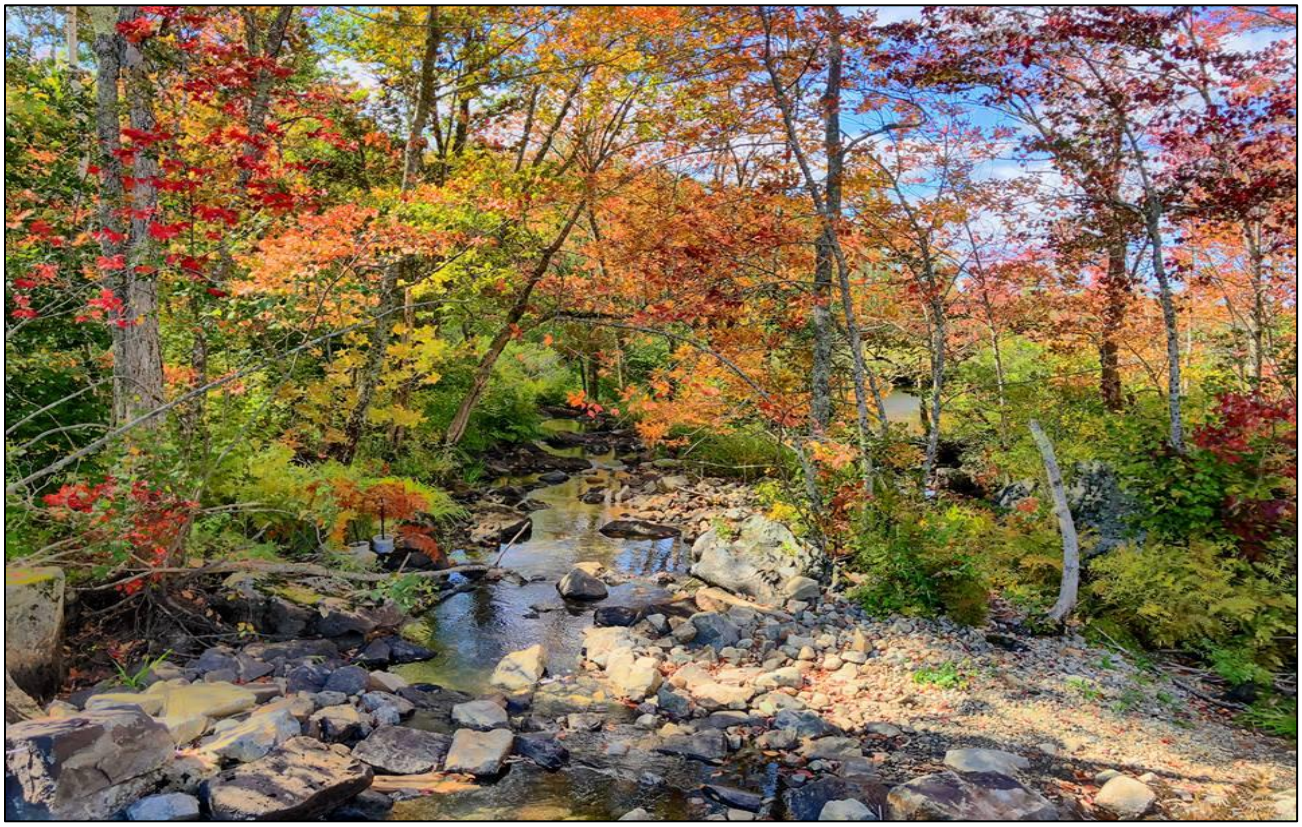
Habitat Management Plan
for
Moosehorn National Wildlife Refuge



August 2024

Habitat Management Plans (HMPs) are dynamic working documents that provide refuge managers with a decision-making process, a long-term vision for managing ecosystems, and ensure continuity and consistency for habitat management on refuges. HMPs include goals, objectives, and strategies needed to accomplish refuge purposes and achieve the refuge long-term vision. These plans detail program levels that are sometimes above current budget and resource allocations. As such, HMPs are primarily for strategic planning and program prioritization purposes. HMPs do not constitute a commitment for staffing increases, operational and maintenance increases, or funding for future land acquisition.

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for
Moosehorn National Wildlife Refuge

Prepared by: _____

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EXECUTIVE SUMMARY

This 15-year plan highlights the U.S. Fish and Wildlife Service's goal of actively managing Moosehorn National Wildlife Refuge (NWR) to improve habitat for fish and wildlife species. The refuge provides breeding and migratory habitat for a variety of bird species, and habitat essential for Brook Trout and other water-dependent species. The refuge encompasses more than 29,000 acres of wetland and forested upland habitat, including several rare plant communities.

Proposed active habitat management is designed to improve habitat characteristics essential for focal species. Focal species for the upland and lowland forests of Moosehorn NWR include Canada Warbler, Blackburnian Warbler, American Woodcock, Black-throated Blue Warbler, and American Black Duck.

Restoration of the refuge's freshwater stream and pond habitats is intended to benefit Eastern Brook Trout, American Eel, River Herring, and many other aquatic species. Currently, some of the refuge's forests are young and homogeneous, and the streams reveal a history of alteration. This plan outlines a combination of active and passive habitat management that aims to restore a diversity of forest successional stages, improve tree species composition, and continue improvements to stream function and connectivity. Management will also benefit numerous species that the Maine Department of Inland Fisheries and Wildlife have designated as species of conservation concern, such as Olive-sided Flycatcher, Eastern Whip-poor-will, and Silver Haired Bat.

Implementation of the management strategies outlined in this planning document will change the former management emphasis on early successional forests to an emphasis on restoring old growth forest, i.e., allowing most of the refuge's forests to grow to late successional stages. In addition, restoring aquatic connectivity will be a priority; some water control structures will be removed and replaced with arch culverts and rock weirs.

The refuge will continue to work with stakeholders, conservation partners, state agencies, and the forest industry. This plan identifies forest management strategies that may generate saleable wood products. Therefore, realizing our conservation goals will partially depend upon the expertise and availability of local contractors, robust timber markets, and operational flexibility.

Acknowledgements

Wildlife Biologists, Ray Brown, and Kirstin Underwood, assisted in writing and researching the content. Assistant Regional Biologist, Jennifer Casey, provided general guidance, contributed content, and assisted with updating the goals and objectives. Refuge Manager John Magera, reviewed and edited the final document. Noah Kahn, Conservation Planner, reviewed and edited drafts while Assistant Planner, Austin Rizzo drafted the Environmental Assessment, and Contractor, Melinda Knutson, provided technical editing and formatting.

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ACRONYMS AND ABBREVIATIONS

AHWP	Annual Habitat Work Plan
ACJV	Atlantic Coast Joint Venture
BCR	Bird Conservation Region
BIDEH	Biological Integrity, Diversity, and Environmental Health
DBH	Diameter at Breast Height (Forest Measure)
HMP	Habitat Management Plan
I&M	Inventory and Monitoring
IMP	Inventory and Monitoring Plan
LCC	Landscape Conservation Cooperatives
MDEP	Maine Department of Environmental Protection
MDIFW	Maine Department of Inland Fisheries and Wildlife
NABCI	North American Bird Conservation Initiative
NWR	National Wildlife Refuge
NWRS, Refuge System	National Wildlife Refuge System
PIF	Partners in Flight
QMD	Quadratic Mean Diameter (Forest Measure)
ROC / ROCs	Resources of Concern
SHC	Strategic Habitat Conservation
SLR	Sea Level Rise
USFWS, FWS	United States Fish and Wildlife Service
WPA	Waterfowl Production Area

1. INTRODUCTION

Scope and Rationale

Mission Mandates

Refuge Setting

Refuge Establishment Authorities and Purposes

Policies, Plans, and Guidance Relevant to Habitat Management

The U.S. Fish and Wildlife Service (FWS, USFWS) is obligated to manage habitats at Moosehorn National Wildlife Refuge (Moosehorn NWR, the refuge) in accordance with an approved plan that, when implemented, will help achieve refuge purposes, fulfill the National Wildlife Refuge System (Refuge System) mission, and comply with all applicable laws, regulations, and policies. Habitat Management Plans (HMP) are dynamic working documents that provide refuge managers and biologists with a description of current and desired habitats, a long-term vision for managing refuge habitats, and ensure continuity and consistency for habitat management. HMPs include goals, objectives, and strategies needed to fulfill establishment purposes and the refuge's vision. HMPs are primarily for strategic planning and prioritization purposes and are needed as refuge staff create Annual Habitat Work Plans that identify the specific management strategies needed to achieve objectives.

This HMP was developed in accordance with the FWS's HMP policy (620 FW 1) and current guidance for selection of priority biological resources and habitats, as well as for writing biological goals, objectives, and strategies (Taylor and Paveglio 2017, Powell and Casey 2019, Casey et al. 2020). Combined, these efforts provided clarity about the desired future conditions we aim to protect, enhance, and/or restore on the refuge over the next 15 years.

SCOPE AND RATIONALE

This HMP focuses on Moosehorn NWR, which is part of the Northern Maine NWR Complex (Complex). Separate HMPs will be prepared for the other refuges within the complex, including Aroostook NWR, Sunkhaze Meadows NWR, and Carlton Pond Waterfowl Production Area (WPA). The lifespan of an HMP is 15 years and HMPs are reviewed every 5 years. Adaptive management is employed to assess and modify management activities, as research, monitoring, and priorities evolve. Inventories and monitoring (I&M) that support the HMP will be identified in accordance with the Habitat and Wildlife Inventory and Monitoring chapter of the FWS Manual (701 FW 2) and documented in the refuge's Inventory and Monitoring Plan (IMP).

Appendix A of this HMP is the Environmental Assessment (EA) that evaluates the potential environmental effects associated with implementing this HMP (the proposed action). The EA complies with the National Environmental Policy Act of 1969 (NEPA; Public Law 91-190, 42 U.S.C. 4321 *et seq*.) in accordance with Council on Environmental Quality regulations (40 Code of Federal Regulations [CFR] 1500–1508) and U.S. Department of the Interior regulations and policies (Secretarial Order 3355; 43 CFR 46; 516 Departmental Manual 8; 550 FW 3).

MISSION MANDATES

U.S. Fish and Wildlife Service

The USFWS's mission is to "work with others to conserve, protect, and enhance fish, wildlife, plants and their habitats for the continuing benefit of the American people." A sampling of specific responsibilities includes enforcing Federal wildlife laws, managing migratory bird populations, restoring nationally significant fisheries, administering the Endangered Species Act (ESA), restoring wildlife habitat such as wetlands, and managing the National Wildlife Refuge System (Refuge System).

National Wildlife Refuge System

The mission of the Refuge System is to "Administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans."

The National Wildlife Refuge System Administration Act (1966) as amended by the National Wildlife Refuge System Improvement Act (1997) (16 U.S.C. 668dd–668ee; Public Law 105-57; Improvement Act) defines the Refuge System; directs the Secretary of the Interior to maintain the biological integrity, diversity, and environmental health (BIDEH) of the Refuge System; and authorizes the Secretary to permit use of a refuge provided such use is compatible with the major purposes for which the refuge was established. The Improvement Act offered a renewed vision for the Refuge System where:

- Wildlife comes first.
- Refuges are cornerstones for biodiversity and ecosystem-level conservation.
- Lands and waters of the Refuge System are biologically healthy.
- Refuge lands reflect national and international leadership in habitat management and wildlife conservation.

The Refuge System Improvement Act established the legitimacy and appropriateness of six priority public uses (hunting, fishing, wildlife observation and photography, environmental education, and interpretation) and created a formal process for determining resource conservation and public use compatibility. Although public uses are allowed within the Refuge System, to fulfill primary habitat function and refuge mandates it is often necessary that the FWS restrict access or activities that conflict with refuge establishment purposes or FWS stewardship responsibilities.

REFUGE SETTING

Moosehorn NWR was established in 1937 to protect migratory birds. Moosehorn NWR has two divisions, the 20,532-acre Baring Division, about 3 miles southwest of Calais, Maine and the 8,822-acre Edmunds Division, about 3 miles south of Dennysville, ME, directly adjacent to Dennys and Whiting Bays along U.S. Highway 1 (Figure 1-1). Within the refuge, 7,392 acres are designated as wilderness areas: 4,680 acres on the Baring Division and 2,712 on the Edmunds Division.

FIGURE 1-1 MAP OF MOOSEHORN NWR IN MAINE, SHOWING THE BARING AND EDMUNDS DIVISIONS.

Moosehorn NWR and the surrounding region are characterized by rolling hills, large rock outcrops, scattered boulders, and second-growth northern hardwood-conifer forest, and some pockets of pure spruce-fir. Numerous streams, beaver flowages, bogs, marshes, and scrub-shrub and forested wetlands are imbedded within the forested landscape. Moosehorn NWR contains over 4,500 acres of wetlands, including 25 functional impoundments or flowages. Over 50 dikes and water control structures were installed from the 1950s to the mid-1980s to benefit nesting and migrating waterfowl. The refuge has 18 miles of rocky shoreline along Dennys and Whiting Bays and 7 miles of shoreline on Meddybemps Lake. A small portion of the Baring Division on Meddybemps Lake is within the Dennys River watershed; the Dennys River is a high priority river for Atlantic Salmon recovery. Cobscook Bay supports the highest

density of nesting Bald Eagles in the northeastern United States (USA) and has been essential to the recovery of the Bald Eagle in the East.

REFUGE ESTABLISHMENT AUTHORITIES AND PURPOSES

National wildlife refuges are established under a variety of authorities. The purposes of a refuge are specified in, or derived from, the law, proclamation, executive order, agreement, public land order, donation document, or administrative memorandum establishing, authorizing, or expanding a refuge, refuge unit, or refuge subunit.

Moosehorn NWR was established on January 13, 1937, as a migratory bird refuge when the first parcel of land was acquired within the Baring Division. Though established for migratory birds, there was particular emphasis placed on the American Woodcock, and to this day, the refuge is highly regarded for its research and demonstration of habitat management techniques that benefit that species. On July 1, 1937, President Franklin D. Roosevelt signed an Executive Order (Executive Order 7650) expanding the Baring Division by an additional 16,000 acres. The 10,880-acre Edmunds Division boundary was similarly established on August 30, 1938 (Executive Order 7967). Not all lands within the approved boundaries have been acquired.

Moosehorn NWR has the following official purposes:

1. "...as a refuge and breeding ground for migratory birds and other wildlife: ..." *Executive Order 7650, dated July 1, 1937.*
2. "...for use as an inviolate sanctuary, or for any other management purpose, for migratory birds." *16 U.S.C. 715d (Migratory Bird Conservation Act).*
3. "...suitable for (1) incidental fish and wildlife-oriented recreational development, (2) the protection of natural resources, (3) the conservation of endangered species or threatened species..." *16 U.S.C. 460k-1 (Refuge Recreation Act).*
4. "...the conservation of the wetlands of the Nation in order to maintain the public benefits they provide and to help fulfill international obligations contained in various migratory bird treaties and conventions..." *16 U.S.C. 3901(b), 100 Stat. 3583 (Emergency Wetlands Resources Act of 1986).*
5. "... for the development, advancement, management, conservation, and protection of fish and wildlife resources ..." *16 U.S.C. § 742f (a) (4)* ... for the benefit of the United States Fish and Wildlife Service, in performing its activities and services. Such acceptance may be subject to the terms of any restrictive or affirmative covenant, or condition of servitude ... *16 U.S.C. § 742f (b) (1) (Fish and Wildlife Act of 1956).*
6. "... conservation, management, and restoration of the fish, wildlife, and plant resources and their habitats for the benefit of present and future generations of Americans..." *16 U.S.C. § 668dd (a) (2) (National Wildlife Refuge System Administration Act).*
7. "... wilderness areas ...shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness: …" *16 U.S.C. § 1131 (Wilderness Act).*

POLICIES, PLANS AND GUIDANCE RELEVANT TO HABITAT MANAGEMENT

Federal Policies

This section lists Federal policies, legal mandates, and regulations, as well as other resource plans and conservation initiatives that influenced the development of this HMP.

1) U.S. Fish and Wildlife Service
    a) Conserving the Future
    b) FWS Manual
        i) 602 FW 1, 2 (Refuge Planning Overview, Land Acquisition Planning)
        ii) 601 FW 3 (Biological Integrity, Diversity and Environmental Health)
        iii) 603 FW 1, 2 (Appropriate Refuge Uses and Compatibility)
        iv) 610 FW 1-3 (Wildlife Stewardship Policy, Wilderness Administration and Resource Stewardship, and Wilderness Stewardship Planning)
        v) 620 FW 1 (Habitat Management Plans)
    c) Strategic Habitat Conservation
2) Native American Laws and Policy
    a) Native American Graves Protection and Repatriation Act (NAGRA)
    b) Executive Order 13007
    c) Secretarial Order 3206
    d) Native American Policy
3) Historic Resources
    a) The Antiquities Act of 1906
    b) The Historic Sites, Buildings and Antiquities Act (Historic Sites Act)
    c) The Archaeological and Historic Preservation Act (AHPA)
    d) The National Historic Preservation Act of 1966 (NHPA)
    e) The Archaeological Resources Protection Act (ARPA)
4) Environmental Justice (Executive Order 12989)

Biological Integrity, Diversity, and Environmental Health (BIDEH) Policy

The policy is an additional directive for refuge managers to follow while achieving refuge purpose(s) and Refuge System mission. It provides for the consideration and protection of the broad spectrum of fish, wildlife, and habitat resources found on refuges and associated ecosystems. Further, it provides refuge managers with an evaluation process to analyze their refuge and recommend the best management direction to prevent further degradation of environmental conditions; and where appropriate and in concert with refuge purposes and Refuge System mission, restore lost or severely degraded components.

Trust Resources

The following have been designated as Trust Resources for the USFWS: threatened and endangered species, migratory birds, certain inter-jurisdictional fish and marine mammals, and wetlands. While the various state fish and wildlife agencies usually have management responsibility for resident wildlife species, the FWS has the responsibility for those that migrate across state and national boundaries. It also focuses on protecting, enhancing, and restoring wetland habitats.

Other Conservation Plans and Policies

Refuge habitat management advances the habitat and wildlife goals of the broader conservation community. In compiling the Resources of Concern (ROCs[1]-see chapter 3), several species' plans and comprehensive species lists were consulted (Table 1-1).

[1] All plant and/or animal species, species groups, or communities specifically identified in refuge purpose(s), Refuge System mission, or international, national, regional, state, or ecosystem conservation plans or acts.

TABLE 1-1. SPECIAL STATUS SPECIES LISTS AND PLANS CONSULTED DURING THE HMP PLANNING PROCESS

Plan Name	Extent	URL
USFWS At-Risk Species	National	*https://www.fws.gov/at-risk/*
Federal Threatened and Endangered Species	National	*https://www.fws.gov/endangered/*
USFWS Birds of Conservation Concern	National	*https://www.fws.gov/birds/management/managed-species/birds-of-conservation-concern.php*
American Woodcock Conservation Plan: A Summary of and Recommendations for Woodcock Conservation in North America	North America	*https://www.fws.gov/migratorybirds/pdf/surveys-and-data/Webless%20Migratory%20Game%20Birds/American%20Woodcock%20pdf%20files/WoodcockConservationPlan.pdf*
USFWS Northeast Region Fish and Aquatic Conservation Priority Species	USFWS Region 5	*https://www.fws.gov/northeast/fisheries/*
The Xerces Society for Invertebrate Conservation	National	*https://xerces.org/*
North American Bird Conservation Initiative (NABCI) State of North America's Birds, Species Assessment Summary and Watch List	National	*http://www.stateofthebirds.org/2016/resources/species-assessments/*
Partners in Flight Landbird Conservation Plan	National	*https://partnersinflight.org/resources/the-plan/*
North Atlantic Landscape Conservation Cooperative (LCC)	North Atlantic LCC	*https://www.fws.gov/northeast/test/northatlanticlcc/*
Terrestrial and Wetland Representative Species of the North Atlantic: Species Selected, Considered, and Associated Habitats	North Atlantic LCC	*https://ecos.fws.gov/ServCat/Reference/Profile/116699*
North American Bird Conservation Initiative (NABCI)	BCR 14: Atlantic Northern Forest	*https://nabci-us.org/ https://www.birdscanada.org/download/gislab/bcrdescriptions_original.pdf*
Northeast Partners in Amphibian and Reptile Conservation (NEPARC), Northeast Amphibian and Reptile Conservation Species of Regional Responsibility and Conservation Concern (2018; 2010)	Northeast Region	*http://www.northeastparc.org/products/pdfs/NEPARC_NEspeciesofresponsibility.pdf*
North American Waterfowl Management Plan	Atlantic Coast Joint Venture (ACJV)	*https://nawmp.org/*
North American Waterfowl Management Plan - Atlantic Coast Joint Venture Waterfowl Implementation Plan (2005)	ACJV	*https://acjv.org/planning/waterfowl-implementation-plan/*
North American Waterfowl Management Plan - Black Duck Joint Venture	ACJV	*https://acjv.org/american-black-duck-accomplishments-2020/*
Maine 2015-2025 Wildlife Action Plan	Maine	*https://www.maine.gov/ifw/fish-wildlife/wildlife/wildlife-action-plan/*

Plan Name	Extent	URL
Maine's List of Endangered and Threatened Species	Maine	*https://www.maine.gov/ifw/fish-wildlife/wildlife/endangered-threatened-species*

Refuge Plans

Refuge management decisions are guided by previously approved local management plans, including:

Moosehorn NWR Master Plan (1971): The Master Plan guides the long-range development of the refuge by identifying and integrating appropriate habitats, management strategies, program elements, and facilities which support the goals and objectives for which the refuge was established. This plan addresses the following topics: operational criteria, physical development, land status, cost estimate, and benefits.

Moosehorn NWR Wilderness Management Plan (1979): The Wilderness Management Plan provides a description of the wilderness area; a summary of management practices; information about public use, health, and safety; a map of research areas; and an overview of funding and personnel.

Moosehorn NWR Trapping Plan (1985): The Trapping Plan provides guidelines for the administration of furbearer trapping, including the development, maintenance, and enforcement of regulations and guidelines.

Moosehorn NWR Marsh and Water Management Plan (1986): The Marsh and Water Management Plan provides a marsh and water management framework that outlines maintenance, rehabilitation, and water level management.

Moosehorn NWR Forest Management Plans (1985, 1993): The Forest Management Plans provide summaries of the location and condition of forest stands, grouped into compartments, and outline management prescriptions for each compartment.

- *Edmunds Division Forest Management Plan (1993)*
- *Baring Division Forest Management Plan (1985)*

Moosehorn NWR Hunting Plan (2021): The Hunting Plan includes a Hunting Compatibility Determination, Environmental Assessment, a Section 7, and a Finding of No Significant Impact.

Northern Maine NWR Complex Inventory and Monitoring Plan (2021): The IMP provides a list of selected surveys that the refuge plans to implement over the next 5 years and ranks those surveys for the development of protocols.

2. NATURAL RESOURCES–HISTORY, STATUS, AND THREATS

Landscape Setting

Land Management History

Aquatic Resources and Water Quality

Climate

Air Quality

Geology and Soils

Vegetation

Wildlife

Rare Species

Invasive Species

LANDSCAPE SETTING

Moosehorn NWR consists of nearly 30,000 acres of federally protected lands in eastern Maine, part of the Gulf of Maine Watershed. The refuge's landscape is varied, with rolling hills, large ledge outcrops, streams, lakes, bogs, and marshes. A northern hardwood forest of aspen, maple, birch, spruce, and fir dominates the uplands. Scattered stands of majestic white pine are common. The Edmunds Division boasts several miles of rocky shoreline where tidal fluctuations of up to 24 feet occur twice a day.

THE LANDSCAPE SURROUNDING MOOSEHORN NWR (MILE BRIDGE ROAD).

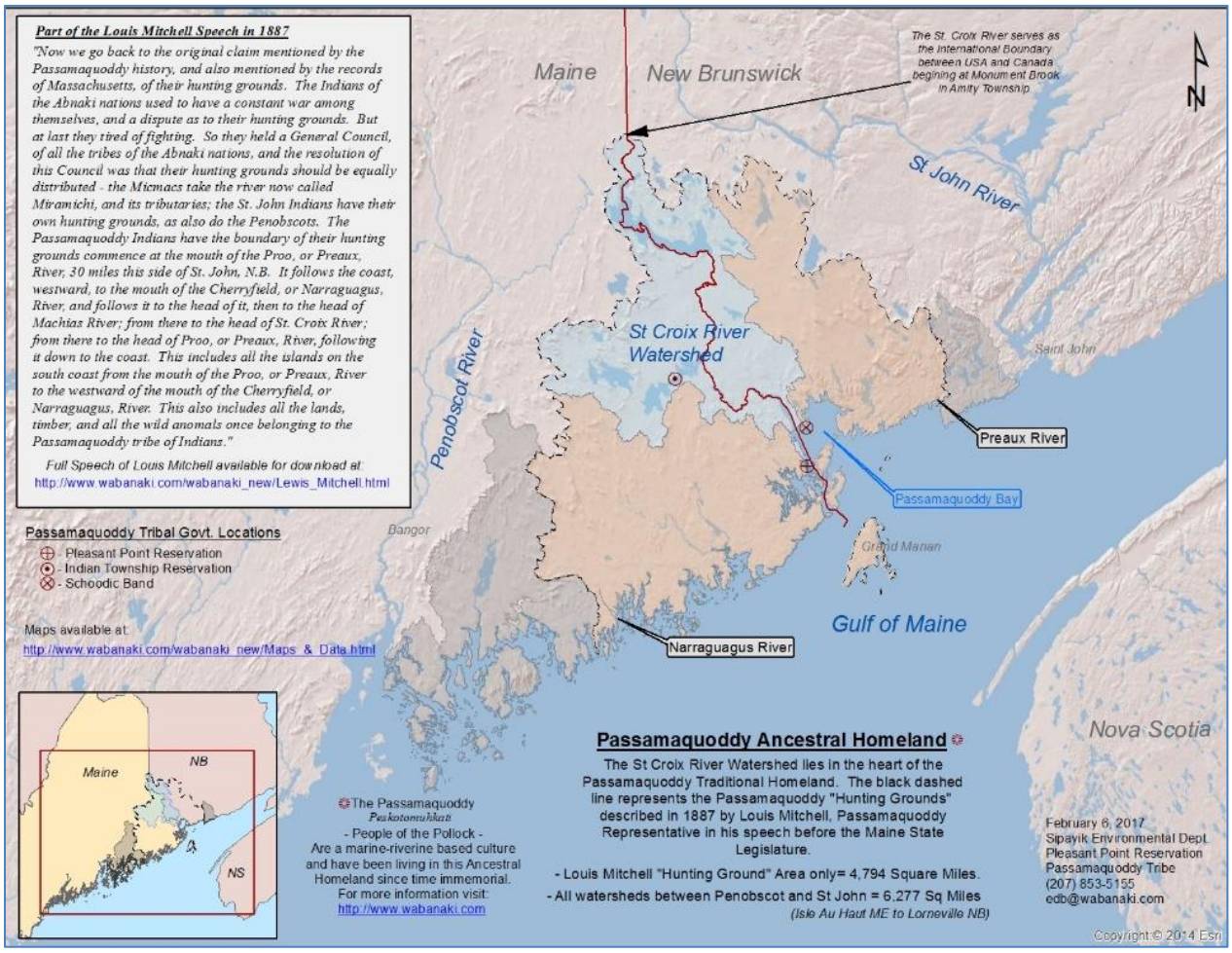
Approximately one-third of the refuge is designated as federal Wilderness, part of the National Wilderness Preservation System. These areas are managed to preserve their wild character for future generations. Habitat management is kept to a minimum to allow the areas to develop into old-growth climax forests.

LAND MANAGEMENT HISTORY

Archaeological evidence indicates that humans first settled in the St. Croix River Valley over 11,000 years ago, after the last glacier retreated northward. The Paleoindian hunter-gatherers were the first inhabitants of this region, and their presence has been documented through several artifacts (e.g., fluted projectile points) found around Calais and West Grand Lake (National Park Service (NPS) 1998). Although the paleontological record of this period is not well preserved in the Northeast, Bonnichsen et al. (1985) offer evidence that Paleoindians in the Northeast were hunting Caribou following the demise of other large mammals. Their conclusions are based, in part, on the prevalence of fluted points for hunting game that were uncovered at several archaeological sites across northern New England. These sites reveal variations in the types of tools created, indicating that distinct and separate groups of people initially colonized this region (Bonnichsen et al. 1985; Spiess et al. 1998; Spiess et al. 2012).

The Archaic Period represents the longest archaeological cultural period in the region, spanning around 6,500 years. This period, from 9,000 to 3,000 years ago, is not well documented in Maine. The available archaeological evidence suggests a change in the style and materials used in making tools over this period. Around 3,000 years ago humans began to first exploit coastal resources in Passamaquoddy Bay, including shellfish and fish (NPS 1998).

FIGURE 2-1. PASSAMAQUODDY ANCESTRAL HOMELAND. CREDIT: WABANAKI.COM.



The Ceramic period dates back 3,000 years in Maine and refers to the first evidence of pottery in the archaeological record. Many shell middens are known from this period around Passamaquoddy Bay. The sites typically have a midden near the water and archaeological evidence of a single-family wigwam dwelling that was built over a shallow depression farther back from the shore (NPS 1998).

At the start of the 16th century, the St. Croix River valley was home to the Passamaquoddy people (Figure 2-1). Throughout the 1500s, various European explorers landed on the Maine coast, although it was not until the early 1600s when they finally reached Passamaquoddy Bay. By the late 16th century, the Souriquois (later known as the Micmacs) were trading with the French and sailing along the Maine coast (NPS 1998).

In 1603, Pierre Dugua, Sieur de Mons, was granted exclusive rights to the "New France" (Canada) fur trade by King Henry IV. Samuel Champlain traveled on the expedition with Dugua in 1604 and

documented the establishment of a French colony on what is now St. Croix Island, near Calais, Maine. A year later, the settlement was moved to a more hospitable location, as St. Croix Island is bitterly cold in winter. This settlement appears to have been the first year-round settlement by Europeans north of Florida. Champlain later went on to found Quebec in 1608. By the 1620s, year-round trading posts and fishing piers were scattered along the Maine coast with more settlers and rapid changes underway (NPS 1998).

For much of the 18th century, the Passamaquoddy were not encroached upon by either English or French settlements as the European powers struggled for control over the region. Settlements (by people of European descent) began along the St. Croix River in the 1760s and Township No. 5 (later known as Calais) was permanently settled in 1779. Most of the early settlement was on the St. Andrews, New Brunswick, side of the river. Washington County was organized in 1789, as part of the Commonwealth of Massachusetts. A few hundred people were living in the vicinity by the end of the 1700s. The 1783 Treaty of Paris ended the American War of Independence and established the St. Croix River as the boundary between the United States and British North America. In 1794, Massachusetts signed a treaty with the Passamaquoddy that gave the Tribe reservations at Pleasant Point and Indian Township totaling 23,000 acres. In addition, the Passamaquoddy retained 15 islands in the St. Croix River (NPS 1998).

The population of Calais was 372 in 1810, a year after it was incorporated as a town. By 1840, the population had grown to 2,934. Calais continued to grow and became incorporated as a city in 1850. By 1900, the population of Calais had peaked at 7,655 (NPS 1998); the population in the 2020 census was 3,123 (U.S. Census Bureau 2020). The 1800s were a boom time of lumbering, new sawmills, shipbuilding, new roads, railroads, and quarrying. In 1853, more than 1,500 ships used Calais Harbor (NPS 1998). The large pine and spruce were felled to build the tall-masted ships. In 1883 alone, the timber products of Washington County were sold for $10,000,000 (USFWS 1971).

