Service)
  - \* Dragonfly surveys
  - \* Study of contaminant effects on frog development (UNH)
  - \* Owl surveys (NH Audubon)
  - \* Research on prescribed burns and mowing (UNH Graduate student)
- Educational Programs
  - \* Cub scout merit badge tour
  - \* UNH Video Services for educational films and television programs
  - \* UNH Fire Ecology class field trip
  - \* UNH Geology class field trip
  - \* UNH Wetlands Delineation class
  - \* Nashua Fish Hatchery education exhibit collecting fish and vegetation

**Research**

Refuge staff, graduate students, conservation organizations, and others have conducted numerous studies on the refuge. A sampling of those efforts follows. Additional information on these studies can be obtained from refuge headquarters.

*Great Bay National Wildlife Refuge Fish Survey Report (Brown 2008)*

In the fall of 1992, the Service’s Laconia Office of Fishery Assistance conducted a survey of fish present in the refuge’s three ponds. They conducted surveys at Upper Peverly, Lower Peverly, and Stubbs Ponds using an 18.0 foot long (5.5 m) electrofishing boat (boom-type with direct current). In 2007, they repeated the survey to determine if there were any significant changes in fish species composition and abundance.

*Forest Health Assessment of Great Bay National Wildlife Refuge (2007)*

In the summer and fall of 2006, the USDA Forest Service, Durham Field Office–Forest Health Protection staff conducted an assessment of the general overall health and condition of the refuge’s forested areas. Appendix H includes their final Forest Health Assessment report.

*Geological Assessment of Cores from the Great Bay National Wildlife Refuge (2007)*

In 2006, U.S. Geological Survey (Foley et al. 2007) sampled two wells on the refuge to analyze geological sources of arsenic and zinc in ground and surface waters.

*Estimating Egg Mass Abundance of Pool-breeding Amphibians (2003)*

In 2002 to 2003, a regional study used a dependent double-observer method to estimate numbers of wood frog and spotted salamander egg masses in three to four pools on the refuge. (Evan H. Campbell Grant et al. 2003).

*Investigation of Frog Abnormalities on National Wildlife Refuges in the Northeast U.S (2003)*

From 1997 to 2001, the Service conducted a regional study to determine any national wildlife refuges had sites with frequently observed frog abnormalities. The study evaluated if the prevalence of abnormalities at a site was consistent within a season and among years, as well as investigated possible causes for abnormalities.

*Field Metabolic Rate of Wild Turkeys in Winter (Coup and Perkins 1999)*

Coup and Perkins (1999) used the refuge as the primary study site to investigate the field metabolic rate of free-ranging eastern wild turkeys.

## Refuge Natural Resources

### Topography and Soil

The refuge's topography is typified by gently rolling coastal hills ranging in elevation from sea level to 100 feet above sea level. The refuge has a variety of soil types, mostly from marine and glacial parent materials. The most common soil type on the refuge is Boxford silt loam, and much of the rest of the refuge is sandy and silty loams. Table 2.8 describes the major soil types on Great Bay Refuge.

For more detailed information on the area's soils, visit the Web Soil Survey online at: <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm> (USDA-NRCS 1994; accessed November 2011). The Web Soil Survey application allows users to generate soil maps for locations throughout the United States, as well as read detailed soil descriptions.