MOUNTAIN LION - PHOTO CREDIT: NATIONAL PARK SERVICE

The 1800s witnessed the demise of many forest wildlife species across New England due to loss of habitat (forest clearing, agriculture), bounty and market hunting, the millinery (hat-making) trade, and natural history specimen collecting (Foster et al. 2002). Mountain Lion, Gray Wolf, Elk, and Caribou were extirpated from New England by the mid-1800s or early 1900s. Humans caused the extinction of the

Heath Hen, Passenger Pigeon, Great Auk, Labrador Duck, and Sea Mink during the same period (DeGraaf and Yamasaki 2001, Foster et al. 2002). Hunting and egg collecting (for food and bait) and the millinery trade in the late 1800s greatly reduced populations of Arctic, Common, and Roseate Terns, as well as many other species of seabirds in the Gulf of Maine (Drury 1973). The Eskimo Curlew has not been seen in many decades. Two Gray Wolves were killed in Maine in 1993 and 1996, but their origin is unknown. A wild, resident wolf population has not been documented. (MDIFW 2003).

The historical record is unclear on the abundance and distribution of open land (e.g., grassland) plant and animal species in New England prior to European settlement (Foster and Motzkin 2003). Scattered large grasslands occurred in coastal areas including the 24,000-hectare Hempstead Plain on Long Island and the blueberry barrens along the Maine Coast (Askins 1997, Winne 1997). Smaller, more temporary forest openings were created when beavers abandoned their dams or by fires caused by lightning or humans (Askins 1997). Some grassland bird species, such as Horned Lark and Dickcissel, likely spread eastward from the Midwest as lands were cleared for agriculture. However, some grassland birds, including Bobolink, Eastern Meadowlark, and Upland Sandpiper, may have been present 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 dependent on thickets, brush-lands, and young forests increased (Litvaitis 2003). At the same time, intense logging, followed by intense fires and heavy rains, continued to set back succession of forest habitat and associated wildlife species in northern New England. The effects of forest fires are still evident today. Many barren mountaintops below 3,800 feet and hardwood-dominated hillsides are artifacts of early 20th century land use (Foss 1992, DeGraaf and Yamasaki 2001).

The young hardwood forests that emerged in the 1920s and 1930s after the old-field pine harvests provided high quality habitat for Ruffed Grouse and American Woodcock (DeGraaf and Yamasaki 2001). Succession of young forest into mature hardwood forests in the late 1900s caused a decline in the grouse and woodcock populations to approximately pre-settlement levels, and an increase in species that prefer more mature forests (Litvaitis 2003).

Eastern Coyotes were first sighted in northern Maine in the 1930s. Wild Turkeys, reintroduced to southern Maine in 1977, are flourishing well beyond their historic range. DeGraaf and Yamasaki (2001) reported three major trends in New England's wildlife: forest species are increasing (e.g., Bear, Beaver, Deer, Wild Turkey, Pileated Woodpecker), grassland and shrubland species are declining (e.g., Grasshopper Sparrow, Bobolink, Upland Sandpiper) and many southern species are expanding their ranges northward (e.g., Glossy Ibis, Willet, Carolina Wren, Northern Cardinal, Northern Mockingbird, Red-bellied Woodpecker, Tufted Titmouse, Virginia Opossum). A few species, such as the Common Raven, are expanding southward.

The number of fish species in Maine has increased over the past 50 years, mostly due to intentional or accidental introductions of nonnative fish as baitfish (e.g., minnows) or game fish (e.g., Largemouth and Smallmouth Bass, Rainbow Trout). The population trends of most native fish in the State are not well known, except for some game fish, such as Atlantic Salmon, which are the focus of intense management. Several factors have reduced native fish populations or degraded their habitat. Dam construction has slowed waters and prevented upstream migration for Atlantic Salmon, American Shad, alewife, and other diadromous fish. Although water quality has improved, pollutants such as DDT, dioxin, and mercury continue to negatively affect fish populations and their predators.

Human Population

The human population of *Washington County*, Maine was estimated at 31,553 in 2020. The main employment in recent years has been in the pulp and paper industry. The economy has been hurt by the loss of manufacturing jobs, including the loss of 150 jobs at the pulp and paper mill in Baileyville in 2007. The mill recovered many of those jobs in 2016 to 2018 with the addition of a new tissue paper production operation.

AQUATIC RESOURCES AND WATER QUALITY

Gulf of Maine Watershed

Moosehorn NWR lies within the Gulf of Maine Watershed that extends from eastern Quebec to Cape Cod in Massachusetts (Figure 2-2). The watershed has a land base of 69,115 square miles and a water surface area of 33,054 square miles. It encompasses the St. John, Penobscot, Kennebec, Androscoggin, and Saco Rivers, as well as the coastal drainages of Downeast Maine.

The Baring Division encompasses parts of three sub-watersheds. The western portion of the Baring Division drains into Meddybemps Lake, the headwaters of the Dennys River. The Dennys River flows south-southeast into Dennys Bay and then into Cobscook Bay. The northeastern portion of the Baring Division drains into the St. Croix River that in turn flows into Passamaquoddy Bay. The southern portion of the Division is in the Moosehorn Stream watershed that eventually drains into the Pennamaquan River and then into Cobscook Bay.

The Edmunds Division lies within the sub-watershed of Cobscook Bay. Hobart Stream forms most of the northerly boundary of this division west of U.S. Route 1. Two smaller streams, Crane Meadow Brook and Cranberry Lake Stream, flow north across the western portion of the Edmunds Division and drain into Hobart Stream. Hobart Stream flows into Dennys Bay at Duck Harbor. Crane Mill Stream and Burnt Cove Brook both empty into Whiting Bay. A small portion of the westerly part of the Edmunds Division drains into Rocky Lake, also known as Sunken Lake, which eventually drains into Orange Lake and River, and finally into Whiting Bay.

Overall, the watershed has generally good water clarity, chlorophyll-*a* levels, and dissolved oxygen levels. Nitrogen and phosphorus levels tend to be higher in the southern portion of the watershed, but lower in the northern part of the watershed where Moosehorn NWR is located (Liebman 2015).

FIGURE 2-2 GULF OF MAINE WATERSHED, SHOWING LOCATION OF MOOSEHORN NWR.

Threats

The major water quality concerns in the Gulf of Maine are eutrophication, degradation of coastal habitats, tidal restrictions, pathogens and biotoxins, and mercury (Gulf of Maine Council on the Marine

Environment 2016). Eutrophication (high levels of nutrients) can lead to excessive growth of algae and phytoplankton, which can cloud waters, kill aquatic vegetation, decrease dissolved oxygen levels, and degrade habitats for aquatic species (Liebman 2015). Indicators of eutrophication include high levels of nitrogen and phosphorus, high chlorophyll-*a* levels, poor water clarity, and low levels of dissolved oxygen.

The Gulf of Maine has been warming at a higher rate than any other water body (Runkle et. At, 2022). This could have multiple impacts on a variety of plant and animal species. Of concern to the refuge is the possible expansion of invasive species.

Mercury (Hg) is a heavy metal that occurs naturally in small amounts in oceans, rocks, and soil. Mercury is mined for use in generating electricity, manufacturing consumer products, and other industrial processes. Eventually, it is released into the water or air as a byproduct of combustion or through waste disposal (e.g., garbage incineration). Once emitted into the air, mercury can travel for days before deposition through dry particles, gases, rain, or snow. The impact of mercury on humans and the environment depends on whether it converts into the toxic form of methylmercury. This form of mercury, if consumed, bioaccumulates as it moves up the food chain, causing various reproductive and neurological problems for fish and wildlife. Mercury does not break down in the environment and is therefore considered a significant health threat to humans and wildlife.

Mercury levels in Maine's fish, Common Loons, and Bald Eagles are among the highest in North America. The high mercury levels are found in both aquatic and terrestrial environments (Shriver et al. 2006; Champoux et al. 2006). Since 1994, the Maine Bureau of Health has issued a statewide advisory recommending that pregnant women, women of childbearing age, and young children limit their consumption of certain species of fish (MDEP 2018). Researchers found a suite of "biological hotpots" where mercury concentrations are elevated in fish and wildlife, including one in Downeast Maine (Evers et. al 2007).

THE ST. CROIX RIVER. PHOTO CREDIT: MAINERIVERS.ORG

There are several reasons that mercury levels are high in Downeast Maine. First, the region is downwind of several major sources of atmospheric pollution. There is also a history of point source pollution in the area (e.g., tanneries). Several site-specific factors also enhance methylmercury production, including high acidity in waterbodies, abundant shoreline wetlands, and small lakes with large watersheds. In addition,

fluctuating water levels in wetland ecosystems tend to create more methylmercury than stable water levels (David Evers and Chris DeSorbo, Biodiversity Research Institute, personal communication).

St. Croix River

The St. Croix River watershed encompasses 1,649 square miles in Maine and New Brunswick. The population centers in the Maine portion of the watershed are Calais and Baileyville. The United States-Canada international border runs along the channel of the St. Croix River for its entire 110-mile length from the river's beginning north of East Grand Lake to the river's outlet into Passamaquoddy Bay. The St. Croix River has played an important role in the history of both countries, beginning prior to European settlement. The northern tip of Moosehorn NWR lies close to the St. Croix River. Current refuge ownership extends to the southerly limit of the railroad right-of-way of the former Maine Central Railroad Company. The railroad track was acquired by Domtar (now Woodland LLC, the pulp and tissue mill in Baileyville). A narrow, privately owned, riparian corridor of hardwoods lies between the railroad track and the St. Croix.

The St. Croix watershed's water quality is generally good. Based on water quality trends from 2007 to 2018 data from the USGS monitoring station in Milltown, New Brunswick (located between Calais and Baring, Maine) the river's water temperature and pH are generally rated good (IJC 2019). However, the river's dissolved oxygen levels were higher than desired and rated poor to fair. Samples from the Milltown monitoring station also occasionally exceed water quality standards for total phosphorus, zinc, and iron (IJC 2019). Water from the St. Croix River occasionally backs up into Magurrewock Marsh on the refuge. It is not known if this has had any negative impacts on refuge water quality (USFWS 1986).

Threats

There are several potential sources of water pollution in the area. The municipal wastewater treatment facility in Baileyville, ME, has occasional minor sanitary sewer overflows after heavy rainfall and snow melt episodes which could impact the St. Croix River's water quality (IJC 2019). Other wastewater treatment facilities along the St. Croix River are complying with DEP regulations. Effluent from the pulp and paper mill in Baileyville, ME, also flows into the St. Croix River and there have been several spills in recent years. Georgia Pacific was fined for a series of spills that occurred at the Baileyville mill between January 1995 and August 2000. Two of these spills were of Kemira UDA, a whitening agent used in the paper-making process. On February 13, 2002, a spill of 100,000 gallons of black liquor resulted in the mortality of Atlantic Salmon parr at the Milltown, New Brunswick, fish hatchery. Another spill occurred on July 1, 2004, when 3.5 million gallons of untreated waste was released into the St. Croix River (Maurice Mills, Moosehorn NWR, personal communication). The most recent reported spill occurred on August 10, 2018, with an estimated 530,000 gallons of partially treated wastewater into the St. Croix River when a pressurized wastewater pipe ruptured (Bangor Daily News, August 14, 2018). Researchers studying Smallmouth and Largemouth Bass found that intersex severity was significantly higher and the gonadosomatic index was lower in male bass at Moosehorn sampling locations situated downstream of the pulp mill and a wastewater treatment plant. This study suggests biological effects associated with proximity to these point sources (Iwanowicz et al. 2016).

Although the refuge does not include any land adjacent to the St. Croix River, Magurrewock Stream connects refuge impoundments with the river. During high water and flood events, such as the spring thaw or periods of heavy rain, water from the river backs up into the Magurrewock Marshes. Wildlife in the area can move freely between the river and refuge wetlands.

Cobscook Bay

Cobscook Bay is a complex of inlets, bays, tidal creeks, and rivers. The bay has approximately 97 miles of shoreline and experiences tidal fluctuations of up to 24 feet, the largest in the United States. As about half of the water in the bay is exchanged with each tidal cycle, huge expanses of mudflats and ice-free conditions are created (USFWS 1990).

Coastal Maine and Cobscook Bay in particular, support a biologically diverse and rich ecosystem. The Edmunds Division has more than 18 miles of rocky shoreline along Dennys and Whiting Bays in Cobscook Bay. Although the refuge has a relatively small portion of shoreline, it is a vital part of the Cobscook Bay ecosystem. The diversity and abundance of marine life in Cobscook Bay is a result of the tremendous tides bringing nutrient-rich water from the Gulf of Maine.

The bay is noted for its extraordinary natural productivity (Larsen 2004), diversity of plant and animal species, and importance to wintering American Black Ducks, nesting Bald Eagles, migrating shorebirds, and shellfish. Cobscook Bay is one of the most important areas in Maine for fall migrating shorebirds with these populations listed as highly imperiled or of high conservation concern (Clark and Niles 2000). Black-bellied Plover, Sanderling, Semipalmated Sandpiper, Least Sandpiper, Greater and Lesser Yellowlegs, and Short-billed Dowitcher are the most observed shorebirds. Shorebirds feed on the mudflats as they follow the tides in and out. Twice a day they spend high tide roosting on rocky shores or sand spits. Development has disturbed some of the roosting sites in Cobscook Bay.

COBSCOOK BAY STATE PARK, MAINE. PHOTO CREDIT: KRISNM FLICKR.COM

The strong tides of Cobscook Bay keep water open in winter, vital to wintering waterfowl along the Atlantic Flyway. A quarter of Maine's wintering Black Duck population is found in Cobscook Bay. The ducks follow the tide in, foraging on invertebrates in the intertidal rockweed and foraging on the mudflats as the tide recedes. Ox Cove and Bellier Cove in Denny's Bay are noted as important areas for Black Ducks within Cobscook Bay (Daigle 2001).

Up to 60 different marine animals and plants use rockweed at low tide. As the tide comes in, tiny air bladders along the rockweed stem and branches cause the plant to rise and sway with the current, creating

an undersea nursery for as many as 31 fish species. Juvenile Herring, Pollock, and Winter Flounder, among other fish species, use rockweed "forests" to escape from predators and feed on invertebrates. Common Eiders use rockweed as brood-rearing habitat, feeding on amphipods and periwinkles among the wrack (Daigle and Dow 2000). Loss of habitat, rockweed harvesting, and potential impacts from oil spills are major management concerns for Cobscook Bay.

Up to 25 percent of wintering American Black Ducks in Maine are found on the bay. Cobscook Bay supports the highest density of nesting Bald Eagles in the northeastern United States (MDIFW 2015). Until the late 1980s, traditional land use patterns and private land stewardship had maintained the unique ecological conditions in this region. Since then, family lands, woodlots, and farms are giving way to increasing coastline development (USFWS 1990, ACJV 2005).

Both the Maine Wildlife Action Plan and the ACJV consider Cobscook Bay an important focus area (MDIFW 2015). Cobscook Bay was also listed as a priority for protection in the Regional Concept Plan under the Emergency Wetlands Resources Act of 1986 (specifically the intertidal and subtidal habitats of Dennys and Whiting Bays) (USFWS 1990), and in the U.S. Environmental Protection Agency's Priority Wetlands of New England (USEPA 1987). The ACJV identified Cobscook Bay as the highest priority focus area for resource protection within Maine and it was the first project in Maine to be approved for a North American Wetlands Conservation Act (NAWCA) grant, received in 1992 (ACJV 2005). Since then, there have been several grants awarded to the MDIFW and Maine Coast Heritage Trust to conserve the productive habitat that Cobscook Bay provides.

Threats

Threats to Cobscook Bay include sea level rise, which will result in the loss or migration of saltmarsh and mudflats, increases in the numbers of invasive species such as the green crab, and new invasives becoming established, harvest of rockweed at unsustainable levels, residential development of uplands adjacent to sensitive coastal habitats that may result in pollution and wildlife disturbance (https://www.maine.gov/dacf/mnap/focusarea/cobscook_bay_focus_area.pdf).

Dennys River Watershed

The 86,400-acre Dennys River watershed drains portions of eight towns (Alexander, Baileyville, Baring, Charlotte, Cooper, Dennysville, and Meddybemps) and three townships (Edmunds, Marion, and Cathance Townships). The watershed's headwaters are located at Pleasant Lake in Alexander, Maine, at an elevation of 232 feet. Sixteenth Stream drains Pleasant Lake, flows easterly for approximately 3 miles through extensive wetlands and enters the western side of Meddybemps Lake. Bearce Lake, at an elevation of 214 feet and within Moosehorn NWR, drains westerly into Meddybemps Lake. Meddybemps Lake forms the headwaters of the Dennys River main stem and is regulated by a dam owned and operated by the Maine Bureau of Sea-Run Fisheries and Habitat since 1973. From the outlet, the river flows southeasterly for approximately 20 miles and is joined by several small streams and brooks along its course. At approximately 19 miles from the headwaters, its only major tributary, Cathance Stream, joins the river. From the confluence, the river flows less than a mile to the head of tide in Dennysville where it flows into Dennys Bay. Mixed deciduous-coniferous forest is the major land cover in the watershed. The major land uses in the watershed are recreation and logging (DRWC 2005).

In 2000, the National Marine Fisheries Service (NMFS) and the FWS officially listed the Atlantic Salmon populations in eight Maine rivers (Dennys, East Machias, Machias, Pleasant, Narraguagus, Ducktrap, and Sheepscot Rivers and Cove Brook) as federally endangered. The Dennys River historically produced

nearly 20 percent of the total U.S. sea-run Atlantic Salmon (DRWC 2005). In addition to supporting Atlantic Salmon, the Dennys River has a rich diversity of wildlife, diverse riverine and riparian plant communities, and long stretches of river without road crossings or camps.

Most of the rivers, streams, and lakes in the Dennys River watershed have good to outstanding water quality (DRWC 2005). In general, the watershed water temperatures and dissolved oxygen level are considered good. Additionally, the main stem of the Dennys River has high calcium levels which benefit salmon development and can help neutralize the effects of acidity.

Threats

Occasionally, portions of the watershed exceed water quality standards. For example, pH levels are sometimes very low (acidic) after stormwater and spring snowmelt episodes. During these episodes, aluminum in waterbodies may convert into toxic forms (DWRC 2005). Although the Dennys River main stem has low levels of *E. coli* bacteria, fecal coliform levels are above the limits for shell fishing in the watershed's estuarine areas. There are also elevated levels of polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), dioxins, and other trace elements and pesticides in the Dennys River, and, as a result, the State has issued a "*fish consumption advisory*" for the river.

Potential sources of pollution in the Dennys River watershed include nonpoint source contamination from road sands, salts, and junkyards, poor timber harvesting practices (e.g., harvesting during the spring, not following best management practices), septic systems, development, recreation, acidity, and the use of pesticides on agricultural fields (DRWC 2005). There is also a Superfund site located near the outlet of Meddybemps Lake. From 1946 to the early 1980s, this property was the location of the Eastern Surplus Company, a retailer of army surplus and salvage items. During an inspection in 1984, the MDEP noted chemical odors, leaking electrical transformers, hundreds of deteriorating drums and containers, compressed gas cylinders, 16,000 pounds of calcium carbide, and numerous areas of stained soil. Since then, MDEP and U.S. EPA have been working to cleanup and monitor the site.

Water Quality at Moosehorn NWR

According to the MDEP, the rivers and streams that flow through Moosehorn NWR generally have high water quality (Table 2.1).

TABLE 2-1. WATER QUALITY RANKINGS FOR RIVERS AND STREAMS ON MOOSEHORN NWR

River Name	**Ranking***
Cobscook Bay estuarine waters	Class SA (highest quality)
Hobart Stream	Class AA (highest quality)
Dennys River (Main stem and tributaries above the Bunker Hill Bridge)	Class AA (highest quality)
Dennys River (Bunker Hill Bridge to Tidewater)	Class B (high quality)
Moosehorn Stream	Class B (high quality)
St. Croix River	Class C (from Woodland Dam to Tidewater) (good quality)
Other Tributaries	Class B (high quality)

*Class B waters must be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; agriculture; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; navigation; and as habitat for fish and other aquatic life. The habitat must be characterized as unimpaired.

Class C waters must be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; agriculture; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; navigation; and as a habitat for fish and other aquatic life.

Class C waters must be of sufficient quality to support all species of fish indigenous to those waters and to maintain the structure and function of the resident biological community. The dissolved oxygen content of Class C water may not be less than 5 parts-per-million or 60 percent of saturation, whichever is higher, except that in identified salmonid spawning areas where water quality is sufficient to ensure spawning, egg incubation and survival of early life stages, that water quality sufficient for these purposes must be maintained. To provide additional protection for the growth of indigenous fish, the following standards apply (https://legislature.maine.gov/statutes/38/title38sec465.html, accessed 11/3/2023).

Threats

According to a 2020 Contaminant Assessment Process (CAP) report by FWS contamination staff, there are several potential sources of contamination on or near the refuge that may impact refuge water quality (USFWS 2020). Historically, there was a small-arms firing range along Young's Road used by refuge officers and other Federal, State, and local law enforcement agencies for training. In 2008, the refuge decommissioned this firing range and over 100 tons of lead-contaminated soil was removed and relocated to a licensed hazardous waste facility. Another firing range on the refuge near Hanson Pit Road, in use from 2006 to 2014, was also cleaned up in 2021, resulting in the removal of 1,200 pounds of lead fragments and 20.5 tons of contaminated soil.

Refuge Impoundments

Moosehorn once had 54 impoundments that were constructed to provide wetland habitat for waterfowl. Each impoundment, or flowage, had an earthen dike and some type of water control structure. The bulk of these impoundments were constructed in the mid- to late 1950s as part of the Accelerated Works Program, whose purpose was to build the road system and infrastructure of the refuge. Over time, some of the impoundments have lost their dikes. The impoundments within the designated Wilderness Area were not maintained and most washed out over time. The 5 impoundments along the Weir Road on the Edmunds Division were decommissioned by removing the water control structures, breaching the dikes, and grading the footprint of the impounded wetland to a state that approximated its condition prior to the 1950s.

In 2009, the refuge staff realized that some of the impoundments should be decommissioned over time because funding and staff to maintain them all was not feasible. A workshop was held in June of 2010 to discuss and decide on a long-term plan for the impoundments. Currently, the refuge plans to maintain 25 of the impoundments with stable dikes and functioning water controls.

Stream Crossings

In 2009 and 2010, staff from the refuge and the FWS's Maine Fishery Resources Office conducted a survey of 48 stream-road crossings on the refuge. For each stream-road crossing, the team assessed five aquatic connectivity factors that can negatively impact stream hydrology and aquatic species:

- The presence of a blocked inlet or beaver fence.
- The absence of substrate in the crossing structure.
- Water velocity or water depth that does not meet that of the stream.
- Inlet or outlet elevation issues.
- The overall stream constriction ratio.

Overall, the survey team found that many of the crossings on the refuge do not provide full aquatic connectivity. The most common issues with stream road crossings were lack of substrate, velocities or depths that did not match the rest of the stream, and high overall stream constriction ratios.

The summary report also listed several ways to improve aquatic connectivity on the refuge, including decommissioning crossings or replacing crossings with more appropriate open arch structures or wooden bridges. Replacing stream road crossings is important to refuge management because many of the refuge's crossings are in poor condition and may fail in the future. Of the 48 stream-road crossings surveyed, the survey team classified 28 (58%) as being at high risk for failure (Craig 2012).

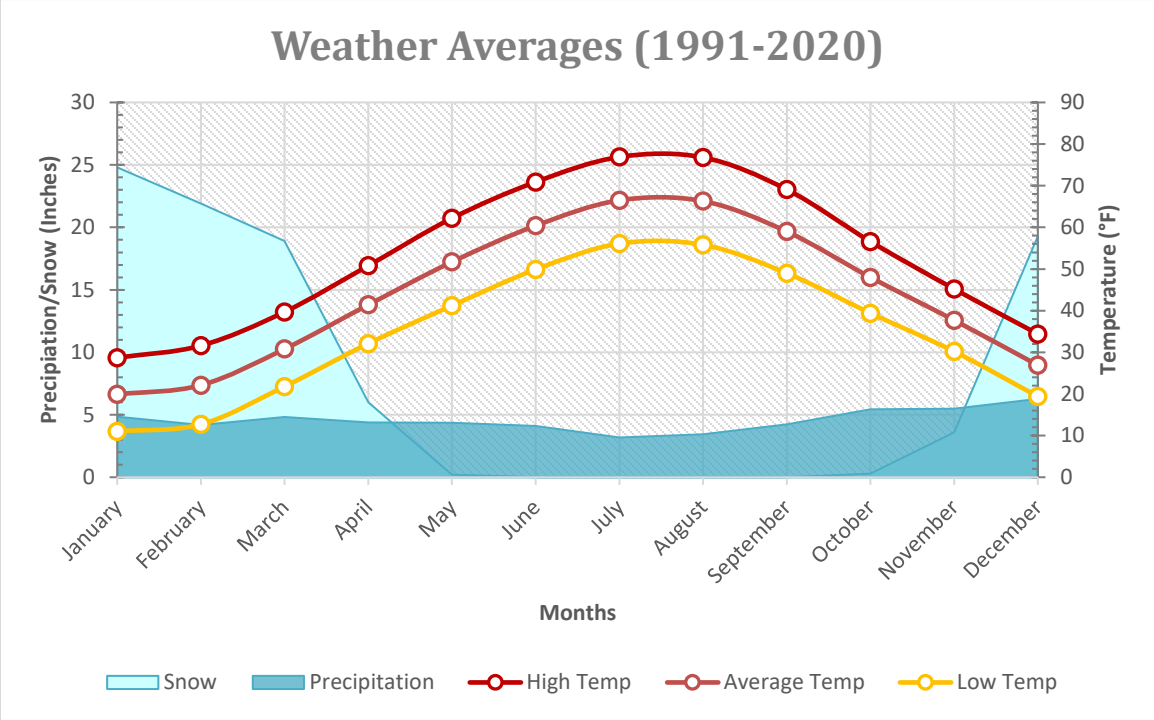
CLIMATE

Local Climate

The National Weather Service separates Maine into three distinct climate divisions - coastal, southern interior, and northern interior (Brandes 2001). The Edmunds Division lies in the coastal division that runs from Kittery, Maine, northeast to Eastport, Maine, and about 20 miles inland. The Baring Division lies within the Southern Interior Climate Region. The two divisions are in different climate zones, with different average temperatures. The average annual temperature at Baring Division is 43.5°F, while along the coast temperatures average 44°F. The Baring Division is within the U.S. Department of Agriculture plant hardiness zone 5A with an average annual minimum temperature of minus 15 to minus 20°F; Edmunds is in zone 5B with average annual minimum temperatures of minus 10 to minus 15° F. In general, the climate here is strongly influenced by the ocean. Prevalent sea breezes are one of the moderating influences on temperature. Average coastal temperatures tend to be cooler in summer and warmer in winter than in the interior of Maine. Fog is frequent in the late spring, early summer, and late fall.

Precipitation averages 45.7 inches annually and is well distributed throughout the year (Figure 2-3). Snowfall is generally heavy, averaging about 89 inches annually. Winter freeze-up generally extends from early December to mid-March (NOAA 2022).

FIGURE 2-3 CLIMATE NORMALS FOR ROBBINSTON, ME (NOAA, 2022).



Threats Due to Climate Change in the Northeastern U.S.

The U.S. Department of the Interior (DOI) issued Secretarial Order 3226 in January 2001, which required that all DOI Federal agencies with land management responsibilities consider potential climate change impacts as part of long-range planning endeavors. The most recent summary of climate by the U. S. Global Change Research Program was issued in 2018, including a section on the Northeast USA (Dupigny-Giroux et al. 2018).

General

The Northeast region is the most heavily forested and most densely populated region in the USA (Dupigny-Giroux et al. 2018).

Temperature

Since 2015, we have witnessed a remarkable escalation in the evidence for a changing planet. The National Aeronautics and Space Administration (NASA) reports that, on average worldwide, 18 of the 19 warmest years on record have occurred since 2001, and the five hottest years are the last 5 years (NASA 2019). Warming rates increase farther north and are highest over the Arctic and sub-Arctic. By 2035, and under both lower and higher modeling scenarios, the Northeast is projected to be more than 3.6°F (2°C) warmer on average than during the preindustrial era (Dupigny-Giroux et al. 2018). This would be the largest increase in the contiguous United States and would occur as much as two decades before global average temperatures reach a similar milestone.

Sea Level Rise

The Northeast has experienced some of the highest rates of sea level rise and ocean warming in the United States, and these exceptional increases relative to other regions are projected to continue through

the end of the century (Dupigny-Giroux et al. 2018). Various scenarios project that sea level rise could be as low as 2 feet and as high as 11 feet, on average, by the end of the century (Sweet et al. 2017). Storm flood heights in New York City, driven by hurricanes, increased by more than 3.9 feet (1.2 m) over the last 1,000 years (USGCRP 2018). Along the Mid-Atlantic coast (from Cape Hatteras, North Carolina, to Cape Cod, Massachusetts), several decades of tide gauge data (through 2009) document that sea level rise rates were three to four times higher than the global average rate (Dupigny-Giroux et al. 2018).

The region's sea level rise rates are increased by land subsidence (sinking)—largely due to vertical land movement related to the melting of glaciers from the last ice age—which leaves much of the land in this region sinking with respect to current sea level. Like a seesaw, the Northeast is moving up in elevation and the Mid-Atlantic is moving down (Boon et al. 2010).

Higher-than-average rates of sea level rise measured in the Northeast have also led to a 100 to 200 percent increase in high tide flooding in some places. Furthermore, the strongest storms are anticipated to become both more frequent and more intense in the future. Thirty-two percent of open-coast north and Mid-Atlantic beaches are predicted to overwash during an intense future nor'easter type storm, a number that increases to more than 80 percent during a Category 4 hurricane (Dupigny-Giroux et al. 2018). Coastal barrier dune systems will continue to migrate landward, experience reductions in width or height, and overwash and breach more frequently (Gutierrez 2009). Shorelines are projected to erode (move inland) at rates of at least 3.3 feet (1-m) per year along 30 percent of sandy beaches along the U.S. Atlantic coast (Gutierrez et al. 2014).

The Northeast region's high density of built environment sites and facilities suggest that urban centers in the Northeast are particularly vulnerable to climate shifts and extreme weather events. Built infrastructure along the coast, such as seawalls, bulkheads, and revetments, as well as natural barriers, such as coastal bluffs, limits landward erosion. An estimated 26 percent of the open ocean coast from Maine to Virginia contains engineering structures (Dupigny-Giroux et al. 2018). Rising sea levels and more-intense coastal storms may compel coastal property owners to armor their shorelines, which would limit the adaptive capacity of coastal habitats by exacerbating erosion and reducing important sources of sediments that could help in the adaptation of both beach and marsh habitats.

Precipitation

Precipitation in the region is projected to continue to increase, with more intense rain events. Monthly precipitation in the Northeast is projected to be about 1 inch greater for December through April by the end of the century (2070 to 2100), under a higher modeling scenario (Dupigny-Giroux et al. 2018). Peak stream flows are expected to be concentrated in the winter and early spring months and minimum streamflow will continue to be concentrated in the summer months (Turner and Wurster 2018). Minimum flows will be lower than in the recent past and the duration of the summer low flow period is expected to increase.

Precipitation patterns will increasingly be punctuated by boom-and-bust cycles of intense precipitation and periods of drought (Kays and Ward 2021; Miller 2019). Modeling scenarios predict that the frequency of severe, persistent drought (more than 6 months) will remain at rates observed in the recent past (Turner and Wurster 2018). Hotter, drier summers and periodic precipitation deficits are expected to increase the frequency of short- (1 to 3 months) and medium-term (3 to 6 months) droughts. Periods of drought will be most pronounced at the end of the growing season in the late summer and early fall.

Because much of the historical development of industry and commerce in New England occurred along rivers, canals, coasts, and other bodies of water, these areas often have a higher density of contaminated sites, waste management facilities, and petroleum storage facilities that are potentially vulnerable to flooding. As a result, increases in flood frequency or severity could increase the spread of contaminants into soils and waterways, resulting in increased risks to the health of nearby ecosystems, animals, and people - a set of phenomena well documented following Hurricane Sandy.

Fire Frequency

Drought conditions will exacerbate fire risks. Globally and nationally, the frequency and severity of wildfires have already increased due to climate change (Kunkel et al. 2020; USGCRP 2018). Catastrophic fires can occur in the Northeast; the multi-year drought that peaked in 1947 was associated with the infamous catastrophic wildfire in Acadia National Park. Droughts are among the greatest stressors on forest ecosystems and can often lead to secondary effects of insect and disease outbreaks on stressed trees, and increased fire risk (Clark et al. 2016).

Ecological Effects of Climate Change in the Northeastern U.S.

The North Atlantic Region is facing multiple threats, which will be amplified by climate change (Catriona and John 2000). Alpine, freshwater aquatic, and certain forest habitats are most at risk. Northern and high-elevation tree species such as spruce and fir are among the most vulnerable to climate change in the Northeast. Fragmentation of the forests may hinder the migration of some species. Warmer winters will likely contribute to earlier insect emergence and expansion in the geographic range and population size of important tree pests such as the Hemlock Woolly Adelgid, Emerald Ash Borer, Spongy (formerly Gypsy) Moth, and Southern Pine Beetle. The impacts of warming on forests and ecosystems during the summer and autumn are less well understood, including impacts on fruit ripening, insect phenology, and the start of bird migration and animal hibernation (Dupigny-Giroux 2018).

Urban development and wetland losses leave the rivers and streams and near-shore areas vulnerable to damage if the frequency and intensity of storms increase. Inputs of sediments, nutrients, and toxic chemicals to streams, lakes and estuaries might increase if precipitation increases. Accelerated sea-level rise could accelerate the loss of coastal wetlands. Highly productive marshes and fisheries are sensitive to changing environmental conditions, including shifts in temperature, ocean acidification, sea level, storm surge, flooding, and erosion. Estuaries are sensitive to changes in temperature, salinity, and nutrient loads, and could be adversely affected by projected climatic changes (Catriona and John 2000). Increases in air and water temperatures could allow aquatic and terrestrial invasive and pest species to expand their ranges, including Asian Shore Crabs, Japanese Honeysuckle, and Hemlock Wooly Adelgid (Whitman et al. 2010, MFS 2017a).

The warming temperatures in the region will benefit some species and push the ranges of other species farther north (Dupigny-Giroux et al. 2018; Karmalkar and Bradley 2017). Early emergence from winter dormancy followed by late frosts will stress trees and other vegetation and negatively affect fruit production that supports a wide variety of wildlife. Phenological mismatch results when interacting species change the timing of regularly repeated phases in their life cycles at different rates (Renner and Zohner 2018). These mismatches can threaten bird populations; for example, migratory bird species may begin nesting before the emergence of specific insects needed to feed their rapidly growing nestlings (Thorup et al. 2017). Birds that are dependent upon spruce–fir forests in the northern and mountainous parts of the region are already declining and especially vulnerable to future change.

Rodenhouse et al. (2008) suggests that the composition and abundance of neotropical and temperate migrants in the region could decline for 44 percent of the species and increase for 33 percent of others because of climate change.

Coastal Areas

The region's oceans and coasts support highly productive marshes, fisheries, and ecosystems that are sensitive to changing environmental conditions, including shifts in temperature, ocean acidification, sea level, storm surge, flooding, and erosion. Marshes and beaches serve as the first line of defense for coastal property and infrastructure in the face of storms. Regional marshes trap and store carbon and help to capture non-point source pollution before it enters seawater. Climate changes are already affecting coastal and marine ecosystems, posing increasing risks to people, traditions, infrastructure, and economies. These risks are exacerbated by increasing demands on these ecosystems to support human use and development.

When coupled with storm surges, sea level rise can pose severe risks of flooding. Rocky and heavily developed coasts have limited infiltration capacity to absorb these impacts; these low-elevation areas will become gradually inundated. Jetties and groins interrupt alongshore sediment supply; culverts and dams create tidal restrictions that can limit habitat suitability for fish communities. However, more dynamic environments, such as mainland and barrier beaches, bluffs, and coastal wetlands, have adapted over thousands of years in response to physical drivers. Such responses include erosion, overwashing, vertical accretion (increasing elevation due to sediment movement), flooding in response to storm events, and landward migration over the longer term as sea level has risen. Uplands, forests, and agricultural lands can provide transitional areas for these more dynamic settings, gradually converting to tidal marsh (Bindoff et al 2019).

Coastal managers along the Atlantic Coast are facing challenges associated with nutrient loading and runoff associated with shoreline development, and the encroachment of invasive species, such as common reed and perennial pepperweed, into the salt marshes. Climate change is likely to cause an even greater expansion of invasive species due to increased carbon dioxide levels and an increase in precipitation and runoff that could reduce salinity levels within the salt marsh (Minchinton 2002).

The ability of marshes in the region to respond to sea level-induced change varies by location, with some areas increasing in elevation, experiencing vegetation shifts, and/or expanding in extent while others are not. At lower rates of sea level rise, marsh health will depend heavily upon site-specific hydrologic, physical, and sediment supply conditions. Increasing sea level rise could alter the extent and composition of coastal marshes, shifting the dominance of high marsh to one co-dominated by high marsh and low marsh; the extent of overall salt marsh habitat would shrink as some marsh habitats are eroded (Giblin, pers. comm.). Coastal habitats such as marshes and beaches may be able to accommodate moderate changes in sea level, at least to some extent, by migrating inland or increasing in elevation through accretion. Under more extreme scenarios, marshes are unlikely to survive and, thus, would convert to open water (Kirwan et al. 2010).

Marshes and beaches provide critical habitat for a variety of migratory shorebirds, which when combined with nearshore seagrass and estuaries, serve as nurseries for many commercial marine species. Losses will result in a decrease in feeding, resting, and breeding habitat for many coastal fish and wildlife species (Frumhoff et al. 2007). Salt marshes and estuaries serve as endemic habitat for Saltmarsh Sparrows, stopover habitat for migrating waterfowl and shorebirds, and breeding habitat for Clapper Rails, Seaside Sparrows, and Common Terns (Erwin et al. 2006; Galbraith et al. 2014). As many as 53

percent of wetland bird species are projected to experience losses under all climate scenarios, with American Bittern, Common Loon, and Sora at particular risk (Rodenhouse et al. 2008), while populations of birds that depend on mud flats and open water such as waterfowl may increase (Erwin et al. 2006). The most severe losses of intertidal habitat for shorebirds are likely to occur where habitats are unable to move inland due to natural or human barriers. This region's narrow, low-profile barrier islands are likely to experience a high degree of storm-induced change, including overwash events and erosion caused by wind and waves.

As coastal areas face rising sea levels, storm surges, and temperature changes, human responses to such changes could lead to reduced adaptive capacity of these natural systems. For example, if warmer, drier summers contribute to shortages of water for human consumption, increased withdrawals upstream may reduce available water resources for fish and wildlife. (Bindoff et al 2019)

Climate Change Effects at Moosehorn NWR

The major predictions for Maine include increasing water and air temperatures, longer growing seasons, changes in precipitation and moisture levels, more frequent and intense storm events, rising sea levels, and more frequent pest and disease outbreaks. Temperatures are increasing statewide. The average annual temperature has increased 3.2 degrees Fahrenheit (°F) in the last 124 years, and the rate of warming has increased most notably since 1960 (Fernandez et al. 2020). The six warmest years on record have occurred since 1998. Indeed, the Northeast is warming faster than any other region in the U.S. and is projected to warm 5.4 °F when the rest of the world reaches 3.6 °F (Fernandez et al. 2020).

The largest air temperature increases are predicted to occur during the winter and across northern Maine. The increase in air temperatures will likely be less along the coast of Maine, including Washington County, where the refuge lies. The growing season (the period between the last frost and first frost) is already more than 2 weeks longer than it was in 1950, mostly due to later frosts in the fall (Fernandez et al. 2020).

Ocean surface temperatures are also projected to increase between 4 and 6 °F by 2100. Additionally, over the next 100 years, sea level is projected to rise at least 5 to 15 inches, with some estimates as high as 45 inches. As sea level rises, the severity and frequency of coastal flooding and erosion will likely also increase (Whitman et al. 2010).

Communities across the state are experiencing more heavy or “intense” precipitation events. A closer look at data from a weather station with a long record (Farmington) shows that most of the increased volume (30 percent over previous decades) was due to more 1-inch and 2-inch events, although large rain events of three or four inches have also become much more common relative to the past. The intensity of precipitation has increased, and it is raining more often. Farmington now experiences 10 to 15 more precipitation events in a year than during the previous century.

Precipitation levels are projected to increase approximately 2 to 14 percent in winter, spring, and fall, while summer precipitation levels are predicted to change very little. Winter precipitation is estimated to increase the most (8 to 16%) with a greater amount falling as rain. These changes in precipitation could also lead to shifts in hydrology if Maine’s rivers and streams transition from a snowmelt-dominated system with peak runoff in the spring to a rain-dominated system with peak runoff in the winter. The frequency and severity of heavy rainfall events is also estimated to increase, and the number of short-term droughts will also increase (Whitman et al. 2010). Increased frequency of droughts may also lead to a higher risk of wildfires (Kunkel et al. 2020; USGCRP 2018).

Global climate change models developed by the U.S. Forest Service Northern Research Station predict the range of spruce-fir forest cover types will recede substantially beyond the refuge boundaries to the north by 2100, and that beech-birch-maple and oak-hickory types will dominate this ecoregion (Iverson et al. 2008).

Uncertainty about the future effects of climate change requires refuge managers to use adaptive management to maintain healthy ecosystems (Inkley et al. 2004). Adaptive management involves improving or adjusting policies and practices based on the outcomes of monitoring or management activities and may result in changes to regulations, shifts in active habitat management, or changing management objectives. Some adaptive management recommendations are to manage for diverse and extreme weather conditions (e.g., drought and flood), maintain healthy, connected, genetically diverse wildlife populations, and protect coastal wetlands to accommodate sea level rise.

AIR QUALITY

Air pollution affects wildlife, vegetation, water, soil, and visibility. Some of these impacts can include ozone injury to vegetation, bioaccumulation of mercury in the food chain, acidification of water, increased carbon emissions, eutrophication of aquatic systems, and impaired visibility (Davis 2007). Carbon emissions and other greenhouse gases are recognized as contributing to global climate change.

The Clean Air Act (CAA) requires that the FWS protect and enhance air quality on refuges (USFWS 2021a). The CAA Amendments of 1977 established a program for the prevention of significant deterioration of air quality (EPA 2021). Certain wildernesses and National Parks established before August 1977, including the wilderness areas at Moosehorn NWR, were designated by the CAA as mandatory Class I areas and afforded the highest air quality protection. Under the CAA, the FWS has the responsibility to protect the air quality and AQRVs of the area from human-caused air pollution. AQRVs include vegetation, wildlife, soils, water quality, visibility, odor, and cultural and archaeological resources.

The refuge maintains an air quality-visibility monitoring station that is part of the Interagency Monitoring of Protected Visual Environments Network (*IMPROVE*). IMPROVE consists of 110 aerosol visibility monitoring sites selected to provide regionally representative coverage and data for 155 Class I federally protected areas. Refuge staff send samples weekly to Crocker Nuclear Laboratory at the University of California, Davis, for processing and analysis. Some of the pollutants measured include nitrates, sulfates, organics, soil, soot, and carbon. You can view a map of the national network of IMPROVE monitoring stations and download monitoring data online http://vista.cira.colostate.edu/Improve/improve-program/ (accessed January 2023). This program is important to the protection of natural resources and studying long-term trends in forest health. From 2004 to 2017, the refuge was also part of the Hazecam Network, which was established to monitor haze and visibility throughout the Northeast. As part of the program, the refuge maintained a high-resolution digital camera that took images every 15 minutes. These images were available for viewing via the Internet. The operation of the Hazecam at Moosehorn NWR was discontinued in 2017 because there were higher priority sites for the equipment. Since the paper mill in Baileyville switched their primary fuel source from oil to natural gas in 2012, the potential for violations of the visibility over the Class I airshed was greatly reduced.

One of the nearby, long-standing potential sources of regional air pollution is the paper mill in Baileyville (Woodland), ME. In 1989, the U.S. EPA formally attributed visibility impairment to the Georgia Pacific (now owned by International Grand Investment Corporation (IGIC)) paper mill in Baileyville. To

establish that the plume from a nearby paper mill was periodically impairing the visibility over the Baring Wilderness Area, a time-lapse video camera was installed in 1994. Although no enforcement action was taken, Georgia Pacific modified their process to improve visibility (Maurice Mills, Moosehorn NWR, personal communication). The time-lapse video camera was operational until 2004 when the Hazecam camera was installed.

The EPA developed an Air Quality Index (AQI) that incorporates their air quality standards for carbon monoxide, nitrogen dioxide, ozone, particulates, and sulfur dioxide. The AQI is used to measure the severity of air quality impacts to human health. Air quality in Washington County, ME is generally good.

GEOLOGY AND SOILS

Typical of this part of New England, the refuge has rolling terrain with elevations between sea level and 480 feet above mean sea level (MSL). The relief of the Baring Division ranges from 80 to 480 feet above MSL, while the Edmunds Division ranges from sea level to 200 feet above MSL. The rolling hills, large rock outcrops, and stream valleys reflect the impacts of the late Pleistocene Wisconsin glaciation. Glacial deposits of till, outwash, and marine clay underlie the local soils. Bedrock in the Edmunds Division is mostly volcanic rock and is exposed in less than 2 percent of the area. Sand, gravel, and clay were considered the only known mineral resources of economic value within the Edmunds Division. These materials are also plentiful in the surrounding area (Pease 1968).

A total of 54 different soil types occurs in the Baring Division and 44 have been identified at the Edmunds Division. Soils vary from sandy loam to clay and peat. The two major soil associations include Lyman-Scantic-Peru group and the Marlow-Peru-Lyman group. The deep, well-drained, stony Marlow soils and the shallow, well-drained Lyman soils occur on crests and upper slopes of ridges. Peru soils are deep, moderately well drained, and developed in very firm glacial till. The deep, poorly drained Scantic soils have a seasonal high-water table and are considered wetland soils (USFWS 1990).

A Soil Survey of the Washington County Area, Maine, provided by the Natural Resource Conservation Service can be found at the *Web Soil Survey* (NRCS 2008 [accessed January 2023]).

VEGETATION

The refuge is comprised of early-successional aspen-birch, pine and mixed forests, pure spruce-fir forests, second-growth northern hardwood-conifer forests, and salt marsh. Numerous streams, beaver flowages, bogs, impoundments, scrub-shrub and forested wetlands are imbedded within the largely forested landscape (Table 2-3). These habitats support a wide variety of migratory and breeding birds, interjurisdictional fishes, and resident wildlife.

TABLE 2-2. ACRES OF HABITAT TYPES ON THE BARING AND EDMUNDS DIVISIONS ON MOOSEHORN NWR.

Land Cover	Baring Division*	Baring Wilderness	Baring Total	Edmunds Division*	Edmunds Wilderness	Edmunds Total	Refuge Total
Spruce-Fir Forest	752	169	921	915	547	1,462	**2,383**
Pine – Hemlock Forest	3,214	2,115	5,329	1,073	919	1,992	**7,321**
Hardwood Forest	2,976	551	3,527	1,352	383	1,735	**5,262**
Aspen-Birch Woodland	3,512	378	3,890	645	378	1,023	**4,913**

Land Cover	Baring Division*	Baring Wilderness	Baring Total	Edmunds Division*	Edmunds Wilderness	Edmunds Total	Refuge Total
Fields, Grassland, Openings	237	0	237	120	0	120	**357**
Emergent Marsh - Open Water	2,101	515	2,616	355	156	511	**3,127**
Bog	150	50	200	32	96	128	**328**
Forested Wetlands	2,517	978	3,495	871	228	1,099	**4,594**
Coastal Habitat - Islands, Mudflats, Rocky Shore, and Saltmarsh				316		316	**316**
Unit Totals	**15,459**	**4,756**	**20,215**	**5,679**	**2,707**	**8,386**	**28,601**

*Acres that are not wilderness.

Forests

Maine is the most heavily forested state in the USA with 17.5 million acres (89% of its area) covered in forest (USDA 2020). Forest cover in Maine has remained relatively stable since the 1600s, except for a dramatic drop in the mid-1800s through early 1900s due to forest clearing, primarily for agriculture (Figure 2-4, Figure 2-5).

Historically, the forests of Maine were approximately 62 percent softwood and 38 percent hardwood. According to the 2019 FIA (*https://doi.org/10.2737/FS-RU-236-Tables*, accessed Feb 2023) the current distribution is 41 percent softwood and 59 percent hardwood cover. This is an artifact of mixed wood stands and recovery from past forest disturbances including the Spruce Budworm outbreak in the 1970s and 80s and subsequent harvests. Overall, Maine's forests are diverse. The most common tree species in the State are balsam fir (34.8 percent of all live trees greater than 1-inch diameter at breast [DBH] height); followed by red, white, and black spruce (14.4%); beech-birch-maple (13.7%); and red maple (12%). (USDA 2021) (*https://doi.org/10.2737/FS-RU-236-Tables*, accessed Feb 2023).

Most of Maine's forests are naturally regenerated stands that are managed extensively, with only about 2 percent the result of planting or other treatment. The current distribution of stand-diameter classes in Maine's forestland is 27 percent sapling (approximately 1 to 5 inches in DBH), 39 percent pole timber (approximately 5 to 10 inches DBH), 34 percent saw timber (greater than10 inches DBH). The number of acres state-wide of the various tree species has not changed significantly over the past two forest inventories. (USDA 2021) (*https://doi.org/10.2737/FS-RU-236-Tables*, accessed Feb 2023).

In the last 50 years, public ownership of Maine's forestland has increased, although it is still a small percentage of the total acreage. Eight-point three percent of the State's forestland is in public stewardship, primarily under the Maine Bureau of Parks and Lands. Since the 1970s, the ownership of private forestlands has shifted with a decline in industrial owners toward more investment firms, which generally have continued to manage their lands as industrial forest. Families and individuals are the primary land-ownership group in the southeast and south-central portions of Maine (McWilliams et al. 2005).

The forest composition at Moosehorn NWR is a mix of aspen-birch, spruce-fir, hemlock, northern hardwoods, and northern white cedar forest types (Cutko and Schlawin 2012). The two most common forest types in both the Baring Division and Edmunds Divisions are aspen-birch and spruce-fir forests (Table 2-3). The aspen-birch stands include a mix of quaking and bigtooth aspen, paper and gray birch, red maple, American beech, and black cherry. Common understory species include winterberry, bracken fern, sedges, beaked hazelnut, several species of *Viburnum*, and bunchberry. The conifers are dominated

by mixed and pure stands of spruce and balsam fir. Large mature white pines are scattered throughout the refuge (USFWS 1990).

WHITE PINE IN THE WILDERNESS AREA. PHOTO CREDIT: RAY BROWN, USFWS

The forests on Moosehorn NWR are generally older and contain larger trees than most forests in Maine (Table 2-5). The average age of forest stands in Maine is 60 years old and stands in Washington County tend to be even younger. However, on the refuge most stands are older, particularly in the two wilderness areas. For example, in the Moosehorn wilderness areas the average stand age is currently 136 years old, which is more than double the State average (Cutko and Schlawin 2012). There are some younger forest stands on the refuge, including areas previously managed for early successional forest habitat, as well as areas impacted by natural disturbances. Much of the mature balsam fir on the refuge was damaged during the Spruce Budworm outbreak in the late 1970s. In 1985, a wildfire burned about 600 acres in the mid-southern portion of the Edmunds Division, mostly in the wilderness area.

FIGURE 2-4 CURRENT LAND COVER MAP FOR THE BARING DIVISION, MOOSEHORN NWR.

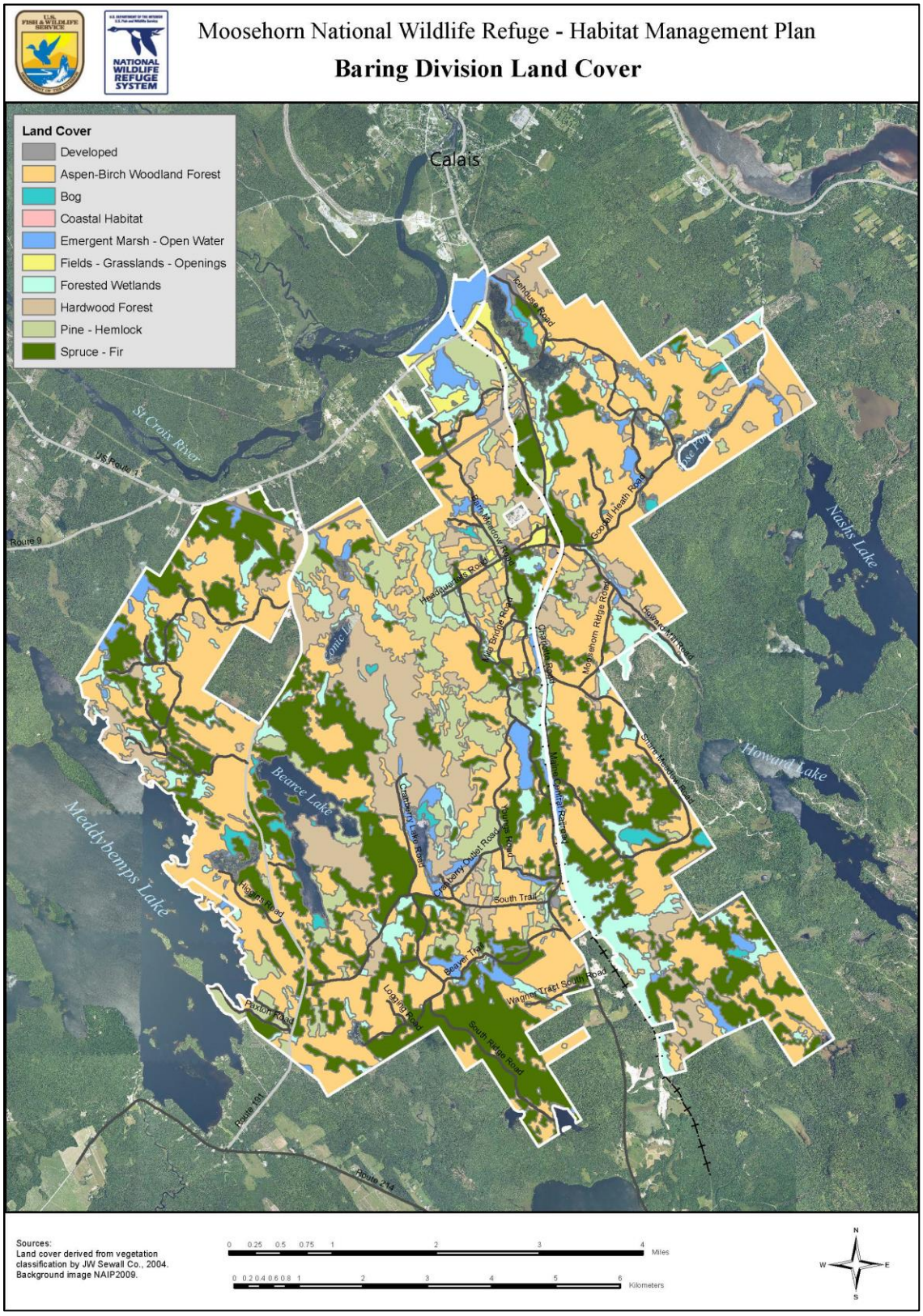
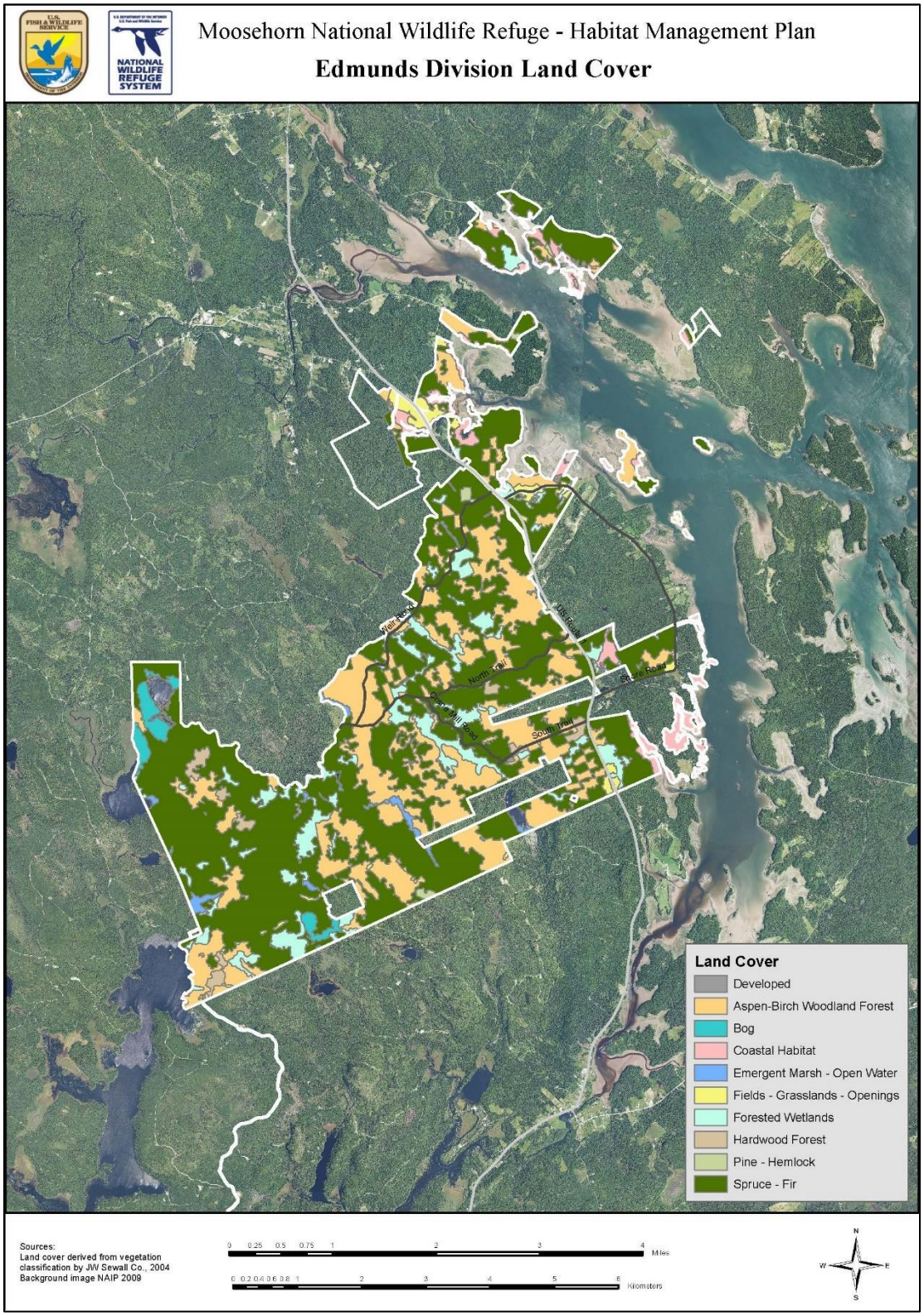


FIGURE 2-5 CURRENT LAND COVER MAP FOR THE EDMUNDS DIVISION, MOOSEHORN NWR.



The refuge began long-term management plans for the Baring Division (1976) and the Edmunds Division (1993) to increase forest diversity by altering tree age and species composition, with a primary focus of providing a shifting mosaic of young forest to benefit American Woodcock and other wildlife species that require early successional habitat. Timber harvesting and other forest management techniques are used on the refuge to benefit wildlife and not necessarily to maximize timber yields (USFWS 1985a). Active forest management under the Forest Management Plan was suspended in the winter of 2009 to 2010 to allow a full range of management options to be considered during planning efforts.

In general, the forest stands that were identified in the Forest Management Plan to be managed under even-aged management were managed to increase or maintain aspen and alder. Oak, an uncommon species on the refuge, was favored through selective cutting. Apple trees were released and pruned to promote fruit production. Active or potential wildlife den trees and other unique microhabitats were left uncut. Wilderness areas, research natural areas, and cedar swamps were allowed to undergo natural succession and disturbances (USFWS 1985a).

Threats

While Spruce Budworm has historically been the forest pest most impactful to the refuge's forests, new pests have either been detected or are anticipated. A population of emerald ash borer (*Agrilus planipennis*) has been established 30 miles northwest of Aroostook NWR. Kevin Dodds, an entomologist with the USDA, expects that the Southern Pine Beetle could potentially arrive at Moosehorn in the future. Both species could heavily and adversely impact Moosehorn's forests.

Hemlock Woolly Adelgid (*Adelges tsugae*) is found south along the Maine coast, and was recently found in New Brunswick, Canada. This pest could colonize Moosehorn NWR as early as next year. The Spongy Moth (*Lymantria dispar*, formerly Gypsy Moth) is a pest of significance in Maine. The moth is currently spreading north towards Aroostook NWR.

The following invasive forest insects have been found in Washington County, Maine:

- European Spruce Sawfly (*Gilpinia hercyniae)*
- Spongy Moth (*Lymantria dispar)*
- Beech Bark Scale Insect (*Cryptococcus fagisuga)*
- European Elm Bark Beetle (*Scolytus multistriatus)*
- Spruce Bud Scale (*Physokermes piceae)*
- Larch Sawfly (*Pristiphora erichsonii)*
- Mountain-ash Sawfly (*Pristiphora geniculate)*
- Norway Maple Aphid (*Periphyllus lyropictus)*
- Birch Leafminer (*Fenusa pusilla)*
- Birch Casebearer (*Coleophora serratella)*

The refuge continues to monitor for the presence of the following insects via trapping or ocular surveillance:

- Brown Spruce Longhorned Beetle (*Tetropium fuscum)*
- Black Fir Sawyer (Monochamus urussovii)
- Large Pine Weevil (*Hylobius abietis)*
- Japanese Pine Sawyer (*Monochamus alternatus)*
- Pine Shoot Beetle (*Tomicus piniperda)*
- Winter Moth (*Operophthera brumata)*
- Southern Pine Beetle (*Dendroctonus frontalis)*

- European Pine Shoot Moth *(Rhyacionia buollana)*
- Emerald Ash Borer (*Agrilus planipennis*)
- Hemlock Woolly Adelgid *(Adelges tsugae)*
- Elongate Hemlock Scale (*Fiorinia externa)*
- Asian Longhorned Beetle (*Anoplophora glabripennis)*
- Red Pine Scale (*Matsucoccus matsumarae)*
- Browntail Moth (*Euproctis chrysorrhoea)*

Early Successional Habitats

The refuge permanently maintains several blueberry fields and old fields as forest openings to provide habitat for American Woodcock and other species dependent on these types of habitats. Much of the merchantable timber on refuge lands was harvested prior to refuge establishment. The location of Moosehorn NWR in the heart of the Woodcock breeding grounds and along the major migration route, as well as the refuge establishment purpose and intent, provided the impetus for increasing Woodcock habitat through experimental habitat management. In the early days of the refuge, at least 100 clearings were made in strips and plots for Woodcock singing and feeding grounds. About 10 miles of secondary access roads were constructed through potential habitat to provide access to areas to be managed for American Woodcock habitat. Although some Woodcock will use roads as singing grounds that was not the primary purpose for the road construction.