Beaver pond on the refuge

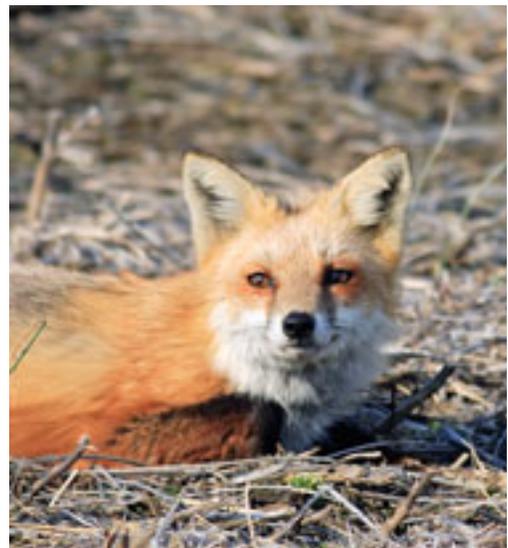
Greg Thompson/USFWS

**Table 2.8. Major Soil Types on Great Bay Refuge from the Soil Survey of Rockingham County (USDA-NRCS 1994)**

Soil Name	Soil Use and Vegetation	Soil Composition	Parent Material	Slope	Drainage
<b>Boxford</b>	Most areas are either forested or used for growing forage crops for livestock, silage corn, and vegetables. Some areas are used for urban structures. Dominant tree species are white pine and a mixture of northern hardwoods.	Silt loam	Marine	0 to 8 percent	Moderately well-drained
<b>Smoothed Udorthents</b>	Most areas are used for urban development, landfills, or left idle.	–	Anthropogenic	–	Not rated
<b>Pennichuck Channery</b>	Gently sloping areas are used for row crops, truck, farming, grassland, and orchards. Sloping areas are used as orchards, grassland, and woodland. Forested areas are mostly white pine, red oak, white oak, red maple, and sugar maple.	Very fine sandy loam	Glacial till	0 to 15 percent	Well drained
<b>Hoosic</b>	Most areas have been cleared and are used for pasture or to grow hay, corn, small grains, vegetable crops, and deciduous fruit. Forested areas contain sugar maple, oak and hickory species, and American beech.	Fine sandy loam	Glacial outwash	3 to 15 percent	Somewhat excessively drained
<b>Squamscott</b>	Most areas are forested. Principle trees are white pine and red maple. Some areas that are drained are in cropland.	Fine sandy loam	Marine	0 to 5 percent	Poorly drained

**Habitat Types and Associated Wildlife**

Despite its relatively small size, Great Bay Refuge supports a diversity of habitat types (table 2.9). The refuge has 2 acres of rocky shoreline, which is important to maintaining the health of the habitats of the Great Bay Estuary, including channel bottom, eelgrass meadows, mudflats, salt marsh, and rocky intertidal. The upland and freshwater habitats of the refuge include oak-hickory forest, shrublands, grasslands, forested and shrub wetlands, and impounded wetlands. The refuge is 60 percent upland forest or rocky upland, 18 percent grassland or shrubland, and 22 percent freshwater or saltwater wetland, including open water and forested wetlands.