Rare or Unique Natural Communities

From 2010 to 2011, the Maine Natural Areas Program (MNAP) conducted ecological inventories on the Baring and Edmunds Divisions of the refuge (Cutko and Schlawin 2012). The primary goals of their project were to:

- Identify rare plants and rare or exemplary natural communities.
- Identify areas of the refuge with invasive plant problems.
- Provide background information to help current and future refuge planning efforts.

During the inventory, MNAP confirmed and updated information on the presence of two rare plants on the refuge: showy lady’s slipper and Gaspé arrow grass.

A small population of showy lady’s slipper, a State-threatened species, occurs on the refuge’s Baring Division. Showy lady’s slipper is Maine’s largest lady’s slipper and occurs in constantly moist habitats. This species is considered rare (S3) in the State of Maine and globally widespread and abundant, but with cause for long-term concern (G4). This flower was originally discovered on the refuge in 2006 by refuge staff. This species is rare because of habitat destruction, collecting, and the scarcity of suitable habitat. The greatest threat to this species is from collecting (Cutko and Schlawin 2012).

SHOWY LADY'S SLIPPER. PHOTO CREDIT: MAURICE MILLS, USFWS

MNAP also confirmed the presence and condition of two previously documented "exemplary natural communities" on the refuge: a 145-acre white pine-mixed conifer forest on Bald Mountain in the Baring Wilderness Area and 75-acre spruce-northern hardwood forest in the Edmunds Wilderness Area. In addition, the refuge has 33 acres of open and wooded peat bogs and 319 acres of northern white cedar swamp, including a pure 10-acre stand in the Hobart Research Natural Area (RNA) on the Edmunds Division. Despite the small size and patchiness of some of these plant communities, they are important to the health, integrity, and biodiversity of the Northern Forest in Downeast Maine.

Additionally, MNAP determined that the entire Baring and Edmunds Wilderness Areas also meet the definition of "exemplary natural communities." MNAP has identified several locations of statewide significance that contain unusually rich concentrations of significant species and/or habitat features. The Edmunds Division includes at least one of these focal areas.

MNAP found that forest stands in the two wilderness areas are considerably older (mean age 136 years old) than most forest stands in Washington County, Maine. MNAP did not find any "exemplary" wetlands on the refuge, but did identify a small, fringing salt marsh along the refuge shoreline in Cobscook Bay, that was in excellent condition and is rare in the State of Maine (Cutko and Schlawin 2012).

Threats

Although MNAP found several invasive species on the refuge (e.g., reed canary grass, and glossy and common buckthorn), they did not consider any of these species to be a significant threat to the refuge's natural habitats at this time (Cutko and Schlawin 2012).

Wetlands

Wetlands comprise over 4,500 acres (15.6%) of the refuge. This includes frontage on parts of 10 natural lakes, beaver ponds, marshes, streams, brooks, and peatlands. There are 32 unmanaged natural marshes and bogs on the refuge. The open-water lakes range in size from 20 to 295 acres. The wetlands support a mix of open water and aquatic vegetation including sedges, pondweeds, and cattails. Alder and willow species are common wetland shrubs, while leatherleaf, sweet gale, and sphagnum moss are common in

refuge bogs. Forested wetlands are dominated by small black spruce, northern white cedar, red maple, cinnamon fern, sphagnum, and some tamarack.

Vernal Pools

Vernal pool communities are important to the health, integrity, and biodiversity of the Atlantic Northern Forest Region. Vernal pools are small (less than 1-acre), seasonal wetlands without perennial inlet or outlet streams and without permanent fish populations (Calhoun and deMaynadier 2004, 2007). Despite their small size and temporary nature, vernal pools are important because they have high productivity and support specialized wildlife species that are dependent upon vernal pools. The protection of vernal pools and adjacent upland habitat is particularly important because vernal pool obligate species require a large area of relatively undisturbed upland habitat for nesting, foraging, and dispersal. Also, the amphibian species that rely on vernal pools for breeding, such as Wood Frogs and Spotted Salamanders, are very sensitive to changes in water quality and quantity; certain types of habitat alteration; nutrient, chemical, and thermal pollution; and acidification of wetlands and forest habitats (Hine 1982, Klemens 1993).

The MDEP defines a vernal pool as "significant" if it meets at least one of the following two criteria:

- A State-listed threatened or endangered species, such as a Spotted Turtle, or a rare species, such as a Ribbon Snake, uses it to complete a critical part of its life history.
- There is a notable abundance of a specific, vernal pool-obligate wildlife species, such as Blue Spotted Salamander, Wood Frog, or Fairy Shrimp.

Vernal pools occur throughout the refuge's forests, both in areas of late and early successional forest. It is estimated that there are at least 3,000 vernal pools on the Baring Division alone (unpublished data, Evan Grant), although this estimate was made prior to the refuge's acquisition of several large tracts on the Baring Division and does not include the Edmunds Division, so it is probably an underestimate.

Impoundments

There were previously 54 impoundments on the refuge: 46 on the Baring Division and 8 on the Edmunds Division. Due to failure of water control structures and dikes and efforts to restore impounded areas back to natural hydrology, 28 impoundments currently have functional water control structures - 27 at Baring and 1 at Edmunds. Impoundment management has focused primarily on waterfowl production with upland management around wetlands aimed at supporting breeding Woodcock, foraging waterfowl (e.g., mowing dikes for Canada Geese), grassland breeding birds, and Bald Eagle and Osprey nesting structures.

As early as 1944, Howard L. Mendall (renowned researcher and educator; director of Maine Cooperative Wildlife Unit) began successful aquatic planting programs in the Magurrewock marsh impoundments. Many other wildlife food production efforts followed, such as upland food plantings from 1951 to 1964 and millet planting in 1969 and 1970 (Fefer 1977). Beavers hamper water management efforts in some impoundments by clogging the water control structures. In the 2000s the refuge installed "Beaver deceivers" at many impoundments to stop the beavers from clogging the structures, but most or all the Beaver deceivers were ineffective, have since deteriorated, and no longer function. Beavers are known to create excellent waterfowl habitat in some unmanaged wetlands on the refuge (USFWS 1986).

Brooks, Streams, and Riparian Areas

Moosehorn and Magurrewock Streams are the two largest stream drainages in the Baring Division. Hobart Stream is the primary drainage in the Edmunds Division. Moosehorn NWR has approximately 20 streams, 13 of which are large enough to support populations of native Brook Trout. Several important trout streams, including Cranberry Brook and Mahar Stream, depend on a continual outflow from refuge impoundments. Fish are an important part of the refuge's aquatic systems and are prey for Bald Eagle, Osprey, Common Loon, River Otter, and other wildlife. Several impoundments have fishways to facilitate fish passage including Middle Magurrewock, Upper Magurrewock, and Howard Mill.

STOCKING ATLANTIC SALMON INTO HOBART STREAM. PHOTO CREDIT: USFWS

Water control structures on the Popple and Vose Pond Outlet flowages previously blocked fish passage into Vose Pond. These structures were removed in 2016 and 2017, respectively, and replaced with open bottom arch culverts and rock weirs. Diadromous fish, such as Alewives and American Eels, are now able to make their way into Vose Pond. Hundreds of Alewife fry were seen in Vose Pond, just upstream of the arch culvert in 2019, evidence that adult fish spawned successfully for the first time in decades. In the past, Alewives from the Dennys River were released into Bearce and Cranberry Lakes on the Baring Division that do not have fishways (USFWS 1986). There were no official surveys but anglers on Bearce Lake reported improved fishing success and during a sampling effort for a different project, juvenile alewives were found in Cranberry Lake, indicating that at least some of the stocked fish spawned.

On October 30, 2006, staff from USFWS and the Maine Atlantic Salmon Commission (ASC) stocked approximately 200 adult Atlantic salmon from the Craig Brook National Fish Hatchery in Hobart Stream, near the North Trail parking lot at the beginning of the Wilderness Area. The salmon were excess brood stock from the Narraguagus, Pleasant, and Dennys River populations.

The purpose of the stocking was (1) to experimentally introduce adult Atlantic salmon to a stream to evaluate the reproductive performance of hatchery reared Atlantic salmon, and (2) to re-introduce salmon to Hobart Stream, which historically contained Atlantic salmon. The salmon did successfully spawn based on redd counts in the fall and sampling via electrofishing the following summer. Juvenile fish were found

downstream of the stocking site to the head of tide. No fish were found above the ledge falls, a short distance upstream of the release site.

Additional adult salmon (excess brood stock) were released into Hobart Stream in October 2007, 2008, and 2009. Spring 2009 was the first year that the offspring of adult releases were expected to emigrate as smolts. Staff from Maine ASC deployed a trap to catch out-migrating smolts to (1) obtain genetic samples from smolts for parentage analysis; (2) obtain a quantitative estimate of the emigrating smolt population; and (3) determine the efficacy of using an alternative smolt trap to sample smolt emigration in a small stream. A total of 14 smolts were captured and released upstream of the trap. Only 1 smolt was recaptured so no population estimate could be made.

The experiment confirmed that hatchery raised fish could successfully spawn in a stream that was different than their origin and that at least some juvenile salmon survived to leave Hobart Steam as smolts. Due to high water and other factors the smolt trapping was delayed so it is unknown if the number captured reflects the actual numbers of smolts produced. Some additional monitoring took place after the final release; the last year of smolt trapping was in 2011.

The refuge assumes water rights for all waters within its boundaries, except Vose Pond. Cranberry, Bearce, and Conic Lakes were deeded to the FWS by the State of Maine. The refuge obtained flowage easements from private landowners adjacent to Howard Mill Flowage at Baring, Burnt Cove Brook, and Hobart Lake at Edmunds. An agreement with Maine Central Railroad states that at Lower Barn Meadow, the water level will be kept below the top of the existing concrete water control structure (USFWS 1986). The 7 miles of shoreline on Meddybemps Lake within the refuge provide a critical undeveloped upland buffer to one of the largest freshwater lakes in the region.

The riparian areas adjacent to waterbodies and unforested wetlands often have high species richness and dynamic and complex biophysical processes. Riparian areas along streams and brooks provide important natural structures including large nest and roost trees for Eagles and Osprey and cavity trees for Wood Ducks, Hooded Mergansers, and songbirds. Riparian areas on the refuge usually contain a mix of native shrubs including alder, elderberry, dogwood, and viburnum that provide food and cover for nesting and migrating songbirds.

Rocky Shore

Coastal Maine, and Cobscook Bay in particular, support a biologically rich ecosystem. The Edmunds Division has more than 18 miles of rocky shoreline along Dennys and Whiting Bays in Cobscook Bay with tidal fluctuations up to 24 feet twice a day. Although the refuge has a relatively small portion of shoreline, it is a vitally important component of the Cobscook Bay ecosystem. The diversity and abundance of marine life in Cobscook Bay is a result of the tremendous tides bringing in nutrient rich water from the Gulf of Maine.

Cobscook Bay is one of the most important areas in Maine for fall migrating shorebirds; some of these populations are of high conservation concern (Clark and Niles 2000). Black-Bellied Plover, Sanderling, Semipalmated Sandpiper, Least Sandpiper, Greater and Lesser Yellowlegs, and Short-Billed Dowitcher are the most observed shorebirds. Shorebirds feed on the mudflats as they follow the tides in and out. Twice a day they spend high tide roosting on rocky shores or sand spits. Development has disturbed some of the roosting sites in Cobscook Bay.

The strong tides of Cobscook Bay keep water open in winter, vital to wintering waterfowl along the Atlantic Flyway. A quarter of Maine's wintering Black Duck population is found in Cobscook Bay. The ducks follow the tide in, foraging on invertebrates in the intertidal rockweed and the mudflats as the tide recedes. Ox Cove and Bellier Cover in Denny's Bay are noted as important areas for Black Ducks within Cobscook Bay (Daigle 2001).

Threats

Loss of habitat, rockweed harvesting, and potential impacts from oil spills are major management concerns for Cobscook Bay.

Rockweed (*Ascophyllum nodosum*) is a species of brown algae or seaweed that is found along the New England coast. Up to 60 different marine animals and plants use rockweed at low tide. As the tide comes in, tiny air bladders along the rockweed stem and branches cause the plant to rise and sway with the current, creating an undersea nursery for as many as 31 fish species. Juvenile Herring, Pollock, and Winter Flounder, among other fish species, use rockweed "forests" to escape from predators and feed on invertebrates. Common Eiders use rockweed as brood-rearing habitat, feeding on amphipods and periwinkles among the wrack (Daigle and Dow 2000).

Rockweed is harvested for a variety of commercial uses. As a packing material for Lobsters or marine bait worms, it provides needed moisture to live organisms during shipping. Rockweed is added directly to gardens as fertilizer and mulch. With processing, it becomes a nutritional additive, providing vitamins and trace elements for pet and livestock feed. Chemical extraction removes a compound called alginate that is used as a thickening agent in food, cosmetics, and some paints.

Rockweed harvest is not allowed on the refuge. In March 2019, Maine's highest court ruled that rockweed in the intertidal zone is not public property (Bangor Daily News, March 28, 2019). Based on 50 CFR 27.51, all the refuges in Maine consider the harvest of rockweed to be an illegal activity when it occurs within the refuge-owned intertidal zone. However, enforcing the prohibition of rockweed harvest on the refuge is a challenge.

The Moosehorn Wilderness Area

The Wilderness Act of 1964 defines a wilderness area as "an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain." The Wilderness Act's purpose is to preserve and protect the natural ecosystems and wild areas and provide opportunities for solitude and retrospective or primitive recreation.

The Wilderness Act further requires that every roadless island and roadless area of 5,000 acres or greater within the Refuge System be studied for potential designation as a wilderness area. In the 1960s, the FWS evaluated both refuge divisions for potential designation as wilderness (USFWS 1971). On October 23, 1970, Congress designated a 2,712-acre portion of the Edmunds Division, including the Birch Islands (6 acres in size) in Whiting Bay, as wilderness. This was followed on January 3, 1975, with the designation of 4,680 acres on the Baring Division as a wilderness area (USFWS 1979). Collectively, these 7,392 acres are known as the Moosehorn Wilderness (Table 2-6; Figure 2-6). These wilderness areas provide an outdoor laboratory for study of the natural processes of ecological succession and are managed according to the following rules:

- No mechanized equipment or vehicles, including snowmobiles and outboard motors.
- Nonmotorized boats are permitted on Bearce Lake and Conic Lake.

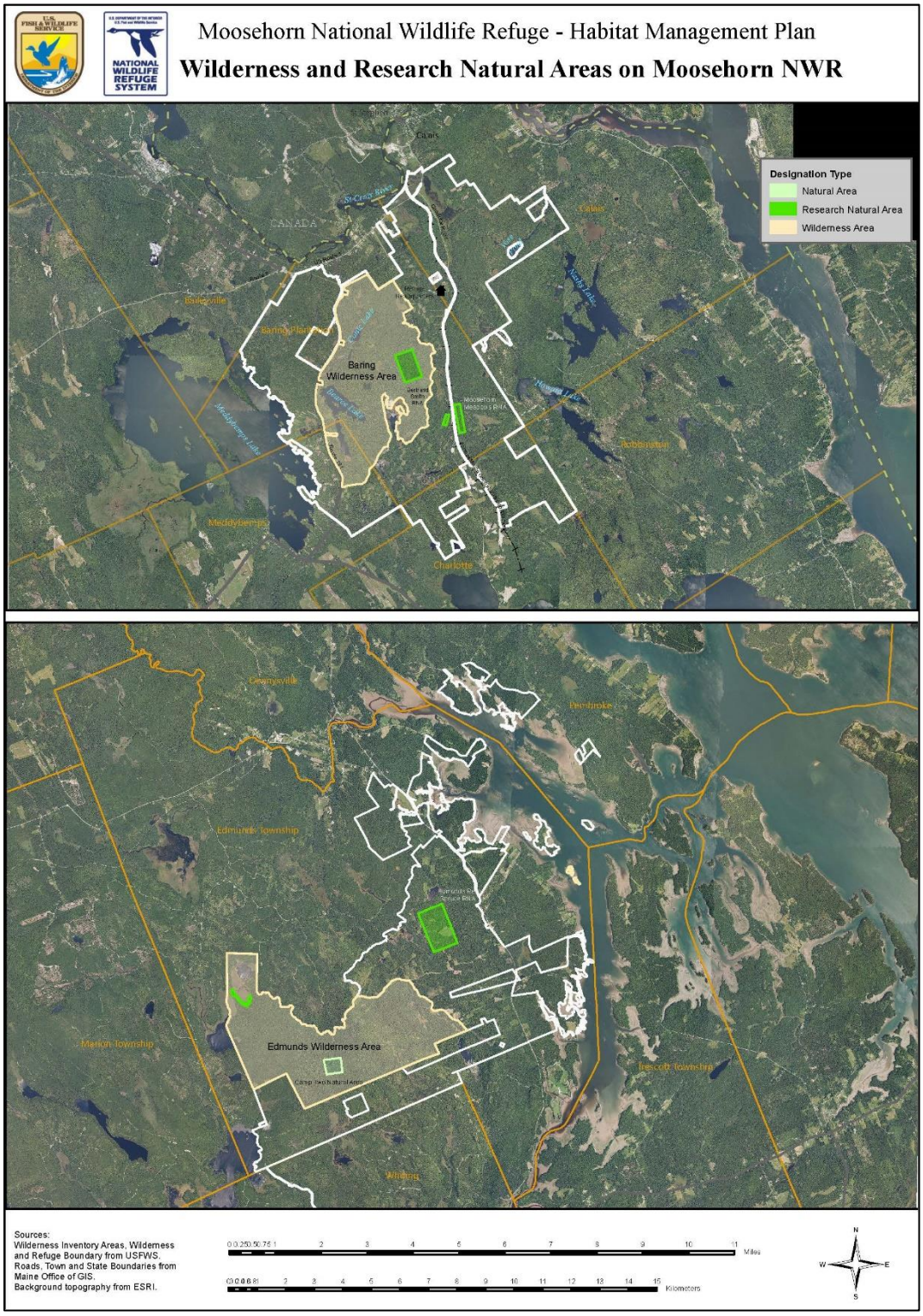
- No commercial logging or other forest management.
- No developments or structures.
- No camping.
- Hunting, fishing, cross-country skiing, hiking, wildlife observation, photography, snowshoeing, research, and nature study are permitted if they are compatible with refuge objectives.
- Unrestricted public access to all parts of the wilderness areas is permitted. Day use only, no wheeled vehicles.
- Fire suppression is allowed.
- No maintenance of or improvements to water control structures.

Both mainland wilderness areas are primarily forested. The major forest types on the Baring Division Wilderness Area are aspen-birch woodland forest, red maple-pine forest, spruce-fir upland forest and flats, and white pine-hemlock forest. Approximately 681 acres of the Baring Wilderness are classified as wetlands, including 6 impoundments with remnant water control structures. Two lakes are within the Baring Wilderness Area, the 295-acre Bearce Lake and 34-acre Conic Lake. Both are shallow lakes that support warm-water fisheries. Common Loons nest on both lakes. The State of Maine deeded all rights to Bearce, Cranberry, and Conic Lakes to the FWS in 1937 (Maine generally claims ownership of all submerged lands [MRS Title 1 chapter 1 § 3, Sovereignty and Jurisdiction, 2007]).

The primary forest type in the Edmunds Wilderness Area is spruce-fir upland forest and flats. The second most common forest type is aspen-birch woodland forest. There are over 260 acres of wetlands on the Edmunds Wilderness Area, including the 110-acre Hobart Bog. Three impoundments which had dikes and water control structures are located within the Edmunds Wilderness. The dike and water control structure at Birch Flowage have washed out, and the stop logs on the Crane Mill Flowage (that lies downstream) have been removed. The concrete structure on Hobart Bog is still standing but there are no stop logs in the bays, and Beaver debris was observed around the structure.

Hobart Stream forms the northern border of the Edmunds Wilderness. Two smaller tributaries of Hobart Stream, Cranberry Brook and Crane Meadow Brook, flow across the Edmunds Wilderness. Interior gravel refuge service roads, that are open to the public most of the year, form the eastern boundary, non-wilderness refuge lands form the southern boundary, and former industrial forest lands, most of which have been harvested within the past 15 to 20 years, form the western boundary.

FIGURE 2-6 WILDERNESS AND RESEARCH NATURAL AREA ON MOOSEHORN NWR.



The Birch Islands lie about 0.3 miles offshore in Whiting Bay and are only accessible by boat. The southernmost island has an active Eagle nest on it that is usually successful at producing eaglets each year. A 0.4-acre wildfire occurred on the northern island in July of 1999; it was caused by an unextinguished, illegal campfire. Both islands are forested and dominated by white pine and paper birch.

The Baring Wilderness Area is bounded by interior refuge gravel service roads on the east and south, by Route 191 on the west, and an electric power company right-of-way and other private lands to the north. In addition to the Bearce Lake vehicle access road, three other small areas along Route 191 were excluded from the wilderness boundary for future development as trailheads and access points.

At the time the areas were designated as wilderness, over 16 miles of gravel roads were closed to vehicle use. These roads are now used as walking trails. Also, some of the trails in both wilderness areas have been maintained with hand tools by refuge staff and volunteers. In addition to their recreational value, these gravel roads/trails provide access into the wilderness area in the event of a wildland fire. One loop trail within the Edmunds Wilderness Area is part of the Cobscook Trails Network.

Threats

In April and May 1985, a wildfire that originated off the refuge burned 1,086 acres, over 500 of which were in the Edmunds Wilderness. This fire was a stand-replacing fire, very difficult to control, and threatened the village of Whiting several times. Heavy equipment was used to open the roads in the wilderness area and construct fire breaks. Rehabilitation after the fire was not adequate to repair the damage the heavy equipment caused and some of the fire breaks are still visible today. In May 2001, 12 acres of same area burned again. An extensive rehabilitation plan was implemented after the 2001 fire and there is little, if any, evidence of the 2001 suppression activities.

Research Natural Areas

In 1947, the Society of American Foresters (SAF) organized a committee to consider the national need for a suite of "natural areas." Their goal was to set aside representative examples of each forest type in the U.S. before "all of our forest lands not specifically reserved will be cut over." They viewed these natural areas as remnants of the primitive forest that foresters could use as reference sites. The purposes of these areas are science, research, and education. Research Natural Areas (RNAs) are a national network of reserved areas on national wildlife refuges. The FWS recognizes the importance of preserving plant and animal communities in a natural state for research purposes. The FWS cooperates with other public and private agencies and organizations to identify, classify, and establish RNAs.

RNAs exist to fulfill three objectives:

- To participate in the national effort to preserve adequate examples of all major ecosystem types or other outstanding physical or biological phenomena.
- To provide research and educational opportunities for scientists and others in the observation, study, and monitoring of the environment.
- To contribute to the national effort to preserve a full range of genetic and behavioral diversity for native plants and animals, including endangered or threatened species.

Natural processes are allowed to predominate without human intervention in RNAs as much as possible. However, under certain circumstances, deliberate manipulation is used to maintain unique features that the RNA was established to protect.

Between 1948 and 1967, six "Research Natural Areas" were designated on Moosehorn NWR, ranging in size from 10 to 160 acres. There are 3 in the Baring Division and 3 in the Edmunds Division (Figure 2-7, Table 2-5). All the Moosehorn NWR RNAs possess unique natural features and fulfill the three stated objectives required of RNAs. At one time, vegetation transects and photo points were established on some of the units, but no research or monitoring is ongoing now.

TABLE 2-3. DESIGNATED WILDERNESS, BY RESEARCH AREA, ON MOOSEHORN NWR

Research Area Name (Division)	**Year Established**	**Size**	**Location**	**Reason for Establishment**	**Description**
Bertrand E. Smith Natural Area (Baring Division)	June 8, 1948	160 acres	West of Charlotte Road	Represents large white pine, up to 40 inches in diameter estimated to be 200 years old. Cedars and firs up to 14 inches and red pine and spruce up to 20 inches.	Rolling glacial till ranging in elevation from 90 to 150 feet. The entire RNA consists of white pine with a few small areas of paper birch, red spruce, and balsam fir. The extreme northwest section of the area contains some of the best examples of old growth white pine in the vicinity.
Moosehorn Meadows Research Natural Area (Baring Division)	June 22, 1967	50 acres	South Central Baring Division Non-Wilderness Area east of Charlotte Road	American Woodcock	Rolling glacial till and alluvial soils, ranging in elevation from 125 to 200 feet. This area consists of alder near a stream, and adjacent slope extending to ridge top. Forest growth on this slope varies from thickets of immature balsam to stands of mature aspen and white birch.
Sunken Bog Research Natural Area (Baring Division)	June 22, 1967	10 acres	South Central Baring Division Non-Wilderness Area, directly west of Moosehorn Meadows Research Natural Area. West of Charlotte Road.	Sphagnum bog lakes	Generally level peat deposits, ranging in elevation from 125 to 140 feet. This area is a small depression in a glacial moraine which has developed into a typical northern bog with a small pond at the center. The forest type most nearly conforms to black spruce and tamarack. Ground cover is primarily sphagnum and leatherleaf. Other native bog plants are also present.

Research Area Name (Division)	Year Established	Size	Location	Reason for Establishment	Description
Camp Two Research Natural Area (Edmunds Division)	December 12, 1972	40 acres	Central Edmunds Division National Wilderness	Represents one of the purest stands of balsam fir on the refuge	Rolling glacial till. This area contains one of the purest stands of balsam fir on the refuge. The ground cover is almost 100 percent sphagnum moss. The Natural Area is within the Edmunds Wilderness Area and is well protected from exploitation.
Edmunds Unit Research Natural Area (Edmunds Division)	June 8,1948	160 acres	Central Edmunds Division Non-Wilderness Area	Red spruce-balsam fir, northern white cedar	Rolling glacial till, ranging in elevation from 90 to 150 feet. In general, the cover types of the area fall in the spruce-fir group, but an estimated ten percent is northern white cedar. The spruce-fir group consists mainly of red spruce and balsam fir. The dense cedar swamps provide winter cover for deer.
Hobart Research Natural Area (Edmunds Division)	April 13, 1973	10 acres	Northwest section of Edmunds Division Wilderness Area	Northern white cedar	Glacial moraine that ranges in elevation from 120 to 140 feet. This area contains a sunken bog, with a peat substrate and ground cover including laurel, sphagnum, pitcher plants, and sundews. Northern white cedar is also prominent within the area.

WILDLIFE

Birds

Moosehorn NWR was established in 1937 as a migratory bird management area, with a special emphasis on American Woodcock. At least 224 species of birds have been recorded on the refuge. Five high priority Bird Species of Conservation Concern in Bird Conservation Region (BCR) 14—American Black Duck, American Woodcock, Bay-breasted Warbler, Canada Warbler, and Nelson's Sparrow—nest on the refuge.

Bald Eagles

Although the Bald Eagle was removed from the federal endangered species list in 2007, and from the Maine threatened species list, it is still protected under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act. The protection of inland and coastal nesting habitat for Bald Eagles remains a high priority on the refuge, as the de-listing was predicated on population numbers remaining strong.

When the MDIFW began monitoring Bald Eagles in 1976, more nesting pairs were found in Cobscook Bay than anywhere else in Maine. Furthermore, the Cobscook Bay eagles were producing three times as many eggs as eagles in other areas. Biologists concluded that the abundant resources and productive fisheries of Cobscook Bay—especially an abundance of Alewives—sustained this healthy population of eagles (Todd et al. 2019). The State now supports over 800 pairs of Bald Eagles.

During 2020, there were three known Bald Eagle nesting territories on the Edmunds Division along the shores of Dennys and Whiting Bays and two active nests on the Baring Division. One nest on the Baring Division is located on the nesting platform visible from US Route 1. The other is located along the Howard Mill Flowage. Two other traditional nest sites at Vose Pond and Bald Mountain have been abandoned in recent years and the nests have fallen or are in disrepair. There are six active eagle nesting territories on refuge islands or along the shores of Dennys and Whiting Bays. The number of active nests has remained constant over the past 5 years, but not every nest is productive every year.

Waterfowl

The ice-free bays around Cobscook Bay provide wintering habitat for the American Black Duck and other waterfowl (e.g., Common Goldeneye, Bufflehead, Long-Tailed Duck) when inland marshes are frozen. Black Duck, Mallard, Ring-necked Duck, Wood Duck, Common Merganser, Hooded Merganser, Blue-winged and Green-winged Teal, and Canada Goose also nest on the refuge.

Historically, the refuge managed water levels in flowages and impoundments, planted food crops, and erected nest boxes to improve conditions for waterfowl. The refuge no longer plants food crops or maintains an active duck box program; however, grassy areas on some dikes are mowed to provide forage for Canada Geese to reduce grazing by geese on wetland plants. The refuge is evaluating the effectiveness of these management strategies, particularly in impoundments with below average productivity as reported by Heirl et al. (2004).

Marsh and Water Birds

The following marshbirds nest in the refuge's impoundments: Pied-billed Grebe, American Bittern, Sora, and Virginia Rail. They are most common in the Barn Meadow and Magurrewock Marshes. Common Loons usually nest on Vose Pond, Bearce Lake, and Conic Lake. Great Blue Herons and Double-crested Cormorants frequently forage in refuge wetlands in spring through fall. Other occasional species include Great Egret, Snowy Egret, Cattle Egret, Green Heron, and Glossy Ibis.

During the winter, Common Loons, Horned Grebes, Red-Necked Grebes, and Great Cormorants are found in the waters of Cobscook Bay adjacent to the Edmunds Division.

Shorebirds

Moosehorn NWR is best known for research and development of habitat management techniques for American Woodcock. When Moosehorn NWR was established, much of the property was abandoned farmland. Mendall and Aldous (1943) estimated a density of 10.4 singing male Woodcock per 100 hectares (247 acres). By 1975, most of the refuge was covered by mature second-growth forest interspersed with wetlands, meadows, and managed blueberry fields, and the density of singing males had declined corresponding to the reduction in old fields and early successional areas. By 1990, 5 years after Moosehorn NWR initiated the current forest management plan, the number of adult male Woodcock on the Baring Division increased 77 percent because of the increased number of singing grounds and the additional areas of early successional forested habitat (Dwyer et al. 1988) from its low point, with an

estimated density of 2.2 singing males per 100 hectares. Since 1985, the number of singing male Woodcock on the Baring Division has increased 73 percent.

Four shorebirds nest on the refuge: American Woodcock, Killdeer, Spotted Sandpiper, and Wilson's Snipe. According to the U.S. Shorebird Plan (Brown et al. 2001), the extensive tidal flats of Cobscook Bay provide internationally significant "staging areas" for more than 20 species of migrating shorebirds including the Red Knot (highly imperiled), Whimbrel (high concern), Sanderling (high concern), Ruddy Turnstone (high concern), as well as large numbers of Semipalmated and Black-bellied Plover, and Semipalmated, Least, and White-rumped Sandpipers. Shorebirds stop in Cobscook Bay during their migration south to feed and build energy reserves before flying on to wintering grounds in Central and South America. Many of the shorebird species that occur in the Western Hemisphere are showing alarming population declines (Andres et al. 2012).

Landbirds

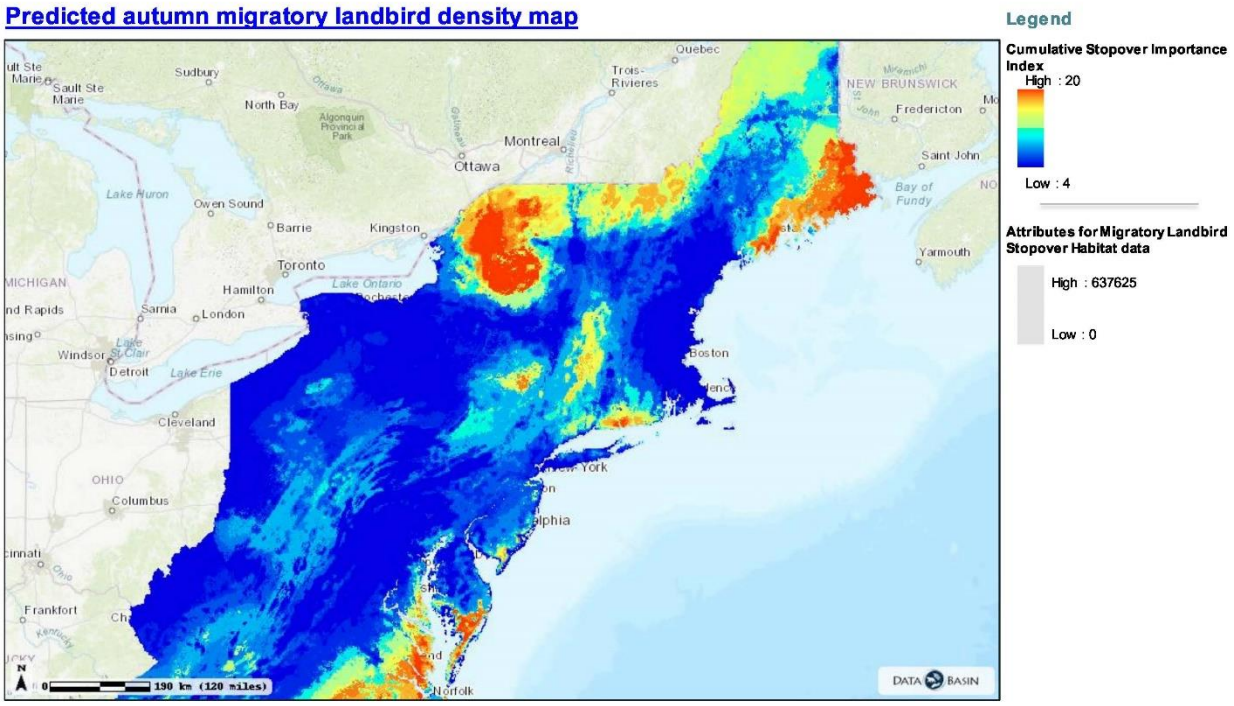
Seventeen species of raptors and owls occur on the refuge, 13 of which nest on the refuge, including Bald Eagle, Osprey, Northern Harrier, Sharp-shinned Hawk, Cooper's Hawk, Northern Goshawk, Red-shouldered Hawk, Broad-winged Hawk, American Kestrel, Merlin, Great Horned Owl, Barred Owl, and Northern Saw-whet Owl. Cobscook Bay supports the highest nesting density of Bald Eagles in the northeastern United States, including at least 3 pairs on the Edmunds Division. Historically there have been 3 active Eagle nests located on the Baring Division, but only 1 or 2 active Eagle nests were located on the Baring Division each year between 2015-2022.

As described above, more than 220 species of birds have been identified on the refuge. Twenty-six species of wood warblers and vireos, and 9 species of flycatchers nest in the forests on Moosehorn NWR. Grassland nesting birds include Savannah Sparrow, Bobolink, and Eastern Meadowlark. Small numbers of boreal species including Spruce Grouse, Canada Jay, Boreal Chickadee, and Black-backed Woodpecker, occur on both divisions of the refuge. Wild Turkeys were reintroduced to southern Maine in 1977 and have been expanding their range northward and eastward. Several have been sighted on both the Baring and Edmunds Divisions over the past few years.

In 1995, USGS researchers established over 114 permanent survey points on the Baring Division, distributed among 12 treatments, to evaluate the long-term effects of our forest management activities on the distribution and relative abundance of nesting land birds (McAuley 2003a). From 1995 to 2012, 10-minute point count bird surveys were conducted annually at these points. In 1998, an additional 80 random points were established on the Edmunds Division and were sampled annually through 2011. From 2000 to 2004, an average of 70 species (89 different species overall) and 2,859 individual birds were detected annually from the counts on both divisions. All data currently resides in the Avian Knowledge Database and will be analyzed using GIS software.

In 2017, researchers from the University of Delaware used weather radar technology to identify key stopover sites for landbirds (Figure 2-7; Buler et al. 2017). This project was funded by the FWS and provides a regional perspective on important sites throughout the Northeast. The areas of highest cumulative stopover importance (colored red and orange) were areas in upstate New York, the area surrounding Chesapeake Bay and Downeast Maine. Both divisions of Moosehorn NWR are marked as areas of highest importance for landbird stopover sites.

FIGURE 2-7. KEY STOPOVER SITES FOR AUTUMN-MIGRATING LANDBIRDS IN THE NORTHEAST.



Mammals

The refuge and surrounding lands support a range of medium to large mammal species including White-tailed Deer, Moose, Black Bear, Coyote, Red Fox, Bobcat, Raccoon, River Otter, Fisher, Mink, Weasels, Beaver, Muskrat, Red and Gray Squirrels, and Snowshoe Hare. Harbor Seals are common in the waters of Cobscook Bay. No detailed surveys of small mammals except bats have been conducted on Moosehorn NWR, though some small mammal trapping has occurred for small-scale projects.

The refuge has conducted acoustic monitoring surveys for bats during the breeding and post breeding periods beginning in 2012 to assess bat use of the refuge's forests, fields, and wetlands. The effort has expanded each year, beginning with 9 points on the northeastern corner of the Baring Division in 2012 and growing to 31 points across both Divisions by 2016. Eight species of bats have been recorded on the refuge, including Little Brown, Big Brown, Red, Silver-haired, Hoary, Tri-colored, Small-footed, and Northern Long-eared Bats.

Beavers occupy nearly every flowage and Muskrat are common in the wetlands of Moosehorn NWR. Beaver, Muskrat, and other furbearing animals were greatly reduced in number in the 1880s due to overexploitation and loss of forested habitat. Laws protecting these animals were passed in the early 1900s and by the time the refuge was established in 1937, Beaver were reestablished. During the 1940s, they occupied many flowages throughout the refuge. As the Beaver population continued to rebound, their activities caused flooding of roads and railroads, plugged culverts and spillways, and blocked trout streams. The refuge instituted a Beaver and Muskrat-trapping program in 1954 to remove nuisance individuals and to ease pressure on declining food supplies. Muskrat populations fluctuated because of winterkill during severe winters when marshes froze solid (USFWS 1985b).

A revised trapping plan was approved in 1985. The plan provided for a fall trapping season to reduce the populations of predators of migratory birds and Muskrats that cause damage to dikes, and a winter Beaver-trapping program to manage the populations of Beavers that plug water control structures and culverts. The new plan was implemented in 1986 and is still in use.

Seven of the eight species of bats found in Maine have been detected on the Moosehorn NWR, with Big Brown Bats and Silver-haired Bats the most abundant. Other species include Hoary, Red, Small-footed, Northern Long-eared, and Tri-colored. The Little Brown Bat and Northern Long-eared Bat were historically considered to be the most common species, but both have experienced severe declines due to White-nose Syndrome (WNS; Vanderwolf and McAlpine 2021). As a result, the Northern Long-eared Bat is listed as federally endangered, and the Little Brown Bat is under status review for federal listing. Maine lists both species as endangered and the Small-footed Bat as threatened.

The Northern Long-eared Bat is considered a forest interior species that uses mature forest with high vegetative complexity. It is a small-bodied bat with relatively short wings adapted to fly in highly "cluttered" environments. During the summer, Northern Long-eared Bats roost singly or in colonies underneath bark, in cavities or in crevices of both live trees and snags (USFWS 2015). Sasse and Pekins (1996) found Northern Long-eared Bats commonly used northern hardwoods in New Hampshire's White Mountains. Late successional hardwood forests are expected to provide large trees, large amounts of standing and downed dead wood, and diverse vertical structure that will be beneficial to bats.

Reptiles and Amphibians

At least 22 species of reptiles and amphibians are known to occur on Moosehorn NWR. Painted and Snapping Turtles are common in most refuge wetlands. Five species of snakes occur on Moosehorn NWR, including the Northern Water Snake, which resides primarily in the Magurrewock Marsh watershed. This population of Northern Water Snake is part of a cluster of documented occurrences in north central Washington County that is separated (by approximately 90 miles) from the nearest population in the Newport area of central Maine.

Since 2001, the refuge has participated in the monitoring of vernal pools coordinated by the Northeast Amphibian Research and Monitoring Initiative (NEARMI), Patuxent Wildlife Research Center. These surveys have identified five species of salamanders on the refuge, including the Spotted and Blue-spotted Salamanders that breed in vernal pools, and nine species of frogs and toads, including the Wood Frog, American Toad, Mink Frog, and Northern Leopard Frog. Although Wood Turtles, a Maine species of conservation concern, have not recently been documented on the refuge, they have been seen on the refuge historically and are known to use vernal pools.

Fish

At least 26 species of freshwater fish are known to occur in Moosehorn NWR brooks, streams, and ponds, although no recent standardized surveys have been conducted. Self-sustaining populations of Brook Trout occur in several streams on both divisions. Smallmouth Bass and Chain Pickerel are common in refuge waters. The Magurrewock Stream complex of wetlands supports large numbers of Alewives that migrate upstream onto the refuge from the St. Croix River each spring to breed. The Dennys River supports runs of Atlantic Salmon, as well as Shad, Alewife, and American Eel. The waters of Cobscook Bay provide habitat for an additional 12 species of saltwater fish. Populations of soft-shelled clams, mussels, and periwinkles are found in the mudflats of the intertidal zone.

RARE SPECIES

The federally listed species known to occur on Moosehorn NWR are the Northern Long-eared Bat (*Myotis septentrionalis*) and the Atlantic Salmon (*Salmo salar*).

Atlantic Salmon historically occurred in Hobart Stream, which forms the northern boundary on most of the Edmunds Division. The Atlantic Salmon is currently listed as an endangered species in five rivers in Downeast Maine, not including Hobart Stream.

As part of an experimental reintroduction program, approximately 200 Atlantic Salmon from Craig Brook National Fish Hatchery were stocked into Hobart Stream in October 2006, 2007, and 2009. This was accomplished through a partnership between the FWS's Craig Brook Hatchery, the Bureau of Sea-Run Fisheries and Habitat (formerly the Atlantic Salmon Commission), and the refuge. An assessment of the stream habitat, which historically was a salmon-spawning stream, found it to be suitable habitat. Surveys in the summer of 2007 found that the 2006 stocking resulted in successful spawning by Salmon and numerous redds were found in November 2007. It is unknown if any Salmon are still present in Hobart Stream.

The Dennys River, which empties into Dennys Bay, is one of the rivers in which the Atlantic Salmon is listed. The refuge does not own any land on the river, but does own properties along the shore of Dennys Bay. The refuge provides equipment and staff to conduct several off-refuge, high priority restoration projects to enhance habitat for the Atlantic Salmon each summer.

The FWS originally listed the Northern Long-eared Bat as a threatened species throughout its range on May 4, 2015; a final rule, listing the species as Endangered was published on November 29, 2022. This species has been recorded in small numbers on the refuge, primarily in areas with old spruce-fir habitat such as Snare Meadow and the Baring and Edmunds wildernesses. Detections of Northern Long-eared Bats have declined in the past few years, mirroring their decline range-wide due to impacts from White Nose Syndrome. In 2018, only one Northern Long-eared Bat was recorded on the refuge, and none were detected in 2019.

The MDIFW lists the Northern Long-Eared Bat and the Little Brown Bat (*Myotis lucifugus*) as endangered and the Eastern Small-Footed Bat, (*Myotis lebii*) as threatened in the State of Maine.

The American Eel was considered for federal listing under the ESA in 2007 and 2015, and it was decided that listing was not warranted. No recent population estimates for eels on the refuge are available; however, when fisheries surveys were conducted in the mid-1980s, eels were common in most refuge waters, and eels continue to be observed in refuge impoundments and streams.

A small population of showy lady's slipper (*Cypripedium reginae* Walter), a State Special Concern Species, occurs on the refuge's Baring Division and was first documented in 2006. Showy lady's slipper is Maine's largest lady's slipper and occurs in constantly moist habitats. This species is considered rare (S3) in the State of Maine and globally widespread and abundant, but with cause for long-term concern (G4). This species is rare because of habitat destruction, collecting, and the scarcity of suitable habitat. The greatest threat to this species is from collecting.

The salt marshes on the Edmunds Division support small populations of Gaspé arrow grass (*Triglochin gaspensis* Lieth and D. Love), a species of special concern in Maine. The plant also occurs along the refuge shoreline at Duck Harbor at the outlet of Hobart Stream. The species is considered imperiled (S2 rank) in Maine due to its rarity and is globally rare (G3 G4 rank). Gaspé arrow grass was first found on

the refuge in 2000. At that time, it was the only known occurrence of the plant documented in the United States. Since then, nearly half a dozen additional populations of Gaspé arrow grass have been found in Maine, primarily in the vicinity of Cobscook Bay. This species is restricted to Washington County, ME and the Canadian Maritime Provinces and its habitat is rare. It may also be threatened by changes in salt marsh hydrology.

INVASIVE SPECIES

The FWS defines an "invasive species" as a species that is (1) nonnative (or alien) to the ecosystem under consideration, and (2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health (*Executive Order 13112*). A report by Pimentel et al. (2000) estimates the economic cost of invasive species in the U.S. at $137 billion every year. Additionally, up to 46 percent of the plants and animals federally listed as endangered species have been negatively impacted by invasive species (Wilcove et al. 1998, National Invasive Species Council 2001).

Moosehorn NWR is relatively free of invasive plant species compared to other refuges in the Northeast Region (Casey et al. 2020). The refuge is conducting Early Detection Rapid Response (EDRR) to detect early infestations. Currently 18 invasive plants species have been documented on the refuge, and one species, Japanese knotweed, is present adjacent to our boundary (Table 2-4, Appendix B).

TABLE 2-4. INVASIVE PLANT SPECIES ON OR ADJACENT TO MOOSEHORN NWR.

Common Name	Scientific Name
Autumn olive	*Elaeagnus umbellate*
Bell's honeysuckle	*Lonicera x bella*
Black locust	*Robinia pseudoacacia*
Canada thistle	*Cirsium arvense*
Climbing nightshade	*Solanum dulcamara*
Coltsfoot	*Tussilago farfara*
Common mullein	*Verbascum Thapsus*
Cypress spurge	*Euphorbia cyparissias*
Garden heliotrope	*Valeriana officinalis*
Glossy buckhorn	*Frangula Alnus*
Japanese barberry	*Berberis thunbergii*
Japanese knotweed	*Polygonum cuspidatum*
Morrow's honeysuckle	*Lonicera morrowii*
Multiflora rose	*Rosa multiflora*
Purple loosestrife	*Lythrum salicaria*
Reed canary grass	*Phalaris arundinacea*
Rugosa rose	*Rosa rugosa*
Smooth bedstraw	*Cruciata laevipes*
Spotted knapweed	*Centaurea maculosa*

3. RESOURCES OF CONCERN

Resources of Concern

Selecting Priority Resources of Concern

Selecting Priority Ecosystems

RESOURCES OF CONCERN

Resources of Concern (ROCs) are the focal point of an HMP. The HMP policy (*620 FW 1*) defines ROCs as:

> *All plant and/or animal species, species groups, or communities specifically identified in refuge purpose(s),Refuge System mission, or international, national, regional, state, or ecosystem conservation plans or acts. For example, waterfowl and shorebirds are a resource of concern on a refuge whose purpose is to protect "migrating waterfowl and shorebirds." Federal or State threatened and endangered species on that same refuge are also a resource of concern under terms of the respective endangered species acts.*

The FWS is entrusted by Congress to conserve the entire suite of biodiversity and natural processes occurring within the refuge system. In addition, there is direction to protect migratory birds, federally listed threatened and endangered species, inter-jurisdictional fishes, and certain marine mammals. Further, each refuge has one or more purposes, for which it was established, that guide its management goals and objectives.

Identifying ROCs allows us to identify management unit- and refuge-wide objectives aimed at maintaining, increasing, and/or improving the habitats required by the species or habitats identified in the refuges' purpose. Concurrent with the IMP process, the ROC selection process facilitates a targeted approach to identifying priority areas and gaps in management that may require additional resources, such as information (data collection and monitoring) or staff and equipment. Resources respond to habitat management differently; identifying ROCs allows us to focus management activities at the level that yields the greatest benefit to trust resources, maintains BIDEH, and fulfills the refuge purposes.

What follows is a description of the process that Moosehorn NWR staff used to identify priority ROCs and develop habitat goals, objectives, and strategies to benefit these species.

Identifying BIDEH at Moosehorn NWR

To translate the BIDEH policy into an operational plan that will benefit ROCs at Moosehorn NWR (Taylor and Paveglio 2017; Casey et al. 2021; Salas and Pranckus 2015), we reviewed information regarding:

- Species and species groups identified in legislation that established Moosehorn NWR (Resources of Concern [ROC] Tables 1 and 2; USFWS 2019a).
- Species known to occupy the refuge (comprehensive ROC list, ROC Table 4; USFWS 2019a) and their habitat needs.
- Literature describing requirements of selected ROCs and their rarity.
- Documentation of species of conservation concern by the state and other conservation organizations, (e.g., The State of Maine's Wildlife Action Plan).
- Literature describing ecosystem processes that regulate natural communities.

The resources we used to describe the Moosehorn NWR's baseline environmental, abiotic, and biotic conditions include:

- Reports and unpublished refuge data regarding site history and capabilities.
- Refuge maps and aerial imagery of existing and historical vegetation types.
- Status and trend information for species listed on the comprehensive ROC list from refuge staff observations or as documented in regional and local assessments and reports.

Based on a review of the existing and historical data listed above, we defined the major plant communities and the associated attributes that represent BIDEH for Moosehorn NWR (Table 3-1) (Casey et al. 2021).

MAGURREWOCK STREAM. PHOTO CREDIT: USFWS

TABLE 3-1. SUMMARY OF PLANT COMMUNITIES THAT REPRESENT BIOLOGICAL INTEGRITY, DIVERSITY, AND ENVIRONMENTAL HEALTH ON MOOSEHORN NWR.

Objective	Maine Natural Communities*	Habitat/Population Attribute(s)	Natural Processes Responsible for Conditions	Limiting Factors
1.1 Spruce-Fir	Spruce-Fir–Broom-moss Forest *Natural community descriptions are adapted from Gawler and Cutko (2018).	Closed canopy (> 75% closure) forest dominated by red spruce (> 60% cover), with few other tree species in any of the layers. Fir is often a minor canopy component (up to 20% cover), particularly in open gaps or in younger stands. Lower layers are sparse or patchy, consisting mostly of tree regeneration. Sparse herb layer, dwarf shrubs are virtually absent except for spotty lowbush blueberry. Herbaceous species cover less than 10 percent of the ground and consist of scattered plants of Canada mayflower, starflower, and bunchberry. Most of the ground surface is bare conifer litter, although Downeast Maine sites have bryophytes (broom-mosses) forming patch to full cover.	Xeric to mesic soils ranging from well drained to imperfectly drained, with charcoal in the soil. Sites are on hill slopes (lower, middle, or upper) at elevations up to 2,200 feet. Slopes are gentle to moderately steep; aspects are various. Podzolic soils are rocky and/or shallow (< 40 cm to obstruction) and are very acidic (pH 4.1 to 5.2).	Extensive harvesting and management. Current stands are more even aged than would be in the absence of past harvesting. Spruce Budworm and past harvesting play significant roles in the age dynamics of this type.
1.1 Spruce-Fir	Spruce-Fir-Cinnamon Fern Forest	Fairly homogeneous closed canopy forest in which red spruce, black spruce or red-black spruce hybrids grow on poorly drained, level to gently sloping sites. Balsam fir may be present in regenerating patches or stands but tend to give way to the longer-lived spruces over time. Even-aged blocks hundreds to thousands of acres in size. Cinnamon fern and three-seeded sedge are typical. Dense carpet of mosses and liverworts.	Drainages or low flats where soil remains moist throughout the growing season and may be saturated or temporarily flooded in the springtime. Substrate is acidic mineral soil and may be very stony, with or without an organic layer (< 30 cm) on top.	Nearly all known occurrences of this community type in Maine have been harvested in the past. Natural disturbance such as fire or Spruce Budworm.
1.2 Spruce-Northern Hardwood	Spruce-Northern Hardwoods	Mixed forest type characterized by red spruce and yellow birch, or less often another hardwood (sugar maple, red maple, or beech). Scattered large super canopy white pine trees are occasional. Balsam fir and paper birch are common, and hemlock may be an associate at some sites. The sapling/shrub layer may be well developed (20 to 40% cover), with striped maple and saplings of canopy species; shrub species vary among sites. The herb layer ranges from sparse to dense but is usually more than 15 percent cover, divided between forbs, ferns, and regenerating trees, with dwarf shrubs virtually absent. The bryoid layer is patchy and locally well developed, with bryophytes (e.g., three-lobed bazzania).	Cooler microsites from near sea level to 2,200 feet, usually on hill slopes ranging from lower to upper slopes and from gentle to steep (up to 50%). Soils are typically well drained, sometimes somewhat excessively drained, sandy to loamy in texture, with pH 5.0 to 5.4.	Nearly all spruce-northern hardwood forests have been harvested and at many sites the spruce has been selectively removed. As a result, the canopies are more often indicative of beech-birch-maple forests, with spruce and fir more common in the understory than in the canopy.

Objective	**Maine Natural Communities***	**Habitat/Population Attribute(s)**	**Natural Processes Responsible for Conditions**	**Limiting Factors**
1.2 Spruce-Northern Hardwood	Hemlock Forest	A closed canopy forest type dominated by hemlock (> 50% cover), or less often, hemlock is co-dominant with red spruce, red oak, yellow birch, red maple, or sugar maple (very rarely with northern white cedar, near the coast). White pine may be co-dominant in stands that are transitional, with pine giving way to hemlock in time. The conifer canopy allows little light to reach below, and the shrub, herb, and bryoid layers are sparse (each usually < 25% and sometimes absent). Small conifers are present in the herb layer, as well as scattered individuals of typical upland conifer forest plants such as Canada mayflower, starflower, Indian cucumber-root, partridgeberry, wild sarsaparilla, and wintergreen. Graminoids are rarely very apparent. The ground layer is mostly conifer litter, with spotty bryophyte cover.	On slopes (typically 5 to 50%) and ravines, with well drained loamy soil. On low slopes and flats, soils may be imperfectly drained. Soils are shallow (< 50 cm) and acidic (pH 4.8 to 5.6). Sites are from sea level to 1,200 feet and often in cool microsites, although aspect varies.	Demand for hemlock in the 1700s to 1800s considerably reduced mature, undisturbed examples of this type, yet recent poor market conditions have caused hemlock to be left in partial harvests. Some evidence suggests that hemlock is less successful in maintaining itself in the face of human-caused disturbance than other hardwoods. Hemlock Woolly Adelgid has decimated hemlock stands.
1.2 Spruce-Northern Hardwood	Red Spruce-Mixed Conifer Woodland	Mixed canopy woodland (25 to 70% closure) in which red spruce and/or white pine is always present. Red spruce or white pine is strongly dominant at some sites; at others, the canopy is mixed with no one tree species dominant. The shrub layer is very sparse (and variable in composition) and the herb layer has mostly 15 to 50% cover). Heath shrubs are the dominate feature of the herb layer, herbs species rarely exceed 8 percent cover. Fruticose lichens typically make up half or more of the bryoid cover.	Some sites show evidence of past fire and are not open ‘balds’, but many do not. Occurs on mid to upper slopes (usually 10 to 20% slope). Soils are thin (< 26 cm) consisting of course mineral soil or poorly decomposed duff and form patches over the bedrock substrate. Very well drained soils are acidic and nutrient poor.	Recreational use. Communications towers or wind turbines could have an impact on woodlands on mid-elevation summits. Little pressure from development or timbering.

Objective	**Maine Natural Communities***	**Habitat/Population Attribute(s)**	**Natural Processes Responsible for Conditions**	**Limiting Factors**
1.3 Pine and Mixed Forest	White Pine-Mixed Conifer Forest	Closed canopy forest with white pine dominant (> 33% cover) with red oak and northern hardwood species (beech, sugar maple, yellow birch) less than 25 percent cover. The dense coniferous canopy limits understory growth. Shrub cover is rarely more than 20 percent and the herb layer rarely exceeds 30 percent. The herb layer can include a spotty mixture of species such as lowbush blueberry, forbs, or ferns, but graminoids are very uncommon. Canada mayflower is frequent. The ground layer is mostly conifer litter with bryoid cover less than 25 percent; large hair-cap moss and red-stemmed moss are common species.	Occurs on sandy to loamy mesic soils (usually well drained, occasionally imperfectly drained, or very well drained), often with slowly decomposing duff layer of conifer needles. Soils are generally shallow (< 40 cm) and moderately acidic (pH 5.0 to 6.0). These forests are usually at low elevations (< 900') on slopes or coarse-textured flats.	Logging, the demand for white pine has considerably reduced mature, undisturbed examples of this type. Most sites known to be of high ecological quality lack formal protection. Maintaining the surrounding lands as forest is important as many known examples are less than 50 acres.
1.3 Pine and Mixed Forest	Red and White Pine Forest	An upland forest with red pine as the dominant tree; white pine, red spruce, or, near the coast, northern white cedar may be co-dominant. The canopy may be somewhat open but is more typically more than 70 percent. In post-fire sites, the canopy may include deciduous trees such as paper birch, red maple, or big-toothed aspen. Lower layers are generally sparse (< 25% cover) and contain few species; some sites may have scattered heath shrubs such as huckleberry, lowbush blueberry, or sheep laurel. Bracken fern and wintergreen are almost always present in the herb layer, but at low cover. Graminoids are virtually absent. The ground is typically covered with conifer litter and patches of bryophytes, or less commonly, lichens.	Sites are usually on flats, slopes of less than 25 percent or low ridges (< 1,000'), on dry-mesic to xeric soils that are somewhat to very shallow (10 to 50 cm to obstruction, usually bedrock). Soils are coarse (sandy loams to sands) and acidic (pH 4.8 to 5.2). Many sites have evidence of past fires.	Red pine has been widely planted, but natural occurrences of this type are rare. These forests apparently require fire for persistence or regeneration, but community dynamics are not well documented. At some known sites clear-cut harvesting has perpetuated the type. Most sites are small, lack formal protection and could be maintained within a forested matrix.
1.3 Pine and Mixed Forest	Oak-Pine Forest	Closed canopy forest (> 75% closure) in which red oak or a mixture of oak and white pine (rarely red spruce or hemlock) dominate. Red maple (up to 30% cover) and paper birch (up to 15% cover) can be common in younger stands. Striped maple is a common subcanopy associate. Herb layer usually sparse (< 30% cover) and features bracken fern, lowbush blueberry and various herbaceous species. Bryoids are sparse and are almost exclusively mosses rather than liverworts or lichens.	Most Oak-Pine Forests are on land that was once cleared or pastured. Sites occur on lower to mid-slopes or occasionally upper slopes on low hills. Slopes are typically 10 to 25 percent and aspect varies. Well drained mineral soils that are somewhat shallow (10 to 50 cm to obstruction), usually sandy loams or loamy sands, and acidic (pH~5.0). Fire or other soil disturbance may be important in maintaining this type.	Subject to fragmentation by timber harvesting, clearing for agriculture and residential development.

Objective	Maine Natural Communities*	Habitat/Population Attribute(s)	Natural Processes Responsible for Conditions	Limiting Factors
1.4 Northern Hardwoods	Beech-Birch-Maple Forest	Closed canopy forests dominated by a combination of beech, yellow birch, and sugar maple. Conifers and red oak can each have less than 25 percent cover. Striped maple is a common subcanopy tree. The shrub layer is dominated by tree regeneration. Herbs are sparse, usually more than 15 percent cover and lacks rich site indicators such as Dutchman's breeches, maidenhair fern and blue cohosh.	Sites are typically found on the lower to middle portion of hillslopes (slopes generally 10 to 15%). Soils are generally mesic and well drained, though not deep formed over glacial till or on stabilized talus.	Extensive harvest and management. Most management techniques diverge from the natural gap pattern, which is at the scale of single trees to small groups of trees. Large (> 1,000 acres) examples reflecting only natural disturbance are scarce (Lorimer 2001).
1.5 Early Successional Aspen-Birch	Aspen-Birch Woodland/Forest Complex	This complex of post fire associations of aspen, birch, and other species can occur as open canopy woodlands, as closed forest, or, in very exposed areas, as stunted, dense shrublands. The canopy is dominated by early successional deciduous trees (poplars, birches, red maple). Conifer and red oak may be present but are not dominant. Shrub layer is usually less than 50 percent cover. Lowbush blueberry and bracken fern are usually present. Sites are on thin mineral soil over till or bedrock.	Nearly all sites are post-fire and/or post-harvest, typically on nutrient-poor soils. The mineral soils are usually less than 25 cm deep and stands occur on thin glacial till or bare granite. Most sites will transition to one of several matrix-forming forest types such as northern hardwood or spruce-northern hardwood forest.	Natural succession dictates that the aspen-birch dominance will not be long lived. Management is needed to maintain a rotation of early successional stages within the aspen-birch complex.
1.6 Old Fields and Lowbush Blueberry		Old fields are comprised of graminoids, forbs and dwarf shrub vegetation, such as low bush blueberry. Areas can be flat to hummocky expanses of dwarf shrub punctuated by sparse pine or spruce trees. In patches among the shrubs, reindeer lichens may form extensive carpets.	Coarse textured glacial outwash deposits form a flat to undulating substrate that can encompass a wide moisture gradient. Xeric conditions on hummocks or raised areas can grade into bog-like vegetation in depressions. Soils are highly acidic and nutrient poor.	Many former natural occurrences have been converted to actively managed blueberry barrens in Downeast Maine. Managed barrens maintain some superficial resemblance to natural barrens, pesticide use may have changed the species composition.
2.1 Freshwater Impounded Wetlands	Mixed Graminoid–Shrub Marsh	Heterogeneous wetland with a mix of herb and shrub wetland species (herbs 25 to 95%, shrubs 0 to 70% cover), without a dominance of tussock sedge, bluejoint grass, or alder. A mixture of graminoids making up at least 50 percent of the cover, often with a sparse shrub layer containing meadowsweet or hardhack. Three-way sedge and yellow loosestrife are indicators.	Mineral soils that are flooded early in the growing season and remain saturated (or occasionally flooded) throughout the season. Soil pH is 5.0 to 6.0.	Beaver activities often affect these wetlands and can cause dramatic (although sometimes temporary) changes in dominance. Maintaining appropriate wetland buffers to protect from adjacent land uses that may degrade the marsh.