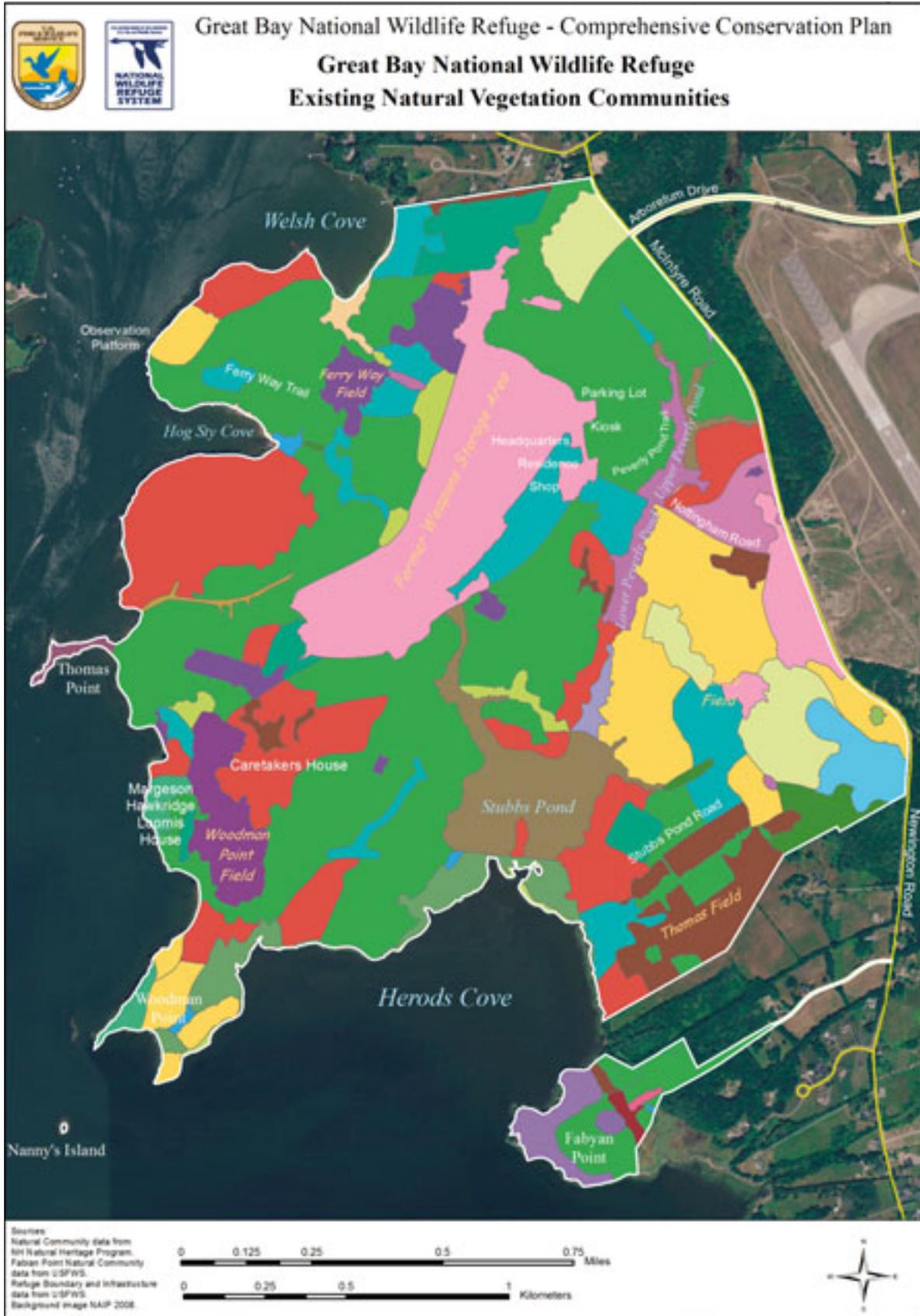
*Red fox*

Tim Williams

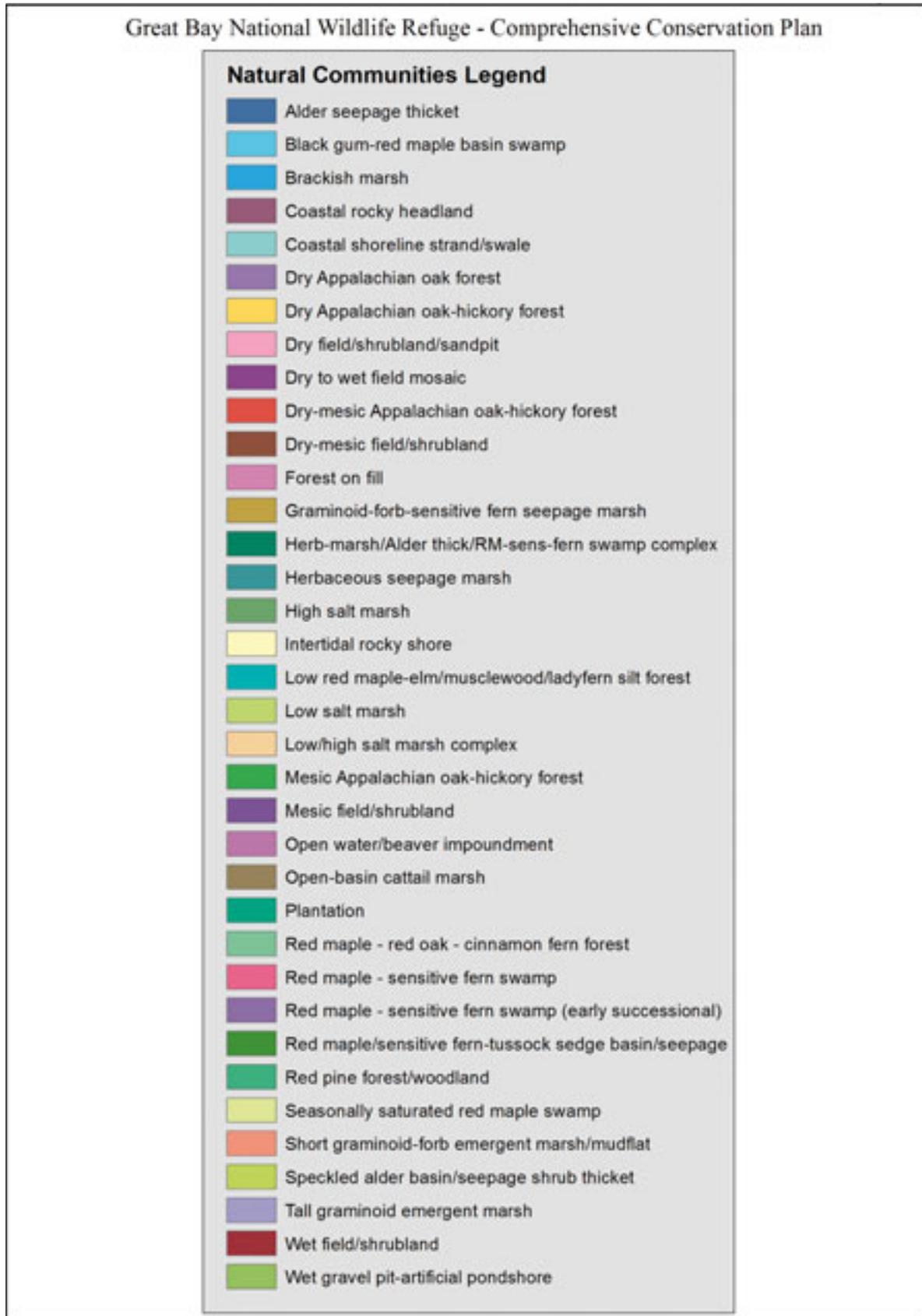
**Table 2.9. Natural Community Types and Associated Habitats on Great Bay Refuge.**