Objective	Maine Natural Communities*	Habitat/Population Attribute(s)	Natural Processes Responsible for Conditions	Limiting Factors
2.1 Freshwater Impounded Wetlands	Tussock Sedge Meadow	Graminoid marsh dominated by hummocks of tussock sedge (> 30%, usually > 50% cover) with bluejoint, other graminoids, and a few shrubs. The shrub cover is usually less than 30 percent but may be higher, meadowsweet is a characteristic shrub. Vegetation is strongly hummocked with standing water between hummocks for much of the growing season. Plant species typically include royal fern, cinnamon fern, sensitive fern, St. John's wort, flat-topped goldenrod, or wool-grass. Bryophytes are usually very sparse.	Saturated soils are usually flooded. Soils may be entirely organic peat or muck or a layer of organic matter over mineral soil. Standing water is present through much of the growing season. Occurs in large flat basins that are often associated with drainage streams and may be influenced by Beaver activity.	Susceptible to degradation from adjacent land use. Maintain appropriate wetland buffers. Alteration from non-native purple loosestrife threaten this community type
2.2 Streams and Associated Wetlands	Mixed Graminoid-Shrub Marsh Tussock Sedge Meadow	See descriptions in *Freshwater Impounded Wetlands*	See descriptions in *Freshwater Impounded Wetlands*	Introduced non-native and invasive plants and non-native animals. Barriers to fish migration by dams and improperly installed culverts. Habitat degradation from lost and damaged riparian areas, stream and shoreline alteration, channelization, increased stormwater, and impoundments. Degraded water quality from non-point source pollution.
2.2 Streams and Associated Wetlands	Alder Thicket	1- to 3-meter shrub dominated wetlands characterized by dense growth of alder. Speckled alder is most typic; rarely, mountain or smooth alder may be dominant. Red maple, gray birch or other trees may be scattered sparsely above the shrubs. Herb layer is well developed (> 35% cover) and a mixture of forbs, graminoids and ferns.	Occurs in basin wetlands that are usually saturated and may be seasonally flooded throughout the season. Usually on muck or peat soils. Commonly old Beaver meadows reverting to forest.	Dependent upon adequate water conditions. Alteration by Beaver activity.
2.3 Forested Wetlands and Peatlands	Northern White Cedar Swamp	Northern white cedar is dominant (up to 95% cover), often forming a uniform stand, but may be interspersed with various amounts of red maple (up to 25% cover), black spruce (up to 40% cover) or less frequently, larch, yellow birch, or balsam fir. Moderate to densely forested (> 60% tree canopy cover), often with little light penetrating to the forest floor. The shrub and ground layers form a lush mosaic of vegetated hummocks interspersed with moist hollows; alder may be frequent. Herb layer well developed (> 30% cover)	Level, poorly drained basins along stream flowages or the perimeter of ponds. Substrate is usually shallow peat (< 50 cm) over mineral soil; some sites are on deep peat accumulations. Alkaline conditions.	Most sites have been logged at least once. Problematic to maintain examples not subject to human disturbance. Difficult to regenerate cedar rather than fir through harvest practices. Alteration by Beaver activity.

Objective	**Maine Natural Communities***	**Habitat/Population Attribute(s)**	**Natural Processes Responsible for Conditions**	**Limiting Factors**
2.3 Forested Wetlands and Peatlands	Cedar-Spruce Seepage Forest	Northern white cedar and other conifers form a moderate to dense canopy cover (70 to 95%), allowing only patchy light to penetrate to the forest floor. Northern white cedar is the dominant tree, though red spruce, white spruce, or black spruce may be co-dominant on some sites. Balsam fir, red maple, or yellow birch may be present but not dominant. Shrubs and dwarf shrubs are typically sparse but may be more abundant in canopy gaps caused by harvesting or natural disturbance. The herb layer may be extensive, typically more than 50 percent cover, and comprised mostly of non-woody species with northern affinities such as bunchberry, twinflower, or creeping snowberry. The forest floor is characterized by a rich growth of mosses; generally, feathermosses and liverworts are more abundant than peat mosses.	Occur on mineral soil (may have a thin organic layer on top, but not deep peat). Groundwater seeps may be visible.	Most known occurrences in Maine have been harvested in the past, often targeting removal of spruce. Forest management generally does not result in permanent conversion of this type, although questions remain about how to successfully regenerate cedar.
2.3 Forested Wetlands and Peatlands	Red Maple- Sensitive Fern Swamp	Somewhat open to nearly closed canopy (20 to 90% closure) dominated my red maple, sometimes with a relatively large component (up to 40% cover) of balsam fir, red spruce, or northern white cedar. Green ash and yellow birch are common associates. Maples may be widely spaced with multiple trunks and arching crowns. The shrub layer is patchy; winterberry is common and various other shrubs may be locally abundant. Herb layer is well developed and dominated by herbs, with dwarf shrubs less than 20 percent of herb cover. Bluejoint and sensitive fern are characteristic herbs. Bryoid layer is less than 35 percent cover; peat mosses are typical but do not form extensive, deep carpets.	Seasonally flooded remaining saturated through the growing season. On mineral soils or well decomposed organic material over mineral soil on flats or gentle slopes in small basins, often on floodplains of streams to small rivers. Soils are typically 30 to 60cm deep, loamy to silty in texture, sometimes with well decomposed muck over the mineral fraction, and pH 4.8 to 5.4.	Maintaining hydrologic integrity of the stream drainages with upland buffers. Harvesting and ATV use.

Objective	Maine Natural Communities*	Habitat/Population Attribute(s)	Natural Processes Responsible for Conditions	Limiting Factors
2.3 Forested Wetlands and Peatlands	Spruce-Larch Wooded Bog	Open canopy (20%, usually 20 to 50% closure) peatland characterized by black spruce and/or larch trees over bog vegetation (e.g., heath shrubs, graminoids, and peat mosses). Black spruce is usually dominant, but in some cases, larch may be more abundant. Red maple may be a component in somewhat more minerotrophic portions, and white pine may occur on hummocks. The shrub layer, including small trees, is usually well developed (> 30% cover). Labrador tea and three-seeded sedge are characteristic species. The bryoid layer has close to 100 percent cover and is dominated by peat mosses (peat generally > 30 cm deep).	Peatland setting usually less than 1,200 feet elevation. Nutrient poor or highly acidic peatlands (pH 4.2 to 5.2). May occur as part of fens, especially in kettle holes and are standard constituents of raised (ombrotrophic) bogs.	Maintaining hydrologic integrity of the entire wetland with upland buffers. Trees remain small and have limited economic use.
2.3 Forested Wetlands and Peatlands	Sheep Laurel Dwarf Shrub Bog	A dense layer of dwarf heath shrubs dominates this open peatland community. Stunted and scattered black spruce and larch trees form less than 25 percent cover. Heath shrubs carpet the hummocks and hollows of the peat substrate. Sedges contribute little cover (usually < 15%, occasionally 20 to 25%), the most common is tufted cotton-grass. Insectivorous plants such as pitcher plant and sundew can be quite numerous. The ground surface is covered by a spongy carpet of peat mosses.	Occurs within raised portions of peatlands, where ombrotrophic conditions prevail (plant growth is raised above the water table, and virtually all nutrients come from precipitation). The peat is commonly saturated with water most of the year. The substrate is highly acidic, pH 3.9 to 4.6.	Peat harvesting. Changes to bog hydrology through impoundment or draining, which leads to vegetation changes. Slow vegetation growth rates, due to poor nutrients, result in slow recovery from physical disturbance such as recreational trail use.
2.3 Forested Wetlands and Peatlands	Leatherleaf Boggy Fen	Vegetation is dominated by leatherleaf and other low heath shrubs. Most vegetation is less than 1-meter tall, although taller shrubs including black huckleberry, maleberry and sweet gale may be sporadic. In the shrub layer, leatherleaf is always present and usually dominate (30 to 60% cover). Typical bog plants include pitcher plant, sundew, and small cranberry scattered on the peat moss substrate.	This type is often a major constituent of ‘kettle hole bog” ecosystems and may be present in lakeshore peatlands or other sites with a fluctuating water table. Most sites are hydrologically fens.	Degradation by adjacent gravel mining. Changes to hydrology through impoundment or draining. Slow vegetation growth rates mean slow recovery from physical disturbances such as recreational trails.
2.4 Salt Marsh	Mixed Salt marsh (Mixed Graminoid-Forb Salt marsh)	Contain a mixture of graminoids and forbs, sometimes with patches of salt marsh cordgrasses, but not strongly dominate. Chair-maker’s rush is almost always present. Indicator species include creeping bent grass, freshwater cordgrass, sea lavender, wire rush, saltmarsh bulrush, New England aster, saltmarsh sedge and narrow-leaved cattail. Vegetation is patchy rather than zoned.	Occurs as a mosaic of dominates and lacks the strong zonation typical of the larger Spartina Salt marshes. Often occur along tidal creeks, or as a shoreline fringe in coves. Vegetation consists predominantly of low salt marsh regularly inundated twice daily by tides.	Development of the uplands that border the marsh.

Objective	Maine Natural Communities*	Habitat/Population Attribute(s)	Natural Processes Responsible for Conditions	Limiting Factors
2.4 Salt Marsh	Salt Hay Salt marsh (*Spartina* Salt marsh)	Tidal marsh consisting of salt meadow cordgrass, smooth cordgrass and/or black-grass, totaling more than 35 percent cover, often in bands corresponding to tidal inundation zones. Shrubs are virtually absent, and the herbaceous cover is usually more than 85 percent. Much of the marsh is high marsh, where salt meadow cordgrass forms meadows, and where black-grass may be dominant at slightly higher elevations. In the low marsh, along creeks or at elevations just below mean high water, smooth cordgrass is abundant. Salt pannes with abundant seashore Saltgrass may dot the high marsh; goose tongue may also be locally common. Sea lavender and seaside goldenrod are often found at the upper tidal fringe.	Associated with beach-dune systems (back barrier marshes) or outer reaches of estuaries (finger marshes). They are extensive along both sides of the tidal river or stream. The high marsh zone is only flooded by above average tides. Salt marsh peat is several meters thick.	Few of the larger salt marshes in Maine are pristine, with some having been filled and nearly all ditched at one time or another. Susceptible to degradation resulting from adjacent land uses.
2.5 Rocky Coast, Mudflats, Tidal Creeks, and Islands in Cobscook Bay	Rocky Coast	An open rocky shoreline found in the narrow zone between the high tide line and the upland areas. The intertidal zones of solid rock are often covered with seaweed that tolerates extremes of exposure to winds, waves, currents, and ice-scour. Species include seaweeds (Irish moss, rockweed, knotted wrack, hallow-stemmed kelp) and invertebrates (blue mussels, common periwinkles, dogwhelks, and springtails). Slopes vary from flat rocks to cliffs.	The intertidal zone widens with increasing maritime influence of wind, salt spray and fog.	Sea-level rise. Illegal and/or over harvest of rockweed for commercial use. Lack of enforcement of regulations.
2.5 Rocky Coast, Mudflats, Tidal Creeks, and Islands in Cobscook Bay	Mudflat	Typically non-vegetated, intertidal environments of silt and clay, with some sand, that occur in calm, sheltered depositional areas such as bays, lagoons, and estuaries. The habitat supports numerous burrowing invertebrates (e.g., clams, worms, and amphipods).	Geologically exposed layers of bay mud resulting from deposition of estuarine silts, clays, and marine animal detritus.	Sea-level rise. Invasive marine species such as green crabs.
2.5 Rocky Coast, Mudflats, Tidal Creeks, and Islands in Cobscook Bay	Tidal Creeks	Tidal creeks, or estuaries have a gradient of salinity becoming fresher further upstream from the ocean. Land-derived nutrients combine with nutrients from tidal marshes, rockweeds, and oceanic sources to stimulate phytoplankton growth throughout the year. Eelgrass and other submerged aquatic vegetation grow in estuaries and provide a three-dimensional habitat that serve as a critically important nurseries for larval and juvenile invertebrates and fish; and feeding and nesting areas for migratory fish and birds.	Location and extent of tidal creeks are influenced by substrate, wave and tidal energy, tidal range, and slope.	Sea-level rise.

Objective	**Maine Natural Communities***	**Habitat/Population Attribute(s)**	**Natural Processes Responsible for Conditions**	**Limiting Factors**
2.5 Rocky Coast, Mudflats, Tidal Creeks, and Islands in Cobscook Bay	Islands	Offshore islands of unique rocky ledges and cobble lined shores. High-energy, climatically extreme environment. Vegetation can range from dense stands of red spruce and balsam fir to mixed grasses and small shrubs.	Geological processes along with wind, salt spray and wave action. Islands cause upwelling of deep, nutrient-rich water to the surface, enriching nearby waters. Currents driven by tidal action swirl around islands and sure through passages creating a fuller effect that increases the volume of food available to filter feeders.	Historically (approximately 100 years ago) islands were cleared for Sheep or Cattle pasture. Many islands were burned repeatedly to remove trees and increase hay production. Reforested islands typically have trees less than 100 years old.

SELECTING PRIORITY RESOURCES OF CONCERN

Management of the refuge requires considering a very large number of species to arrive at a smaller set of species or species groups (ROCs) that will focus objectives and drive future management actions (Taylor and Paveglio 2017). The comprehensive ROC list (ROC Table 4; USFWS 2019a) contains the full array of species known to be on the refuge; this list allowed the refuge staff to take stock of the many species present and their associated conservation status. The Priority ROC Selection Tool was used to prioritize the comprehensive ROC list and arrive at the Priority ROCs for the refuge (Casey et al. 2021). The species and species groups that received the highest scores on the following criteria were selected as Priority ROCs (Table 3-2, Table 3-3):

- Species/species groups that are most in need of help (high conservation priority).
- Species reliant on refuge resources.
- Species likely to benefit from habitat management efforts.
- Species strongly associated with overall ecosystem health.

TABLE 3-2. PRIORITY RESOURCES OF CONCERN AND OTHER BENEFITTING SPECIES FOR MOOSEHORN NWR.

Objective / Habitat Type	Focal Species	Other Benefitting Species
1.1 Spruce-Fir	Bay-breasted Warbler Magnolia Warbler Swainson's Thrush	Migrating landbirds, Breeding: Cape May Warbler, Blackpoll Warbler, Boreal Chickadee, Olive-sided Flycatcher, Yellow-bellied Flycatcher, Purple Finch, Blackburnian Warbler, Spruce Grouse, American Redstart, Sharp-shinned Hawk, Black-backed Woodpecker, American Marten
1.2 Spruce-Northern Hardwood Forest	Blackburnian Warbler Northern Parula Black-throated Green Warbler Black-throated Blue Warbler	Migrating landbirds, Breeding: Cape May Warbler, Spruce Grouse, Swainson's Thrush, Ovenbird, Sharp-shinned Hawk
1.3 Pine-Mixed Forest	Black-throated Green Warbler Pine Warbler Ovenbird	Migrating landbirds, Breeding: Blackburnian Warbler, Red Crossbill, Sharp-shinned Hawk
1.4 Northern Hardwood Forest	Veery Ovenbird Black-throated Blue Warbler Canada Warbler	Migrating landbirds, Breeding: Chestnut-sided Warbler, Purple Finch, Little Brown Bat, Black-and-white Warbler, Broad-winged Hawk, Eastern Wood-pewee, Northern Flicker, Northern Goshawk, Rose-breasted Grosbeak, American Marten
1.5 Early Successional Aspen-Birch	American Woodcock Chestnut-sided Warbler Yellow-bellied Sapsucker	Olive-sided Flycatcher, Canada Warbler, Whip-poor-will, Common Nighthawk, American Redstart, Ruffed Grouse, Northern Flicker, Nashville Warbler

Objective / Habitat Type	Focal Species	Other Benefitting Species
1.6 Old Fields and Lowbush Blueberry	American Woodcock Bobolink Monarch Butterfly (bees and native pollinators)	Migrating landbirds, Breeding: Field Sparrow, Brown Thrasher, Song Sparrow, Native Bee species
2.1 Freshwater Impoundments	American Black Duck Ring-necked Duck (waterfowl) American Bittern (marsh birds) American Eel Alewife	Wood Duck, Green-winged Teal, Blue-winged Teal, Common Merganser, Hooded Merganser, Beaver, American Woodcock, Canada Warbler, Northern Parula, Virginia Rail, Sora, Pied-billed Grebe, Marsh Wren, Northern Leopard Frog
2.2 Streams and Associated Wetlands	American Black Duck Alder Flycatcher American Bittern (marsh birds) Eastern Brook Trout American Eel Alewife	Cavity nesting waterfowl, Beaver, American Woodcock, Canada Warbler, Northern Parula, Atlantic Salmon, freshwater mussels
2.3 Forested Wetlands and Peatland	Palm Warbler Northern Waterthrush Wood Duck (waterfowl)	Northern white cedar, Black-backed Woodpecker, Palm Warbler, Yellow-bellied Flycatcher, Canada Jay, Boreal Chickadee, Swainson's Thrush, Olive-sided Flycatcher, American Three-toed Woodpecker, Common Yellowthroat
2.4 - Salt Marsh	Nelson's Sparrow American Black Duck	Gaspé arrow grass, migrating waterfowl and wading birds
2.4 Rocky Coast, Mudflats, Tidal Creeks, and Islands in Cobscook Bay	American Black Duck Semipalmated Sandpiper (shorebirds)	Rockweed, Bald Eagle, migrating shorebirds, and migrating and wintering waterfowl

TABLE 3-3. PRIORITY SPECIES AND PREFERRED HABITAT STRUCTURE.

*Priority Species**	Habitat Structure
Bay-breasted Warbler	Dense spruce-fir stands with intermixed deciduous trees, particularly early successional stages of conifer stands and edges. Numbers greatly increase with Spruce Budworm outbreaks; average territory is 2.5 acres (Venier 2020)

*Priority Species**	**Habitat Structure**
Magnolia Warbler	Small, close-growing, young conifers in either pure stands or mixed with hardwoods. Presence of young conifers is an aspect of habitat. Broadly tolerant of tree size. Highest concentrations in young second-growth spruce but found in mature forest if dense understory is present (Dunn and Hall 2020).
Swainson's Thrush	Most strongly associated with coniferous forests. Is a bird of mature forests, but also use early successional habitat. Canopy closure (64%), moderate understory cover, tree density (22 to 38 cm DBH) and conifer component are important attributes (Mack and Yong 2020).
Blackburnian Warbler	Mature conifer forests (greater than 80% canopy cover) of spruce, fir, hemlock, and pines, and in mixed forests including deciduous forest with patches of conifers; territories along the coast of Maine range from 1 to 1.5 acres (Morse 2020).
Northern Parula	Prefers tall, mature coniferous forest with spruce, hemlock and fir in moist bog and swamp habitat where beard moss is abundant. In hardwood stands of sugar maple, red maple, paper birch and yellow birch. Most abundant in 40-year-old stands (Moldenhauer and Regelski 2020).
Black-throated Green Warbler	Characteristic inhabitant of boreal coniferous forest and transitional area between coniferous and deciduous forests; inhabits red and white spruce forest. Uncommon in lowland spruce-fir dominated by Bay-breasted Warbler (Morse and Poole 2020)
Black-throated Blue Warbler	Breeding habitat includes mature deciduous and mixed deciduous-conifer forests with a shrubby understory (Holmes et al. 2020)
Black-throated Green Warbler	Characteristic inhabitant of boreal coniferous forest and transitional area between coniferous and deciduous forests; inhabits red and white spruce forest. Uncommon in lowland spruce-fir dominated by Bay-breasted Warbler (Morse and Poole 2020)
Pine Warbler	Characteristic of pine forests of eastern North America. Uses a variety of upland pine and pine-hardwood forest types. Optimal nesting habit is pure, dense, mature pine stands that lack a tall deciduous understory (Rodewald et al. 2020)
Ovenbird	Typically found in relatively mature, large, contiguous tracts of deciduous or mixed deciduous/coniferous closed-canopy forest. Favors territories with less ground cover, deeper leaf litter, and higher prey biomass than average. Canopy heights of 16 to 22 m and percent canopy closure from 60to 90 percent are repeatedly cited as important parameters. Percent ground cover, slope and basal area and related measurements are important, but vary widely among studies. The minimum contiguous habitat area required for this species to breed is 100 ha. Ovenbirds breeding in mature forest habitat use early successional patches such as regenerating clearcuts during the post-fledging period. (Porneluzi 2020)
Veery	Generally, inhabits damp, deciduous forest. Strong preference for riparian habitat, often associated with Beaver wetlands. Uses mixed balsam fir and birch forests with understory of fir saplings, birch samplings, mountain ash and other broadleaf species (Heckscher et al. 2020).
Canada Warbler	Breeding habitat includes contiguous deciduous, mixed wood and coniferous forests interspersed with openings that provide an average overstory tree height of 55 feet within greater than 30 percent canopy closure, a dense foliar mid-story and well-developed shrub layer 7 to 20 feet in height, and moist soils. Average territory is 2.5 acres (Reitsma 2020)
American Woodcock	Fertile moist soil that contains earthworms for foraging (typically in alder swales). Fields or forest openings at least three acres for courtship and nocturnal roosting; dense, brushy (> 60% shrub cover) swales or young hardwoods (1 to 20 years old) dominated by aspen and birch in proximity to alder wetlands and herbaceous openings for diurnal cover; nest on the ground; spring singing grounds of the male range from 0.25 acres to more than 100 acres; four to seven males per mile in good habitat. (Sepik et al. 1988, Dwyer et al. 1988, Kelley et al. 2008, McAuley et al. 2020)
Chestnut-sided Warbler	Nests in dense early successional hardwoods up to 10 feet tall with less than 35 percent overstory canopy closure. Territory is 1 to 3 acres. Prefers forest patches larger than 250 acres (Byers et al. 2020)

*Priority Species**	**Habitat Structure**
Yellow-bellied Sapsucker	Nests in second growth deciduous or mixed forests with aspen, paper birch, American beech, white pine, and hemlock, often in riparian areas. Requires dead or live trees with decay. Prefers aspen for constructing nest cavity. Home range is 5.1 to 5.4 acres. Forages in orchards, parks, and woodlands (Walters et al. 2020)
Bobolink	In the eastern U.S., Bobolinks prefer fields comprised of a mixture of grasses and broad-leaved forbs (e.g., red clover, dandelion). At the patch level, they can show strong area sensitivity, with probability of occurrence only reaching 20 percent in fields in Maine greater than 100 ha. Fields greater than 30 ha support more than twice the number of males per 100 m of transects than fields less than 10 ha. (Renfrew 2020)
Monarch Butterfly (bees and native pollinators)	Native milkweed species are a food source for monarch larvae and provide nectar for adults and a variety of other insect species. Spring blooming nectar plants (blooming approximately April 20 to June 1) to support migration and early pollinator species. Summer blooming nectar plants (blooming approximately June 2 to August 15) to support breeding populations. Fall blooming nectar plants (blooming approximately August 16 to October 30) as a source in fall to store enough energy to survive the long journey to overwintering sites and to survive winter with minimal nectar availability.
American Black Duck	Breeding and migrating habitat include herbaceous wetlands, flooded meadows and shrub-swamps (Longcore et al. 2020).
Ring-necked Duck (waterfowl)	Commonly breeds in shallow (< 1.5m), dense swamps, marshes, and bogs with low vegetation cover (especially sweet gale or leatherleaf), typically with a pH range of 5.5 to 6.8, and preferably near or in woodlands. Also uses sloughs, Beaver flowages, and small potholes near larger wooded lakes, rivers, or reservoirs with submerged and emergent vegetation. In winter, fresh or brackish marshes, lakes, rivers, and estuaries. (DeGraff and Yamasaki 2001).
American Bittern (marsh birds)	Freshwater wetlands with tall, dense emergent vegetation, such as cattail and bulrush, interspersed with clumps of woody vegetation and open water with water depth greater than 18 inches and a vegetation/open water ratio of 50:50 (Lowther et al. 2020)
American Eel	American Eels have multiple habitat requirements (open oceans, large coastal tributaries, small freshwater streams, lakes, and ponds). Eggs hatch at sea. The larval stage lasts about a year and is transported along the eastern coast of the US by ocean currents. When they reach 6 to 9 cm, they become elvers and migrate toward estuaries and freshwater in the spring, most moving up rivers and streams over a period of months or years. They enter sub-adult stage known as yellow eels. They mature over a 6 to 7-year period, longer in the northern cold waters. Important habitat for yellow eels includes the soft, undisturbed sediments of river and lake bottoms, estuaries, and large streams. At sexual maturity, Eels undergo a final metamorphosis into the silver eel stage. This occurs in autumn and the Eels descend the streams by night, no longer feeding. Migrating Eels are highly capable of passing over, around, and under stream barriers. The digestive tract degenerates, and maturation of the gonads occurs after they reach salt water. Spawning occurs midwinter in the Sargasso Sea of the Atlantic, and death follows. (Strickland 2001)
Alewife	Alewife can adjust to a wide range of salinities and may prefer cooler water than other anadromous fish. Spawning habitat ranges from areas with sand, gravel, or coarse stone substrate to those containing submerged aquatic vegetation or organic detritus. Substrates with 75 percent silt or other soft material containing detritus and vegetation are suggested as optimal for spawning, egg, and larval habitat. Adult and sub-adults spend most of their lives at sea following a north-south seasonal migration along the Atlantic coast and only return to rivers to spawn. After spawning, fish return downstream. Beginning in late summer, juveniles move downstream in waves in response to dropping water temperatures and generally are found in the lower ends of rivers and in freshwater tributaries. (ASMFC 2022)
Alder Flycatcher	Described as a bird of wet thickets. Found in brush and shrubby wetlands, at edges of woods, damp thickets of alder-buckthorn. In Nova Scotia, most common in early successional stands, 3 to 8 years after clearcutting or fire, in hardwood forests, when shrub stem density and shrub foliage cover peak. (Lowther 2020)
Eastern Brook Trout	Brook trout are specific in their habitat selection at different stages of their life. Habitat preference varies depending on other factors, such as temperature, dissolved oxygen, and food availability. Brook

*Priority Species**	**Habitat Structure**
	Trout eggs are usually found in gravel depressions, influenced by groundwater. Stream flow in these areas is usually low to moderate. Larvae tend to seek out protected zones, which usually consist of pockets under and in between rocks and highly vegetated areas. Nursery habitat for larvae and juveniles includes littoral and sublittoral zones in lakes and ponds, where submerged aquatic vegetation and macro algal beds provide important nursery habitat. Juveniles rely on several different substrate and habitat types, including cobble and boulder stream bottoms, small undercut banks, and pools. As they become adults, they tend to choose habitats that fit their size and afford protection from predators (e.g., deeper pools and larger undercut banks). (*Brook Trout Species Account*)
Palm Warbler	Prefers bogs, open coniferous forest and partly open habitat with scattered trees and heavy undergrowth, usually near water. Typically, in bogs with scattered conifers interspersed with sedges or low shrub cover. In Maine peatlands, highest breeding densities found in areas with ground cover of sphagnum moss, a well-developed ericaceous layer, and 25 to 50 percent forest cover (black spruce, tamarack, white pine) (Wilson 2020)
Northern Waterthrush	Dense cover near ground level, combined with the presence of surface water, are the two most consistent habitat requirements throughout the breeding range. Typical breeding habitats include cool, dark, wooded swamps, thickets of bogs, and riparian thickets along the shores of lakes, rivers, and streams. In boreal forests across Canada, nests primarily in spruce bogs, along alder-and willow-bordered rivers and lakes, and in swamps and wet woodlands. (Whitaker and Eaton 2020)
Wood Duck (waterfowl)	Mature forests with suitable cavities. Prefer sites close to or over water and near good brood-rearing areas. Will use nest sites within 2 km of water. Abundant plant and invertebrate food bases close to suitable nest sites are essential components of breeding habitat. Interspersion of flooded shrubs, water-tolerant trees, and small areas of open water with 50 to 75 percent cover are favored. Scrub/shrub wetlands with overhead cover of downed timber and woody shrubs such as buttonbush, willow, and alder are used extensively (Hepp and Bellrose 2020)
Nelson's Sparrow	Found in high salt marsh dominated by saltmeadow grass (Spartina patens) and blackgrass (Juncus gerardii). Along the coast of Maine, found in salt marshes where smooth cordgrass, saltmeadow grass, and blackgrass are bordered by cattail and marsh elder. Typically nest in drier sections of salt marshes; territory size is 1.0 to 7.7 acres (Shriver et al. 2020)
Semipalmated Sandpiper (shorebirds)	Birds stage (flock in preparation for migration) in areas of shallow fresh or salt water and little vegetation, muddy intertidal zones, or along edges of lakes, usually on soft silt/clay mudflats, or at junction of short-grass marsh and tidal flats. In fall, often roost in large numbers on exposed beaches during high tide when marshlands are flooded (Hicklin and Gratto-Trevor 2020)

*Species accounts for birds are found in Billerman et al. (2020), unless otherwise mentioned.

SELECTING PRIORITY ECOSYSTEMS

With a limited budget and staff time, the refuge also needed to prioritize the ecosystems and habitats described in Table 3-1 for planning and management purposes. Each ecosystem was classified as Priority I or Priority II (Table 3-4). Prioritizing helps ensure that refuge staff know where to spend their limited time and funding. Priority 1 areas are either:

- sufficient in *extent and/or quality* to contribute to the refuge's highest priority ROCs, or
- are experiencing a *high threat* or *urgent need* for management to support the refuge's highest priority ROCs (Casey et al. 2021).

This ranking was used to develop the Moosehorn NWR IMP (Mills et al. 2021). Inventory and monitoring surveys are time-intensive; the ranking allows the refuge staff to focus most surveys on Priority I habitats.

TABLE 3-4. PRIORITY ECOSYSTEMS AT MOOSEHORN NWR.

Ecosystem	Priority Level	Reasons for Ranking	Limiting Factors/Threats
Spruce-Fir Forest	I	The Spruce-Fir Forest is predicted to shift north under some climate change scenarios; due to coastal influence of Cobscook Bay it is possible that the areas of spruce-fir forest on the Edmunds Division may remain intact as this forest type migrates north and is replaced by other types such as pine-oak. This forest type provides nesting habitat for several species of birds that are high (very high) priority in BCR 14 and Partners in Flight (PIF) 28, such as the Bay-breasted Warbler, Blackburnian Warbler, Cape May Warbler, and Black-throated Green Warbler.	Climate change; insect outbreaks; large scale natural disturbances like fire and windstorms
Spruce-Northern Hardwood	I	This is a predominant forest type on the refuge, it provides nesting habitat for several high priority species identified in the PIF and BCR plans, including the Blackburnian, Black-throated Blue, Black-throated Green Warblers, and Northern Parula.	Climate change; insect outbreaks; large scale natural disturbances like fire and windstorms
Early Successional Aspen-Birch	I	One of the primary reasons Moosehorn was established was to provide habitat for and to study the American Woodcock. This species, as well as several other priority species, require early successional hardwood habitats to persist. Moosehorn has a long history of research and demonstrating habitat management techniques to benefit early successional wildlife.	Succession; lack of disturbance; invasive plants and insects
Freshwater Impounded Wetlands	I	Moosehorn has 25 functional freshwater impoundments; at one point, there were over 50. These are the only places some wetland species are found, such as the Sora and Virginia Rail and Pied-billed Grebe. They also provide nesting and brood rearing cover for American Black Ducks and several other priority species.	Climate change; invasive plant species; pollution from off-refuge sources
Old Fields and Lowbush Blueberry	II	Old fields provide the open habitat needed by American Woodcock; old fields provide nesting habitat for bobolinks, a declining species in this area; fields also provide a variety of flowering plants that provide nectar for pollinators.	Succession, requires regular mowing or other treatments; invasive plants
Salt marsh	II	Salt marsh habitat at Moosehorn is limited in size, but important since there has been little or no human alteration of the habitat. Although it is an important ecosystem, we function largely as stewards since we primarily just protect salt marsh rather than doing any actual management. Options to facilitate inland, upslope marsh migration are very limited.	Climate change, sea level rise; disturbance from commercial harvesters and recreational boaters
Northern Hardwood	II	This is not a common forest type at Moosehorn at the present time. It will be monitored, and where appropriate, managed to maintain its integrity.	Climate change; invasive insect outbreaks; invasive plants
Streams and Associated Wetlands	II	Refuge streams are important for several species of fish including Brook Trout, Alewives, and American Eels. Management will focus on protection of water quality by maintaining adequate buffers and monitoring of temperature and other parameters, and breaching select beaver dams on streams particularly important for fish passage.	Climate change; pollution from off-refuge sources; invasive species; degraded riparian habitat, stream blockages (e.g., failing culverts

Ecosystem	Priority Level	Reasons for Ranking	Limiting Factors/Threats
Rocky Coast, Mudflats, Tidal Creeks, and Islands in Cobscook Bay	II	An important habitat for migrating and wintering waterfowl, including the American Black Duck; migrating shorebirds. Little management is needed to maintain these habitats. Management will consist of monitoring and preventing disturbance and illegal harvest of rockweed.	Over-harvest of rockweed; human disturbance from commercial and recreational boats; climate change, invasive marine species; oil or other toxic material spill
Pine and Mixed Forest	II	This forest type is limited at Moosehorn but provides habitat for several priority species as well as pine warblers.	Climate change; invasive species
Forested Wetlands and Peatlands	II	Vernal pools are important and common parts of the forested landscape. The refuge can passively protect these habitats by maintaining adequate forested buffers.	Climate change, invasive species

4. HABITAT GOALS AND OBJECTIVES

Goal 1. Uplands

Objective 1.1 Spruce-Fir Forest
Objective 1.2 Spruce-Northern Hardwood Forest
Objective 1.3 White Pine-Mixed Conifer Forest
Objective 1.4 Northern Hardwood Forest
Objective 1.5 Early Successional Aspen-Birch
Objective 1.6 Old Fields and Lowbush Blueberry

Goal 2. Coastal and Freshwater Wetlands and Streams

Objective 2.1 Freshwater Impounded Wetlands
Objective 2.2 Lakes, Streams, and Associated Wetlands
Objective 2.3 Forested Wetlands and Peatlands
Objective 2.4 Salt Marsh
Objective 2.5 Rocky Coast, Mudflats, Tidal Creeks, and Islands in Cobscook Bay

INTRODUCTION

The refuge's ROCs were used to develop biological goals and objectives. The format of the objectives follows a regional template created in 2021 to standardize the objective statements across refuge units (USFWS 2021d). Five fundamental management objectives are defined for each ecosystem. Some objectives may not apply in all systems (for example, federally threatened and endangered species are not found in all ecosystems). The fundamental objectives include:

- Maintain the ecosystem over time.
- Support migratory bird populations.
- Support recovery of federally threatened and endangered species.
- Support refuge priority ROCs.
- Maintain biological diversity and ecological integrity.

Each fundamental objective is described by a set of SMART, measurable attributes that could be measured. SMART (Specific, Measurable, Attainable, Results-oriented and Time bound) criteria provide clarity about the desired future conditions described in the objective (Powell and Casey 2019). Each attribute has a measurement unit (the thing to measure) and a direction of preference (more, less, or within a range), which then guide the development and selection of management strategies (chapter 5) and monitoring tools (Mills et al. 2021).

The objective statements describe what the refuge hopes to achieve and are 'aspirational' (i.e., they represent the desired future condition of the ecosystems, not necessarily what they look like today). Development of habitat-based management objectives facilitates the development of annual habitat management work plans that direct on-the-ground activities aimed at optimizing conditions for native wildlife and plants.

Note: *The acreages presented throughout the HMP are estimated from Geographic Information Systems (GIS) software (ArcMap and ArcGIS pro packages by ESRI). The calculated acres may vary from the official acreages maintained by the USFWS Division of Realty. Many of the tracts at Moosehorn NWR were acquired in the 1930s, 1940s, and 1950s, prior to the advances in technology which now permit accurate measurements.*

FIGURE 4-1 BARING DIVISION HABITAT OBJECTIVES FOR MOOSEHORN NWR.

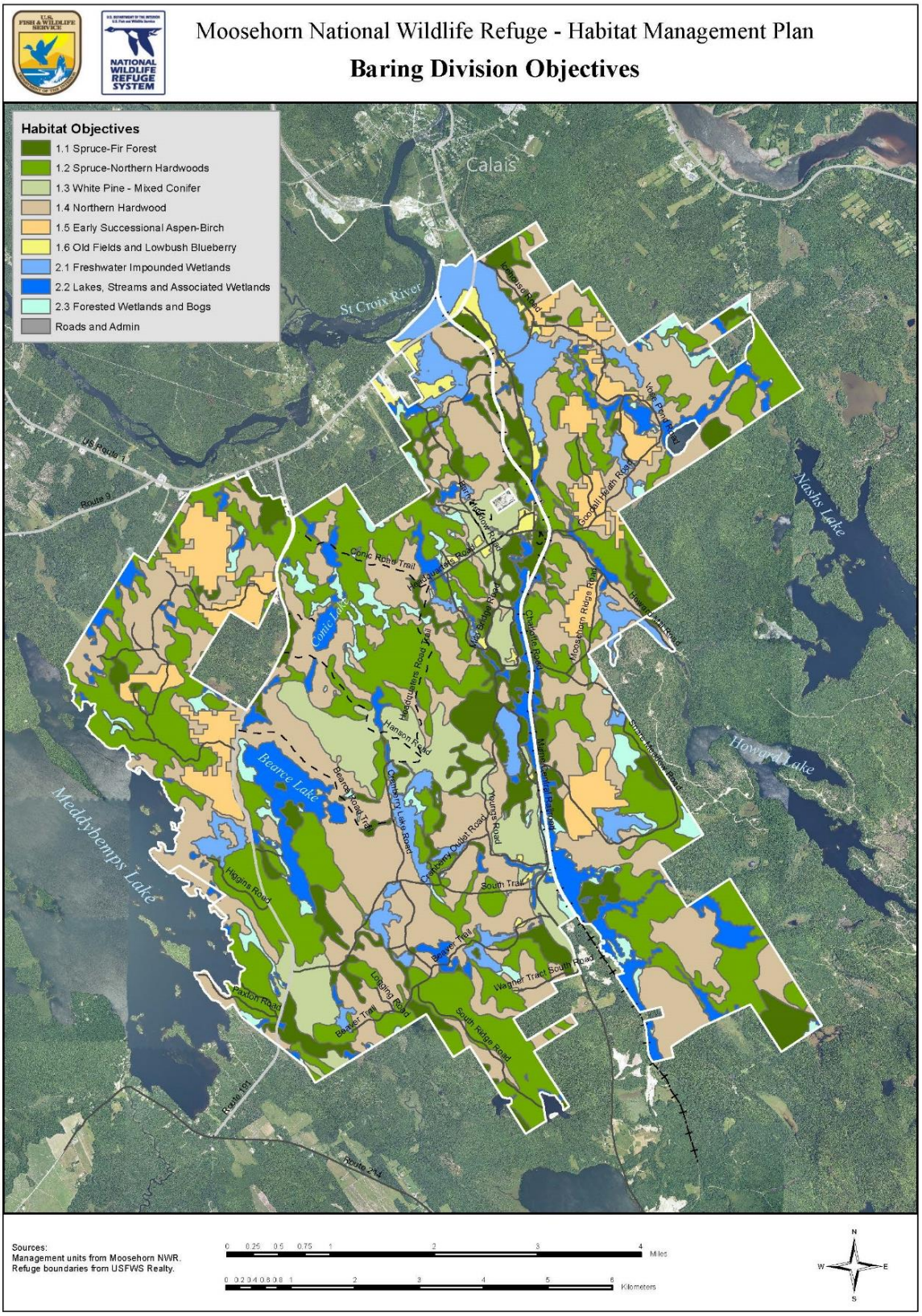
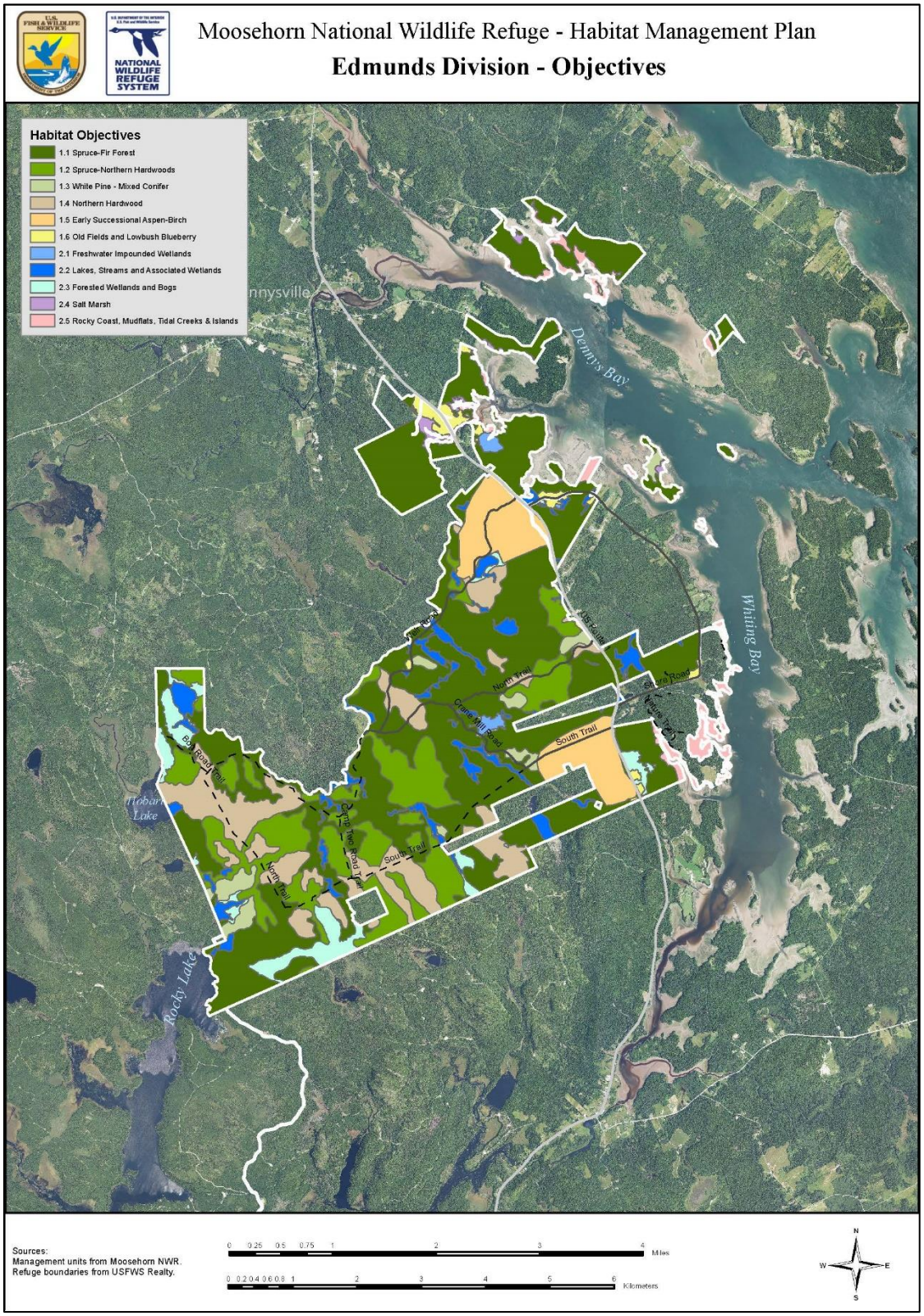


FIGURE 4-2 EDMUNDS DIVISION HABITAT OBJECTIVES FOR MOOSEHORN NWR.



Goal 1. Uplands

Perpetuate the biological integrity, diversity, and resiliency of Moosehorn NWR's upland ecosystems to sustain plant communities and wildlife native to the Atlantic Northern Forest Region, including species of concern.

MOOSEHORN NWR SPRUCE-FIR FOREST VIEWED FROM THE BALD MOUNTAIN EAGLE NEST. PHOTO CREDIT: USFWS

OBJECTIVE 1.1 SPRUCE-FIR FOREST

Manage 6,439 acres of late-successional spruce-fir forests (approximately 1,932 acres on Baring Division, and 4,507 acres on Edmunds Division) on Moosehorn NWR that reflect ecological site conditions to maintain the ecosystem over time (e.g., species composition, regeneration, size class distribution), support migratory bird species (e.g., migrating and breeding landbirds), maintain native biological diversity and ecological integrity (e.g., reduce invasive species), and provide for management demonstration areas, from 2023 to 2038 with the following attributes (measurement units) and aspirational targets (values):

Maintain the ecosystem over time

Spruce-fir Broom-moss Forest (upland spruce-fir)

- Present on hill slopes with very acidic (pH 4.1 to 5.2), rocky and/or shallow (< 15 inches to bedrock) xeric to mesic soils.
- Greater than 70 percent overstory canopy closure (canopies > 16 ft. in height) with trees greater than 50 feet in height dominated by red spruce (> 60% cover) mixed with less than 40 percent cover of other species (e.g., paper birch, yellow birch, red maple, northern white cedar, white pine, or balsam fir).

- Approximately 30 percent canopy closure in the midstory (canopies 6 to 16 ft. in height) and understory (2 to 6 ft. in height) dominated by red spruce and balsam fir.
- Ground layer (canopies < 2 ft. in height) is a dense (60 to 70% cover) carpet of bryophytes (e.g., red-stemmed moss, stair step moss, three-lobed bazzania moss and broom moss), bracken fern and reindeer lichen.

Spruce-fir Cinnamon Fern Forest (lowland spruce-fir)

- Present on low flats where acidic mineral soil remains moist throughout the growing season.
- Greater than 70 percent overstory canopy closure (canopies > 16 ft. in height) with trees greater than 50 feet in height dominated by red spruce (> 40% cover) with occasional stands of black spruce and cedar.
- Approximately 30 percent canopy closure in the midstory (canopies 6 to 16 ft. in height) dominated by red spruce and balsam fir.
- Approximately 30 percent understory canopy closure (2 to 6 ft. in height) with sheep laurel and mountain holly.
- Ground layer (canopies < 2 ft. in height) dominated by cinnamon fern, three-seeded sedge, and a thick carpet of sphagnum moss.

Both Forest Types

- Small canopy gap openings of varying size (0.25 to 2.0 acres) with dense native spruce and fir regeneration (approximately 1% of the forest per year in regeneration).
- A minimum of 300 trees per acre > 5 inches DBH, 180 to 240 feet[2] basal area per acre, and a 10-inch quadratic mean diameter (QMD[2]) with greater than 300 percent CV.
- A range of tree diameters, including 200 live trees 5 to 8 inches DBH per acre, 70 live trees 9 to 12 inches DBH per acre, 23 live trees 13 to 16 inches DBH per acre, at least 9 live trees greater than 17 inches DBH per acre and approximately 15,000 seedlings/acre and 300 saplings/acre.
- Approximately one to two mature red spruce trees (200 to 300 years old) per acre.
- Less than 50 percent of stems less than 6 feet in height browsed by White-tailed Deer or Moose.

Support migratory birds

- At least 20 species of landbirds (e.g., Bay-breasted Warbler, Magnolia Warbler, Swainson's Thrush) are annually present during the breeding season (June to July), spring migration (April to May) and fall migration (August to September)

Maintain biological diversity and ecological integrity

Forest Structure

- Contiguous forest blocks (i.e., > 250 acres and at least 550 yards wide), and greater than 90 percent of forest blocks are connected by corridors at least 55 yards wide or within approximately 1.2 miles of another forest block.
- Indicator plants of arboreal lichens (long *Usnea* spp. or *Bryoria* spp.) are present on overstory trees.

[2] Quadratic Mean Diameter (QMD) is considered more appropriate for estimating the average DBH of trees than the arithmetic average. It is always larger than the arithmetic average and is directly related to the basal area. The coefficient of variation (CV) is a measure of variability. It is the ratio of the standard deviation to the mean (average). For example, a CV of 200 percent means that the standard deviation is 200 percent of the quadratic mean. Together, these measures indicate the average size of the trees and how variable they are in size. A high QMD indicates a forest with larger trees and a high CV indicates more variability in tree sizes, both attributes may be related to high structural diversity, which is considered positive for most wildlife.

- At least four snags per acre 8 to 11 inches DBH, six snags per acre 12 to 22 inches DBH, and 0.25 snags per acre greater than 22 inches DBH.
- At least four cavity trees per acre greater than 12 inches DBH including 1 tree per acre greater than 20 inches DBH.
- At least 9 tons of downed woody material (DWM) per acre with an average large end diameter greater than 10 inches and average length greater than 24 feet, the larger the better, and presence of fine material including smaller limbs and branches.

Invasive Species

- Eradication of high priority invasive plant species (e.g., common and alder buckthorn, black locust) to zero areas occupied.

Rationale

The spruce-fir forest ecosystem is found over most of the northern half of Maine, including the Downeast region that includes Moosehorn NWR (Gawler and Cutko 2018). The dominant conifers in this region are red spruce and balsam fir. The spruce-fir forest communities on the refuge include Spruce Fir Broom-moss Forest (with an abundance of the common broom moss, *Dicranum scaparium*) and Spruce fir-Cinnamon Fern Forest. The latter community is noted for the presence of cinnamon fern, three-way sedge, and a dense carpet of mosses, including *Sphagnum* sp., red-stemmed moss, and three-lobed bazzania. Spruce-fir forests on the refuge are primarily in the lowlands, while the hardwood-dominated forests occur on mid-elevation hillsides (Gawler and Cutko 2018). Approximately 8.7 percent of the refuge's soils, as determined by ecological site capabilities that relate plant communities to the landforms and soils on which they occur, support spruce-fir forest (182 acres are within the Wilderness areas and 2,317 acres are outside of the Wilderness) (Johanson et al. 2016). Some of the best examples of low elevation spruce-fir occur at the southern end of the Baring Division near James Pond and Bald Ledge.

REFUGE FORESTER, MICHAEL HEATH, MEASURING A TREE. PHOTO CREDIT: USFWS

Late successional forests and their associated features—large trees, large amounts of standing and downed dead wood, diverse vertical structure, and certain ecological processes absent from young forests (such as soil churning by wind throw tip-ups)—are important to conserving forest biodiversity (Whitman and Hagan 2007) and offer other benefits such as carbon storage (Ducey et al. 2013). In Maine, older forests (stand age of more than 120 years) represent less than 3 percent of the forests, and true old growth (little or no human disturbance) may be as little as 0.1 percent (MDIFW 2015). Less than 2 percent of Washington County's forest stands were estimated to be over 120 years old (Cutko and Schlawen 2012).

The Moosehorn NWR contains several stands of late successional forests. The forests on the refuge, particularly in the Wilderness Areas, are generally older and contain larger trees than most forests in surrounding Washington County and throughout Maine. During a survey of the refuge for rare and invasive plants in 2012, the average age of forest stands in the State of Maine was 60 years old, while the average stand age in the Moosehorn Wilderness Areas was determined to be 136 years old (Cutko and Schlawin 2012). In contrast, it is unlikely that economic pressures will allow many other forest tracts, primarily private ownerships, in Downeast Maine to develop old forest characteristics. This situation, combined with the knowledge that old forests and associated habitat features are declining globally (Whitman and Hagan 2007), affirms that the Moosehorn NWR is an important site for maintaining late successional forests.

Currently, aspen-birch forest is the dominant forest type on the Baring Division. In contrast, the aspen-birch type in Washington County accounts for only 13 percent of the forest cover. Many older aspen-birch stands on the refuge are transitioning over time to softwood or mixed wood stands, a pattern characteristic of this early successional type throughout eastern Maine. Due to a history of past fire and logging, areas on the Baring Division are undergoing a temporal transition from aspen-birch to spruce-fir (Cutko and Schlawin 2012).

ARBOREAL LICHEN *USNEA*, SPP. (BEARD LICHEN). PHOTO CREDIT: D.J. TAYLOR

Species most dependent on older, late successional forests tend to be small, non-vertebrate species, such as mosses, lichens, fungi, and insects (Hagan and Whitman 2004), which are important components of the biodiversity of many forest types (MFS 2010). In a study of lichens in northern hardwood and spruce-fir forests of northern New England and western New Brunswick, Selva (1994) found that epiphytic lichen flora became richer over time, with older stands harboring more rare species. The presence of adequate populations of late successional epiphytes is evidence of the continuity of the functions and processes of late successional forests. Continuity refers to the persistence of big trees and big logs in a forest stand over hundreds of years, even when the forest is affected by different disturbances, such as wind, disease, fire, or logging. Species that move or disperse slowly through the landscape and prefer old trees or logs, are the species most at risk if late-successional forest is not sustained (Hagan and Whitman 2004).

A suite of bird species nest in spruce-fir forest on the refuge, including Bay-breasted, Cape May, Tennessee, Blackburnian, and Magnolia Warblers, Northern Parula, Olive-sided Flycatcher, Spruce Grouse, and Swainson's Thrush. Several of these species are of regional or national conservation concern due to population declines (Dettmers 2006, USFWS 2021c, Rosenberg et al. 2016). The Partners in Flight Landbird Conservation Plan (Rosenberg et al. 2016) lists the Olive-sided Flycatcher and Bay-breasted Warbler as two of the 86 birds of continental (range-wide) concern. Each bird species uses different habitat features or niches within spruce-fir forests. For example, the Olive-sided Flycatcher takes insects by sallying out from a tall perch, typically from tall spruces or standing dead trees near a bog, wetland, wooded stream, or forest edge. The Northern Parula prefers spruce, hemlock, or fir woodlands where the moss-like *Usnea* lichen is found, which the warbler uses as nesting material. Spruce Grouse feed on conifer buds and needles and is a resident bird in large, dense stands of spruce-fir (DeGraaf and Yamasaki 2001).

The Bay-breasted Warbler is a bird of conservation concern in the Northeast (USFWS 2021c) and a bird of highest conservation concern in the BCR 14 region (Dettmers 2006). They typically breed in mature stands containing spruce and/or fir, and often near water. The Bay-Breasted is one of three warbler species, along with Tennessee and Cape May, that are generally considered "budworm specialists," in that they can increase in density very rapidly during a Budworm outbreak, and even produce larger clutches. Budworm populations are highly cyclic in nature, and these fluctuations may be responsible for much of the variation seen in population data for the Bay-breasted Warbler (Sauer et al. 2014, NHFG 2015).

Spruce Budworm outbreaks generally reach higher densities in older forests, and thus late successional or old growth forests are likely to support more Bay-breasted Warblers (NHFG 2015). Crawford and Jennings (1989) estimated that during Budworm outbreaks, Bay-breasted Warblers typically ate more than 13,000 Budworms per hectare (2.5 acres) in a 41-day period and that Budworm-eating birds can reduce the extent of a Budworm infestation if enough suitable habitat is available to maintain high bird populations. Although the Bay-breasted Warbler has been established as an old forest specialist, it appears to expand into young and intermediate aged stands in response to Budworm outbreaks (Venier et al. 2020).

Prescribed fire has in the past been used to control Spruce Budworm outbreaks by breaking up large stands of balsam fir and to eliminate heavy slash loads (USFWS 1985a). However, in the future, staff at the refuge will consider budworm outbreaks to be natural, periodic occurrences; they do not anticipate responding with management actions. A 2018 trapping survey at Moosehorn NWR showed no significant rise in the Spruce Budworm population since 2012.

MAGNOLIA WARBLER. PHOTO CREDIT USFWS.

The Magnolia Warbler is a bird of dense growth, usually nesting in young spruce. In the breeding season, they glean weevils, leaf and click beetles, leafhoppers, aphids, scale insects, spiders, moths, butterflies, and especially caterpillars (Dunn and Hall 2020). During Spruce Budworm eruptions, they consume large numbers of Budworm larvae (Crawford et al. 1983). Magnolia Warbler nests are difficult to find in thick spruce regeneration and thus much of the biology of this warbler is little known. Historically, natural disturbances such as wind, fire, and disease created canopy gaps that spurred dense softwood regeneration, amid a matrix of older forest (Maine Audubon 2017).

Although the Swainson's Thrush is considered a common bird of northern spruce-fir forests, populations are declining even where abundant, particularly in Alaska and the Northeast. The reasons for the decline are not clear. Canopy closure, understory cover, tree density, and a conifer component appear to be important habitat features (Mack and Young 2020). The Swainson’s Thrush is often found in dense spruce-fir near water or in low damp areas (DeGraaf and Yamasaki 2001). It feeds extensively on Saddled Prominent Caterpillars when available, and population changes were correlated with irruptive outbreaks of this food source in New Hampshire (Holmes et al. 1986). Crawford and Titterington (1979) found Swainson’s Thrushes more abundant in eastern spruce forests with Budworm than without.

Large live, standing dead, and downed dead trees are important components of a healthy forest and research indicates that late successional and old growth forests contain more large trees and higher

amounts of coarse woody debris (Ducey et al. 2013, MFS 2010, Burrascono et al. 2013). Dead and down woody material (also called coarse woody material) is important for nutrient cycling, as nurse logs for regeneration, and as wildlife habitat. Large (> 18 inches) hollow or rotten logs generally are more valuable and softwood forests usually contain more and lasting down woody material than hardwood forests (Bennett 2010). Birds and mammals are not tightly dependent on old trees, but some require large trees (e.g., > 18" DBH), particularly those relying on tree cavities (e.g., Pileated Woodpecker, Barred Owl, Wood Duck, porcupine, and bats).

Pre-settlement forests were likely composed of late successional stands with a mosaic of small-scale, relatively frequent disturbances, such as tree fall and small wind events. Large-scale, catastrophic disturbances such as hurricanes and stand-replacing fires affected very large acreages, but on a timeframe of hundreds or thousands of years (Seymour et al. 2002). Native insect outbreaks (e.g., Spruce Budworm) fall in between, severely affecting their hosts over large acreages on periodic cycles as short as 30 to 50 years. Spruce Budworm, a native insect, affects millions of acres of spruce-fir forest in northern New England and southern Canada, on a 40-year cycle. Large areas of balsam fir and red spruce are defoliated, followed by high tree mortality, then re-growth and recovery of the forest through seedling and sapling release in the newly opened canopy (Boulanger and Arsenault 2004). This natural disturbance pattern creates a diverse age structure from young, regenerating forests to old forests. However, Maine's forests have been heavily harvested for more than 200 years, with a heavy emphasis on extracting spruce. This has increased the dominance of balsam fir, leaving the forest more susceptible to major Budworm outbreaks, as the insect favors fir more than spruce.

Outside the Wilderness Areas, the refuge will assess the need and feasibility of restoring mature spruce and associated late successional characteristics based on site capability. This would be achieved through active management, such as creating small forest openings, girdling trees, or felling large trees to mimic small-scale natural disturbances. Increasing the amount of contiguous, late successional spruce-fir forest will benefit species of conservation concern and help perpetuate biological integrity, diversity, and resiliency on the refuge.

VERNAL POOL WITHIN THE SPRUCE-NORTHERN HARDWOOD FOREST AT MOOSEHORN NWR. PHOTO CREDIT: USFWS

OBJECTIVE 1.2 SPRUCE-NORTHERN HARDWOOD FOREST

Manage 6,932 acres of late successional spruce-northern hardwood forest (approximately 5,633 acres on Baring Division, and 1,299 acres on Edmunds Division) on Moosehorn NWR that reflect ecological site conditions to maintain the ecosystem over time (e.g., species composition, regeneration, size class distribution), support migratory bird species (e.g., migrating and breeding landbirds), maintain native biological diversity and ecological integrity (e.g., reduce invasive species), and provide for management demonstration areas, from 2023 to 2038 with the following attributes (measurement units) and aspirational targets (values):

Maintain the ecosystem over time

- On well drained to excessively drained soils, on hillslopes, ranging from lower to upper slopes and from gentle to steep (up to 50%) slopes:
    - Greater than 70 percent overstory canopy closure (canopies > 16 ft. in height) with trees greater than 50 feet in height dominated by mature native red spruce (60% cover), red maple (20% cover) and yellow birch (20% cover)
- On sites with deeper, slightly richer, more fertile soil (indicated by the presence of Christmas fern):
    - Seventy percent overstory canopy closure (canopies > 16 ft. in height) with trees greater than 50 feet in height dominated (> 50%) by a combination of sugar maple, beech and yellow birch with red spruce and balsam fir (< 20%)
- Approximately 20 to 40 percent midstory and understory canopy closure (canopies 2 to 16 ft. in height), dominated by red spruce, red maple, yellow birch, beech, striped maple, mountain ash, and mountain maple.

- Greater than 15 percent ground layer (canopies < 2 ft. in height) dominated by intermediate wood fern, mountain wood fern, bluebead (also called yellow clintonia), Canada mayflower, Christmas fern, starflower, Indian cucumber-root, partridgeberry, wild sarsaparilla, and wintergreen, and bryophytes.
- Small forest openings within the natural range of variation (< 1-acre), with occasional larger openings (1 to 2 acres) spaced widely apart (> 1,000 ft.), occurring infrequently for long durations of time (1 to 500 years).
- A minimum of 200 trees per acre greater than 5 inches DBH, 100 to 130 feet^2 basal area per acre, and a 10-inch QMD with greater than 200 percent CV.
- A range of tree diameters, including 175 live trees 5 to 10 inches DBH per acre, 40 live trees 11 to 20 inches DBH per acre, 2 live trees 21 to 24 inches DBH per acre, at least 1 live tree greater than 24 inches DBH per acre and approximately2,500 seedlings/acre and 250 to 500 saplings/acre.
- Approximately one to two mature red spruce trees (200 to 300 years old) per acre on well drained sites; and approximately one to two mature sugar maple, yellow birch (150 to 200 years old) and beech (120 to 150 years old) trees per acre on richer more fertile sites.
- Less than 50 percent of stems less than 6 feet in height browsed by White-tailed Deer and Moose.

Support migratory birds

- At least 25 species of landbirds (e.g., Blackburnian, Black-throated Blue and Black-throated Green Warblers, Northern Parula) are annually present during the breeding season (June to July), spring migration (April to May) and fall migration (August to September)

Maintain biological diversity and ecological integrity

- Contiguous forest blocks (i.e., > 250 acres and at least 550 yards wide), and greater than 90 percent of forest blocks are connected by corridors at least 55 yards wide or within approximately 1.2 miles of another forest block.
- At least six snag trees per acre with three exceeding 14 inches DBH and one exceeding 16 inches DBH.
- At least six live cavity trees per acre with one exceeding 18 inches DBH and three exceeding 12 inches DBH.
- At least 10 tons of downed woody material per acre with an average large end diameter greater than 10 inches and average length greater than 24 feet, the larger the better, and presence of fine material including smaller limbs and branches.