Habitat	Habitat Acres	Natural Community Type	Acres
Salt marsh	36	High salt marsh	23
		Low salt marsh	6
		Low/high salt marsh complex	5
		Brackish marsh	2
Rocky shoreline	2	Coastal rocky headland	2
Freshwater impoundments	62	Open-basin cattail marsh	45
		Open water/beaver impoundment	14
		Tall graminoid emergent marsh	3
Forested and scrub-shrub wetlands and vernal pools	149	Low red maple–elm/musclewood/ladyfern silt forest	69
		Seasonally saturated red maple swamp	38
		Black gum–red maple basin swamp	14
		Speckled alder basin/seepage shrub thicket	12
		Red maple–sensitive fern-tussock sedge basin/ seepage	12
		Graminoid-forb-sensitive fern seepage marsh	2
		Wet gravel pit-artificial pondshore	<1
Oak-hickory forest	659	Mesic Appalachian oak–hickory forest	375
		Dry mesic Appalachian oak–hickory forest	147
		Dry Appalachian oak-hickory forest	90
		Plantation	25
		Forest on fill	12
		Red pine forest woodland	8
		Dry-mesic field/shrubland; reverting to forest	2
		Dry-mesic field/shrubland	23
Shrubland	26	Mesic field/shrubland	3
Grassland	169	Dry field	95
		Dry to wet field mosaic	19
		Dry-mesic field	55
<b>TOTAL</b>			<b>1,103</b>

*\*Table summarized by refuge staff based on field visits by Sperduto (2000, 2010) and GIS analysis. Acres rounded up to nearest whole number.*



Legend for Map 2.3.



In 2000 and 2010, the New Hampshire Natural Heritage Bureau (NHB) identified and mapped natural community types and other cover types on the refuge (Sperduto 2000 and 2010) (map 2.3). Natural communities are recurring assemblages of plants found in particular physical environments that are distinguished by three characteristics: 1) a definite plant species composition; 2) a consistent physical structure (such as forest, shrubland, or grassland); and 3) a specific set of physical conditions (such as different combinations of soils, nutrients, drainage, and climate conditions). Most wildlife species do not select habitats on as fine a scale as natural community types. Therefore, we have combined some of the natural community types with broader wildlife habitat types. Both classifications are important to understanding and maintaining the refuge's biological diversity, integrity, and environmental health.

Exemplary natural communities are those that have been minimally impacted by humans, contain a species composition representative of the type, and have intact ecological processes that maintain these species. The NHB identified the following six “exemplary” natural communities on Great Bay Refuge (<http://www.nhdf.org/natural-heritage-and-habitats/>; accessed December 2011):

- Dry Appalachian oak–hickory forest
- Mesic Appalachian oak–hickory forest
- Coastal rocky headland
- Red maple–sensitive fern swamp
- Black gum–red maple basin swamp
- High salt marsh

## Estuarine Habitats

### Salt Marsh

Several areas of substantial salt marsh, totaling approximately 39 acres, occur along the refuge' shore, with the best developed occurring behind Woodman Point and Stubbs Pond. The low salt marsh is dominated by smooth cordgrass, while salt meadow cordgrass, spike grass, and black-grass are dominant in the high salt marsh. Small brackish marsh occur at the upland edge of salt marshes where drainages meet the bay, and are dominated by narrow-leaf cattail and sedge species. The NHB reported several rare plants in the refuge's salt marsh, including seaside mallow, a State-listed threatened species (NHNHB 2009). Estuarine communities are uncommon in New Hampshire because of the limited shoreline within the State and the intense development and disturbance near much of the coastal salt marsh.

In 1992, prior to refuge establishment, the town of Newington hired a contractor to spray the pesticide *Bacillus thuringensis* serotype *israelensis* (Bti) on marshes to control the extensive mosquito breeding occurring in areas of the marsh heavily impacted by humans. Beginning in 1996, in an effort to eliminate chemical application on the marshes and restore fish and wildlife habitat, the refuge initiated four open marsh water management (OMWM) projects. In total, 16.3 acres were completed at Herods Cove, 9.9 acres at Woodman Point, and 3.4 acres at Welch Cove.

OMWM objectives included elimination of invasive plants (e.g., *Phragmites*, cattail); restoration of native salt marsh vegetation, such as wigeongrass; and creation of refugia habitat for the mummichog minnow. This minnow is a predator of mosquito larvae and its presence could eliminate the need to spray Bti for mosquito control. Various techniques were used. Ditch plugs were constructed to block man made drainage ditches and create open water habitat. Pannes (beginning at 2 inches and gradually sloping to 24 inches in depth) were excavated to increase open water habitat and to facilitate wading bird access. Sumps (2-foot-deep depressions) were excavated within pannes to ensure minnow

survival during drought conditions. In some areas, shallow connector ditches were also excavated to allow minnow access between pannes.

### **Rocky Shoreline**

Woodman Point and Thomas Point support approximately 2 acres of southern New England coastal rocky headland, considered an unusual but exemplary community type by the NHB. The headlands have a largely natural character with narrow vegetation zones representing both estuarine and upland plant associations. The upland portion at Thomas Point is dominated by red cedar and some black oak, red oak, alders, bayberry, and common juniper. The salt marsh and rocky areas of the point support estuarine plants such as seaside goldenrod (NHNHB 1990).

Large red and white pines grow on the headlands, providing important perch and roost trees for bald eagles wintering on Great Bay. The refuge has suitable eagle nest sites, although it was not until this year that eagles have nested on Great Bay. Two red pine forests (approximately 4 acres each) are found by Woodman Point and west of the Margeson Estate. These pines are estimated to be about 150 years old and are natural communities disjunct from larger patches found primarily in the White Mountains region (Sperduto 2010).

The 0.25-acre Nannie Island off Woodman Point is the only island on Great Bay Refuge. A mallard pair occasionally nests on the island. Some invasive plants are present. The island was evaluated for tern nesting possibilities but was deemed not suitable due to its small size and susceptibility to predation and human disturbance.

### **Eelgrass and Shellfish Beds**

Two other regionally significant habitat types lie just off the refuge boundary in State waters: eelgrass beds and shellfish beds. Their protection is a priority amongst partners in the Great Bay Estuary. Refuge staff, as a partner in these protection efforts, conduct informal monitoring to evaluate if refuge management actions are impacting these habitats.

Eelgrass beds are an essential habitat in the Great Bay Estuary and the basis of an estuarine food chain, providing food for migrating and wintering waterfowl and habitat for juvenile fish and invertebrates. Eelgrass beds are particularly important to juvenile rainbow smelt, Atlantic silversides, nine-spined sticklebacks, alewife, and blueback herring. Eelgrass leaves slow water flow, filtering suspended sediments from the water column (Short et al. 1992a). A dramatic decline in eelgrass beds in 1989, to only 300 acres, was linked to an outbreak of the *Labryrinthula zosterae* slime mold, commonly called “wasting disease.” Eelgrass populations recovered from the disease but have been showing a slow steady decline since 1990 (PREP 1999). Reduced water clarity from suspended sediments, nutrient loading, and decreased filtering capacity may be contributing to eelgrass populations decline. This is an ongoing management issue in Great Bay (Short et al. 1992b). A significant eelgrass bed exists in Herods Cove, part of which is within the refuge boundary.

The Great Bay Estuary and its tributaries support 52 acres of oyster beds, over 2,500 acres of scattered clam flats, and significant areas with blue mussel beds, razor clams, and scallops. Softshell clams are an important food source for wintering black ducks. The estuarine habitat extending from Herods Cove to Nannie Island is an important nursery area for oysters and clams, supporting more than half of the spawning oyster population in the bay (PREP 2009).

**Freshwater Impoundments**

*Historical Uses*

The refuge has five freshwater impoundments: Lower Peverly Pond, Upper Peverly Pond, Stubbs Pond, and two small impoundments in the Weapons Storage Area and along Ferry Way Trail. Upper Peverly Pond (12 acres), Lower Peverly Pond (7 acres), and Stubbs Pond (44 acres) are interconnected by Peverly Brook and fed by springs and small tributaries. These impounded wetlands are part of the 907-acre Peverly Brook watershed.

Upper and Lower Peverly Ponds were constructed as a water supply for the city of Portsmouth around 1900. During 1956 to 1959, the dike between the two ponds was improved with a spillway and a new dam. At the same time, Lower Peverly Pond was dredged to provide a swimming area and the water control structure boards were raised 3 feet. Maps 2.4 through 2.6 are aerial photographs that show these changes to the freshwater impoundments from 1952 to 1998 (Public Archaeological Laboratory, 2010).

The Air Force used Upper Peverly Pond for boating and angling, and used Lower Peverly Pond as a recreational swimming pond. Stubbs Pond area was a salt marsh until it was diked for mosquito control in 1963. Several years later, the dike was raised to provide for a warm water fishery and the pond was named after General Stubbs. The Air Force managed vegetation in all three ponds to improve recreational fish habitat. They also stocked the three ponds with recreational fish (table 2.10). No stocking has occurred since the refuge was established in 1992. Table 2.17 provides a description of the current fisheries resources in these ponds.

Prior to 1980, the Air Force’s impoundment management generally consisted of herbicide application. Records indicate that Upper and Lower Peverly Ponds were treated with Diquat in 1966. Generally, management activities were not documented; however, a 1980 Fishery Management Plan by the Air Force stated that annual programs to control algae growth in all three ponds were implemented. The 1980 plan recommended minimizing the application of herbicides and suggested mechanical control instead. In 1979, 7 acres of Stubbs Pond were mechanically cleared. In the 1980s, plastic tarps were placed over weed growth in Stubbs Pond. It appears that the tarps were largely ineffective. During the 1980s, vegetation (documented as *Chara spp.*) was estimated to be covering 90 percent of the surface area of Stubbs Pond.

**Table 2.10. Fish Stocking During Air Force Management of Upper Peverly, Lower Peverly, and Stubbs Ponds**

Pond	Year Stocked	Species
Upper Peverly	1956	Rainbow and brook trout
	1965 and 1966	Largemouth bass
	1972	Crayfish
Lower Peverly Pond	1956	Rainbow and brook trout
	1965 and 1966	Largemouth bass
Stubbs Pond	1965 and 1966	Largemouth bass
	between 1971 and 1981	Alewife (stocked 4 times)
	1972	Crayfish

Source: Great Bay Refuge Fisheries Management Plan, 1994