Rationale

The broad spruce–northern hardwoods forest ecosystem found over northern and Downeast Maine encompasses 20, mainly terrestrial, forest communities (Gawler and Cutko 2018). This diversity is due, in part, to Maine's position in the transition zone between the Boreal Forest to the North and the Eastern Deciduous Forest to the South. Barton et al. (2012) noted that the Maine woods are unique with distinctive features, such as red spruce, and a natural disturbance regime different from both the boreal and temperate hardwood forests. The spruce-northern hardwoods forest found on the Moosehorn NWR represents this gradation of mixed forest communities (Gawler and Cutko 2018). As a result of its size, condition and landscape context, the entire Baring Wilderness Area (4,736 acres) is an exemplary spruce-northern hardwood forest ecosystem with most of the forest mature to late successional and trees that average 128 years old.

The spruce-northern hardwoods forest currently is found on 8,689 acres or 30 percent of the refuge. Approximately 2,140 acres are in Wilderness and 6,549 acres are outside the wilderness areas. This mixed forest type is characterized by red spruce and northern hardwoods (most often yellow birch) in the canopy and lesser amounts of red maple. Richer sites support more northern hardwoods (i.e., sugar maple, beech, and yellow birch). There are occasional large super canopy white pines. A well-developed sapling/shrub layer—that includes striped maple, and often hobblebush—is common. Balsam fir and paper birch occur in the sub canopy. Mosses and liverworts are more abundant than lichens. This forest type represents forests that are truly "mixed" at the stand scale, rather than large blocks of distinct conifer or hardwood stands. Most of this forest type on non-conservation land was harvested in the past, often with spruce selectively removed (Gawler and Cutko 2018), hence the importance of the Moosehorn NWR in providing late successional spruce-northern hardwood forest.

Blackburnian and Black-throated Green warblers commonly nest in spruce-northern hardwood forests. Both bird species are considered as forest-interior species, with numbers declining in forest fragments (Morse 2020, Morse and Poole 2020). The Blackburnian Warbler nests in the tops of tall conifer trees where it also forages for insects (Morse 2020), while the Black-throated Green Warbler nests lower down, often close to the trunk (Morse and Poole 2020). Hemlock forests also provide unique habitat for other species, such as porcupine and white-tailed deer, which take advantage of the thermal cover provided by the thick canopy.

A forest interior bird, the Black-throated Blue Warbler inhabits large tracts (> 250 acres) of relatively undisturbed hardwood and mixed deciduous-coniferous forests and prefers a dense understory of hobblebush or small saplings of sugar maple, striped maple, beech, or softwoods (Holmes et al. 2020, Maine Audubon 2017). The Northern Parula is also area sensitive; however, it prefers mature, moist forests where the lichen *Usnea* is present and used in nest building (DeGraaf and Yamasaki 2001).

All four warblers—Black-throated Blue, Black-throated Green, Blackburnian, and Northern Parula—are priority species in BCR 14 (Dettmers 2006) and in PIF Physiographic Area 28 due to the large proportion of their breeding populations in this region (Rosenberg and Hodgman 2000).

As with the spruce-fir forests, the mixed wood forests have less complex structure with smaller and younger trees than during pre-settlement time. Returning to the pre-settlement forest is not possible; however, managing for late successional forest will recover elements of that landscape: older and larger trees, coarse woody material, snags, and cavity trees (Barton et al 2012). Natural disturbance regimes are like those in spruce-fir, except Spruce Budworm would likely have minimal impact on more hardwood-dominated sites. Active management outside Wilderness Areas that emulates small-scale disturbances to create small gaps, will be considered to enhance late successional forest conditions and benefit species such as Black-throated Blue Warbler that rely on dense vegetation in spruce-northern hardwood forests.

OBJECTIVE 1.3 WHITE PINE–MIXED CONIFER FOREST

Manage 1,638 acres of pine (e.g. white and red pine), hemlock, and mixed oak-pine forest (approximately 1,397 acres on Baring Division, and 241 acres on Edmunds Division) on Moosehorn NWR that reflect ecological site conditions to maintain the ecosystem over time (e.g., species composition, regeneration, size class distribution), support migratory bird species (e.g., migrating and breeding landbirds), maintain native biological diversity and ecological integrity (e.g., reduce invasive species), and provide for management demonstration areas, from 2023 to 2038 with the following attributes (measurement units) and aspirational targets (values):

Maintain the ecosystem over time

White Pine–Mixed Conifer Forest

- Present on shallow (< 15 inches) sandy to loamy mesic soils (usually well drained) that are moderately acidic (pH 5 to 6), usually on slopes or coarse textured flats at low elevations (< 900 ft.).
- Seventy-five to 100 percent overstory canopy closure (canopies > 16 ft. in height) with trees greater than 50 feet in height dominated by white pine (> 50% cover), with a smaller component of red spruce, red pine, hemlock, or northern white cedar.
- More than 20 percent midstory canopy (canopies 6 to 16 ft. in height) and understory canopy cover (canopies 2 to 6 ft. in height) dominated by red spruce, balsam fir, and white pine.
- Ground layer (canopies < 2 ft. in height) of greater than 30 percent cover of lowbush blueberry, Canada mayflower, wintergreen, round-leaved pyrola and trailing arbutus, with greater than 25 percent conifer litter with bryoids (e.g., large hair-cap moss, red-stemmed moss).
- Approximately 1 to 2 mature white pine trees (150 to 200 years old) per acre.
- White pine sites adjacent to poorly drained soils may transition to spruce-fir through natural succession.

Red Pine–White Pine Forest

- Present on dry-mesic to xeric soils that are somewhat to very shallow (3 to 20 inches to obstruction) with acidic (pH 4.8 to 5.2) coarse sandy loams to sandy soils.
- Seventy-five to 100 percent overstory canopy closure (canopies > 16 ft. in height) with trees greater than 50 feet in height dominated by red pine (60 to 80% canopy cover) and white pine (20% canopy cover).
- Less than 25 percent midstory canopy closure (canopies 6 to 16 ft. in height) dominated by white pine and red spruce (> 50% cover).
- Less than 20 percent understory cover (canopies 2 to 6 ft. in height) dominated by sheep laurel, blueberry.
- Ground layer (canopies < 2 ft. in height) of conifer litter with Canada mayflower, winterberry, and patches of bryophytes (graminoids uncommon or absent).

Both Pine dominated forests managed for multi-aged structure:

- A minimum of 275 trees per acre greater than 5 inches DBH, 125 to 150 feet2 basal area per acre, and a 10-inch QMD with greater than 200 percent CV.
- A range of tree diameters, including 216 live trees 5 to 10 inches DBH per acre, 53 live trees 11 to 20 inches DBH per acre, 3 live trees 21 to 24 inches DBH per acre, at least 1 live tree greater than 24 inches DBH per acre and greater than 1,000 seedlings/acre and 250 to 500 saplings/acre.
- Alternatively, regeneration system with greater than 200 seedlings and saplings/acre arranged in small even-aged groups and patches distributed throughout 5 to 15 percent of the mature forest.

Oak-Pine Forest

- Present on well drained, shallow (10 to 19 inches) mineral soils (acidic sandy loams or loamy sands).
- Seventy-five to 100 percent overstory canopy closure (canopies > 16 ft. in height) with trees greater than 50 feet in height dominated by red oak and white pine (> 50%), with red maple (up to 15% cover) and paper birch (up to 15% cover) common in younger stands.
- Midstory canopy (canopies 6 to 16 ft. in height) containing striped maple.
- Less than 30 percent understory canopy cover (canopies 2 to 6 ft. in height) with lowbush blueberry and dwarf shrubs (0 to 15% cover).

- Ground layer (canopies < 2 ft. in height) with bracken fern and a sparse bryoid layer almost exclusively mosses, when present.
- A minimum of 200 trees per acre greater than 5 inches DBH, 100 to 130 feet2 basal area per acre, and a 10-inch QMD with greater than 200 percent CV.
- A range of tree diameters, including 175 live trees 5 to 10 inches DBH per acre, 40 live trees 11 to 20 inches DBH per acre, 2 live trees 21 to 24 inches DBH per acre, at least 1 live tree greater than 24-inch DBH per acre and approximately 2,500 seedlings/acre and 250 to 500 saplings/acre.

Red Spruce-Mixed Conifer Woodland

- Present on sites with thin (< 10 inches) coarse mineral soil over bedrock substrate, on mid to upper slopes.
- Seventy-five to 100 percent overstory canopy closure (canopies > 16 ft. in height) with trees greater than 50 feet in height dominated by red spruce and white pine (25 to 70% cover).
- Less than 8 percent understory cover (canopies 2 to 6 ft. in height) dominated by heath shrubs.
- Ground layer (canopies < 2 ft. in height) ranging from sparse (< 25% cover) to well developed (35 to 70% cover) bryoid layer.
- Approximately one to two mature red spruce trees (200 to 300 years old) and white pine trees (150 to 200 years old) per acre.

Hemlock Forest

- Present on sites with shallow (< 20 inches) acidic (pH 4.8 to 5.6) soil.
- Seventy-five to 100 percent overstory canopy closure (canopies > 16 ft. in height) with trees greater than 50 feet in height dominated by hemlock (> 50% cover) and scattered white pines greater than 30 inches DBH.
- Sparse midstory (canopies 6 to 16 ft.), understory (canopies 2 to 6 ft.) and ground layer (canopies < 2 ft.) are each less than 25 percent cover with spruce, hemlock, and white pine regeneration present.
- Approximately one to two mature hemlock trees (200 to 300 years old) per acre.
- A minimum of 250 trees per acre greater than 5 inches DBH, approximately 120 feet^2 basal area per acre, and an 8-inch QMD with greater than 200 percent CV.
- A range of tree diameters, including 208 live trees 5 to 10 inches DBH per acre, 50 live trees 11 to 20 inches DBH per acre, 3 live trees 21 to 24 inches DBH per acre, at least 1 live tree greater than 24-inch DBH per acre and approximately 2,500 seedlings/acre and 250 to 500 saplings/acre.

All Types

- Small forest openings that are within the natural range of variation (< 1 acre) occurring infrequently, for long durations of time, 1 to 500 years.
- Less than 50 percent of stems less than 6 feet in height browsed by White-tailed Deer or Moose.

Support migratory birds

- At least 20 species of landbirds (e.g., Ovenbird, Black-throated Green Warbler, Pine Warbler) are annually present during the breeding season (June to July), spring migration (April to May) and fall migration (August to September)

Maintain biological diversity and ecological integrity

- Contiguous forest blocks (i.e., > 250 acres and at least 550 yards wide), and greater than 90 percent of forest blocks are connected by corridors at least 55 yards wide or within approximately 1.2 miles of another forest block.
- The presence of arboreal lichens (e.g., *Usnea* spp., *Bryoria* spp. or *Lobaria quercizans*).

- At least six snag trees per acre with three exceeding 14 inches DBH and one exceeding 16 inches DBH.
- At least six live cavity trees per acre with one exceeding 18 inches DBH and three exceeding 12 inches DBH.
- At least 10 tons of downed woody material per acre with an average large end diameter greater than 10-inch and average length greater than 24 feet, the larger the better, and presence of fine material including smaller limbs and branches.

Rationale

Five forest communities, each with a component of white pine in the overstory, occur on the refuge: white pine–mixed conifer forest, red pine–white pine forest, oak-pine forest, red spruce-mixed conifer woodland and hemlock forest. The white pine-mixed conifer forest has a closed canopy in which white pine is dominant. Occasionally, red spruce, red pine, hemlock, or northern white cedar is co-dominant with the white pine. Red oak and northern hardwood species may also be present. Canada mayflower, large-hair-capped moss, and red-stemmed moss are common. The red pine-white pine forest has a somewhat more open canopy with red pine dominant; white pine, red spruce, or northern white cedar may be co-dominant on some sites. Bracken fern and wintergreen are usually present. Many sites show evidence of past fires. In Maine, natural occurrences of red pine are rare outside the eastern region (Gawler and Cutko 2018). The red pine-white pine forest type is rare on the refuge. The 160-acre Bertrand E. Smith Natural Research Area in the Baring Wilderness Area contains some of the best old growth (200+ years) white pine in the region.

The oak-pine forest type is a closed canopy forest with red oak or a mixture of red oak and white pine. This forest community typically has few northern hardwoods or other oak species. A variety of shrubs may be present including black huckleberry, lowbush blueberry, beaked hazelnut, as well as bracken fern. Most oak-pine forests in Maine are on sites once cleared or pastured and are more common in southern and central Maine (Gawler and Cutko 2018). Stands dominated by white pine are found on sites that were most recently fields and on well-drained sand and gravel, while the driest sites tend toward red oak. Natural disturbances caused by wind or fire, as well as Native American management practices, may have played a role in maintaining this community type. Gray Squirrels and Blue Jays help with oak regeneration by burying acorns (Maine Audubon 2017). Large blocks of late successional oak-pine forest are likely rare to non-existent in southern and central Maine, where logging, development, and fragmentation by roads is more prevalent. This is an uncommon forest type on the refuge, although soils will support hardwoods in the future.

The red spruce-mixed conifer woodland is a more open forest with a 25 to 70 percent canopy closure, where either red spruce or white pine is dominant, or a mix of both. Heath species, including black huckleberry, lowbush blueberry, and sheep laurel, are the dominant shrub layer with a range of densities of moss and lichens. These woodlands occur on acidic, well-drained, thin soils on bedrock on mid to upper slopes (Gawler and Cutko 2018).

The hemlock forest is a closed-canopy forest dominated by hemlock. The dense canopy prevents light from filtering through, resulting in a sparse understory and groundcover. During the 1700s and 1800s, hemlock was heavily harvested in the Northeast for use in the tanning industry, due to its high tannic acid content. Since the demise of that industry in the early 1900s, hemlock has largely recovered, and some hemlocks are now quite old (Gawler and Cutko 2018).

Eastern hemlock is a large, magnificent tree that can live for 800 years or more (Godman and Lancaster 1990). However, the accidentally introduced Hemlock Woolly Adelgid (HWA), an aphid-like insect, is now a threat. According to Ward et al. (2004), certain hemlock stands are better able to survive an infestation: those growing in better moisture regimes, on northeast-facing slopes, or deep in ravines. Distribution maps of HWA show that the insect moves northerly up along the coast in advance of the inland northern advance. In New Hampshire, cold winters kill enough HWA that hemlocks can recover, until the HWA populations build up again (Karen Bennett, 2019, personal communication). However, due to climate change and temperature-moderating ocean effects, Moosehorn NWR might be susceptible to HWA in the future.

Several warblers commonly nest in these mixed pine forests, including Pine Warbler, Black-throated Green Warbler, and Ovenbird; the latter two being priority species in BCR 14 (USFWS, 2021) (*https://acjv.org/planning/bird-conservation-regions/bcr-14/* accessed 2/2023). The Black-throated Green Warbler has an affinity for hardwood-hemlock stands, including white pine mixed forests (DeGraaf and Yamasaki 2001). Ovenbirds prefer older, larger contiguous tracts (> 250 acres) of hardwood or mixed-wood forest with 60 to 90 percent canopy cover and canopy heights greater than 50 feet and areas with less ground cover and deeper leaf litter (Maine Audubon 2017). The Ovenbird builds a domed nest with a side opening that resembles a clay oven, usually in a depression of dead leaves. As its name suggests, the Pine Warbler is a species closely associated with pine forests, nesting in tall red or white pine in this region (DeGraaf and Yamasaki 2001).

Late successional pine, hemlock, and mixed forests will provide a range of habitat conditions including large trees, cavity trees, mast crops, downed wood, and canopy gaps that benefit many wildlife species. Acorn-producing oaks provide an important food source ("mast") for many wildlife species including White-tailed Deer, Northern Flying Squirrels, Gray Squirrels, Wild Turkeys, Wood Ducks, and Blue Jays. Peak production of acorns occurs on large, older oak trees 19 to 22 inches in diameter (Bennett 2010).

Active management outside Wilderness areas that emulates small-scale disturbances to create small gaps will be considered to enhance late successional forest conditions and benefit species such as Black-throated Green Warbler, Pine Warbler, and Ovenbird that rely on dense vegetation in mixed pine forests.

NORTHERN HARDWOOD FOREST IN FALL. PHOTO CREDIT: USFWS

OBJECTIVE 1.4 NORTHERN HARDWOOD FOREST

Manage 7,594 acres of northern hardwood forest (approximately 6,705 acres on Baring Division, and 889 acres on Edmunds Division) on Moosehorn NWR that reflect ecological site conditions to maintain the ecosystem over time (e.g., species composition, regeneration, size class distribution), support migratory bird species (e.g., breeding and migrating landbirds), and maintain native biological diversity and ecological integrity (e.g., reduce invasive species), and provide for management demonstration areas, from 2023 to 2038 with the following attributes (measurement units) and aspirational targets (values):

Maintain the ecosystem over time

- Present on lower to middle portions of hillslopes (generally 10 to 50% slope) with mesic and well drained soils (silty loams to sandy loams to loamy sands), bedrock is greater than 20 inches below the mineral soil surface and soils may be underlain by a densely compacted till layer within 4 to 20 inches deep.
- Seventy percent overstory canopy closure (canopies > 16 ft. in height) with trees greater than 50 feet in height dominated (> 50% cover) with a combination of shade-tolerant species (e.g., yellow birch, red maple) and less than 25 percent conifers and red oak; on richer soil the overstory is sugar maple and white ash.
- Midstory (canopies 6 to 16 ft. in height) and understory (canopies 2 to 6 ft. in height) are dominated by regenerating overstory tree species along with balsam fir and striped maple.
- Ground layer (canopies < 2 ft. in height) lacks rich soil plant species (e.g., Dutchman's breeches, maidenhair fern and blue cohosh).
- Small forest openings that are within the natural range of variability (< 1-acre) occurring infrequently, for long durations of time, 1 to 500 years.

- A minimum of 200 trees per acre greater than 5 inches DBH, 100 to 130 ft^2 basal area per acre, and a 10-inch QMD with greater than 200 percent CV.
- A range of tree diameters, including 175 live trees 5 to 10 inches DBH per acre, 40 live trees 11 to 20 inches DBH per acre, 2 live trees 21 to 24 inches DBH per acre, at least 1 live tree greater than 24 inches DBH per acre and approximately 2,500 seedlings/acre and 250 to 500 saplings/acre.
- Less than 50 percent of stems less 6 feet in height browsed by White-tailed Deer and Moose.

Support migratory birds

- At least 20 species of landbirds (e.g., Ovenbird, Black-throated Blue Warbler, Canada Warbler, Veery) are annually present during the breeding season (June to July), spring migration (April to May) and fall migration (August to September).

Maintain biological diversity and ecological integrity

Forest Structure

- Contiguous forest blocks (i.e., > 250 acres and at least 550 yards wide), and greater than 90 percent of forest blocks are connected by corridors at least 55 yards wide or within approximately 1.2 miles of another forest block.
- At least six snag trees per acre with three exceeding 14 inches DBH and one exceeding 16 inches DBH.
- At least six live cavity trees per acre with one exceeding 18 inches DBH and three exceeding 12 inches DBH.
- At least 10 tons of downed woody material (DWM) per acre with an average large end diameter greater than 10 inches and average length greater than 24 feet, the larger the better, and presence of fine material including smaller limbs and branches.
- Epiphytic lichens are present (e.g., *Collema* spp. or *Lobaria querizans*).

Invasive Species

- Eradication of high priority invasive plant species (common and alder buckthorn) to zero areas occupied.

Rationale

The beech-birch-maple forest is the classic northern hardwood forest type, dominated by sugar maple, beech, and yellow birch, with striped maple as a common subcanopy tree. Plant species richness and composition varies with site conditions. Hobblebush is a common understory shrub on some sites (Gawler and Cutko 2018). This is the dominant hardwood type in Maine and on the refuge. Beech scale disease has affected many stands of beech in eastern Maine, including those on the refuge. White birch, quaking and big tooth aspen, and pin cherry can dominate an area following a large disturbance such as fire; however, these shade intolerant species are eventually replaced with more shade tolerant species characteristic of the site conditions.

Currently, classic northern hardwood forest is quite rare on the refuge, accounting for less than 1 percent of the Baring Division and less than 1 percent of the Edmunds Division. In the southeast corner of the Baring Division, between Rocky Meadow and Moosehorn Stream, is an area that most closely resembles true northern hardwood forest. Much of the area has signs of past harvesting or an old fire, suggesting that the stands are in transition (Cutko and Schlawin 2012). The ecological site data indicate that the soil of

this area along with larger areas of Baring and a few areas of Edmunds could potentially support a higher amount of northern hardwood than what currently exists.

The Canada Warbler is listed as threatened in Canada and as a species of conservation concern in nearly every state where it breeds in the US, including Maine. Partners in Flight identified the Canada Warbler as one of 86 species of continental concern. Since 1966, population declines have been especially significant in the eastern US (Harding et al. 2017); it is a highest priority species in BCR 14 (Dettmers 2006). Factors contributing to their decline likely include forest loss and fragmentation due to development or land use change on breeding and wintering grounds. Many breeding areas currently lack diverse vertical layering and patchiness due to heavy deer browsing, the spread of invasive plants, or forest management that reduces structural complexity (Harding et al. 2017).

Breeding habitat includes contiguous deciduous, mixed wood and coniferous forests interspersed with openings that provide an average overstory tree height of 55 feet within greater than 30 percent canopy closure, a dense foliar mid-story and well-developed shrub layer 7 to 20 feet in height, and moist soils. Average territory is 2.5 acres (Reitsma 2020)

Throughout the eastern U.S., Canada Warblers select moist and structurally complex forests featuring an open or broken canopy with exposed song perches elevated above a leafy understory and uneven forest floor. Studies in Maine have found Canada Warblers to be more common in mixed forests than in pure stands, often with a dense, moist understory. Forested wetlands and naturally disturbed areas within old forests often provide sustained habitat. Preferred site characteristics include uneven forest floor with down woody material (logs, branches, stumps, and root masses) comprising greater than 10 percent of the ground cover, a complex forest floor, leafy sub canopy with trees 6 to 20 feet high, and open song perches. The Canada Warbler nests on or near the ground, hidden among root masses, stumps, fallen logs, ferns, or mossy hummocks. Its breeding territories often occur in clusters, which are referred to as neighborhoods. Canada Warblers appear to be sensitive to forest fragmentation, preferring forests of 1,000 acres or more (Harding et al. 2017).

Several other high priority species in BCR 14 and PIF 28, nest in northern hardwoods: Black-throated Blue Warbler, Ovenbird, and Veery (USFWS,2021, Rosenberg et al, 2016). Black-throated Blue Warbler and Ovenbird habitat preferences are described under the spruce-northern hardwood and pine-mixed forest objectives, respectively. The Veery nests in moist hardwood forests with intermediate (30 to 80%) canopy cover and a dense understory of ferns, shrubs, and saplings (Maine Audubon 2017). The nest is built on the ground or in a low shrub or tree, often tucked inside a fern tussock or other thick groundcover (DeGraaf and Yamasaki 2001).

ASPEN REGENERATION. PHOTO CREDIT: USFWS

OBJECTIVE 1.5 EARLY SUCCESSIONAL ASPEN-BIRCH

Manage 1,807 acres of aspen-birch forest as a mosaic of early- (0 to 15 years) and mid- (16 to 50 years) successional forest, alder thicket and openings, as management demonstration areas on Moosehorn NWR (i.e. approximately 1,216 acres on Baring Division, and approximately 591 acres on Edmunds Division) that reflect ecological site conditions to maintain the ecosystem over time (e.g. species composition, regeneration, size class distribution), to support migratory birds (e.g. American Woodcock, Chestnut-sided Warbler, Yellow-bellied Sapsucker), and maintain native biological diversity and ecological integrity (e.g. reduce invasive species) from 2023 to 2038 with the following attributes (measurement units) and aspirational targets (values):

Maintain the ecosystem over time

- Present on post-fire or post-harvest sites with nutrient-poor soil (mineral soils < 10 inches, thin glacial till, or bare granite).
- Fifty-three to 64 percent overstory canopy closure (canopies > 16 ft. in height) dominated by white birch, poplars, and red maple; conifers and red oak may be present.
- Contiguous, regenerating clearcuts or natural openings greater than 5 acres with greater than 5,000 seedlings (< 1" diameter) stems per acre of shade-intolerant species such as aspen and birch.
- Openings have less than 30 feet^2 of basal area per acre.

Support migratory birds

- At least 20 species of landbirds (e.g., Chestnut-sided Warbler, Yellow-bellied Sapsucker) are annually present during the breeding season (June to July), spring migration (April to May) and fall migration (August to September).
- An average number of 0.5 male American Woodcock detected per stop on 19 established Woodcock singing ground survey routes on the Baring Division:

- A mosaic of successional stages and openings with an alder thicket or forested wetland near the center of the mosaic.
- Singing and display grounds comprised of scattered, small openings (> 100 ft2) with greater than 60 percent grass or forb cover and 5 to 15 percent bare ground, located less than 110 yards from diurnal cover.
- Nesting and brood-rearing habitat comprised of young, second-growth forest stands with (5,911 to 19,838 stems/acre) (< 5 inches DBH) and greater than 75 percent shrub canopy cover, less than 70 feet from singing and display grounds.
- On moist rich soils high in organic matter (e.g., muck), the overstory (canopy cover 75 to 87%) is a high density (> 10,000 stems/acre) of alder and root suckering tree species (e.g., aspen, birch) to support foraging of earthworms.
- Nocturnal roosting areas comprised of blueberry barrens, pastures, recently harvested woodlands greater than 3 acres in size and located within 0.25 miles of breeding areas.

Rationale

Aspen-birch woodland is an association of aspen, birch, and other species, that occur after a fire, logging, or other disturbance, typically on nutrient poor soils. The most common species are gray birch, paper birch, big-toothed aspen, quaking aspen, and red maple. In time, these sites usually transition to one of several matrix-forming forest types such as northern hardwood or spruce-northern hardwood. Exemplary sites that best reflect the composition and condition of natural processes develop after fire or other natural disturbance (Gawler and Cutko 2018); many of these sites will be allowed to transition to matrix forest, with natural disturbance patterns continuing to create patches of the aspen-birch complex. These young forest conditions scattered throughout a matrix of older forests will also be used by bird species that are linked to mature forest, as they often forage for insects and other food sources in these openings (King et al. 2009).

To augment the natural disturbance-created young forest, the refuge will actively maintain up to 1,807 acres in young forest (aspen-birch) or alder stand to benefit a range of species including American Woodcock. The best sites for this early successional management were identified by using a GIS analysis of existing forest cover based on Sewall mapped types, soil drainage, and soil texture. The selected areas have the following characteristics: poplar overstory (36 to 50 ft. tall) with 61 to 90 percent canopy closure and white birch understory and somewhat poorly drained, loamy soils. Areas that were excluded from consideration were late successional old growth (71+ ft. canopy height and 91 to 100 percent canopy closure), Wilderness areas and other no-harvest areas, and sites without road access or that were too small (Thomas LaPointe, personal communication). The model results were used along with logistical and infrastructure considerations to determine the areas of the refuge with the greatest potential to meet American Woodcock habitat requirements, as well as demonstration areas.

DEMONSTRATION AREA FOR AMERICAN WOODCOCK AND OTHER EARLY SUCCESSIONAL FOREST WILDLIFE. PHOTO CREDIT: USFWS

The American Woodcock is a species of highest conservation priority in BCR 14 (USFWS, 2021b). Widely distributed in eastern North America, woodcock are migratory and nest in young forests and old fields and typically forage in alder thickets in this part of their range. Although woodcock had declined in abundance, particularly in the eastern part of their range (likely due to natural succession and forestry practices), there is no evidence that the overall range has shrunk (McAuley et al. 2020). In addition, singing ground surveys indicate that range-wide declines have been halted, with significant increases in the population where habitat was created to benefit woodcock and other early successional species over the past 10 to 12 years (Wildlife Management Institute 2014).

Some of the most seminal work on the life history and habitat needs of American Woodcock was conducted on Moosehorn NWR from the 1930s to 1980s (e.g., Mendall and Aldous 1943, Reardon 1950, Clark 1969, Sepik et al. 1981, Dwyer et al. 1988). Techniques and practices developed at the refuge are now widely used in woodcock management throughout the species' range, made available through the publication *A Landowner's Guide to Woodcock Management in the Northeast* and are implemented by the Northern Forest Woodcock Initiative to achieve habitat objectives of the American Woodcock Conservation Plan (Kelley et al. 2008). Moosehorn NWR will continue as a research, management, and demonstration area for Woodcock and other early successional forest wildlife.

The original Forest Management Plan called for the creation of managed areas; these were demonstration areas used to show how owners of small woodlots can manage wildlife habitat on their own lands through timber harvesting. The original eight forest management units in the Baring Division totaled 6,645 acres of which a maximum of 5,159 acres was to be harvested by the year 2020, or an average of 130 acres per year. Approximately 10,000 acres of forest in the Baring Division was left to develop through natural succession.

AMERICAN WOODCOCK NESTLINGS. PHOTO CREDIT: RAY BROWN, USFWS

Within each forest management unit, merchantable timber stands were harvested on a 40- to 50-year rotation with 10-year cutting intervals using clearcut blocks or strips of varying sizes. Wildlife den trees or other ecologically significant trees were left uncut. Also, some small trees were retained as perches for insect-hawking birds. Most blocks are approximately 5 acres with boundaries 330 feet by 660 feet, and strips are 100 feet or more wide and of variable length. Within each MU, some stands or blocks are identified as "no cut." Alder and other noncommercial stands are cut in strips 60 to 100 feet wide on a 20-year rotation with 5-year cutting intervals (USFWS 1993).

Shrub habitat, especially alder, is one of several different habitat conditions used by woodcock during the breeding season. Alder thickets that support a dense earthworm population serve as foraging areas for adult woodcock and their broods. The best alder cover for woodcock is typically less than 30 years old, as older thickets provide less cover and support fewer earthworms. Alder responds well to clear-cutting and provides suitable habitat for woodcock when juxtaposed near the other habitat requirements of woodcock, such as open roosting sites and nesting areas in young hardwoods including aspen-birch stands (Sepik et al. 1988).

Other species that use young aspen-birch forest include Chestnut-sided Warbler and Ruffed Grouse. The Chestnut-sided Warbler is a bird of early successional habitats (e.g., abandoned farmlands, regenerating clear-cuts, forest edges, and other scrubby second-growth areas). Its population greatly expanded since the 1800s and became among the most abundant breeding warblers in second-growth deciduous woodlands. The species has undergone a slow decline from the early 1960s to the present as forests regrow. Despite these declines, this species appears to maintain relatively healthy populations (Byers et al. 2013).

The Yellow-bellied Sapsucker is a high priority species in BCR 14 (USFWS, 2021b). This migratory woodpecker nests in second growth woodlands especially aspen-birch and are commonly found in orchards in spring and fall. Sapsuckers drill small, evenly spaced holes around trees, creating sap wells. They consume the sap along with insects attracted to the sweet liquid. Other species take advantage of the sap, including the Ruby-throated Hummingbird, which appears to be closely associated with sapsuckers. The hummingbird places its nest near sap wells, follows sapsuckers in their daily movements, and may even time migration to coincide with that of sapsuckers (Miller and Nero 1983). The Yellow-bellied Sapsucker excavates nest cavities in dead trees, snags, or live trees with a decayed center, often in an aspen. Sapsucker cavities are often used as nest or roost sites by other bird species and some mammals (e.g., Northern Flying Squirrel) (DeGraaf and Yamasaki 2001, Walters et al. 2020). Yellow-bellied

Sapsuckers are stable or increasing in some places but are considered a stewardship species in Maine because over 30 percent of their global population breeds in the Atlantic Northern Forest (northern New England, New York and the Maritime Provinces) (Maine Audubon 2017).

NAT SMITH OLD FIELD AT MOOSEHORN NWR. PHOTO CREDIT: USFWS

OBJECTIVE 1.6 OLD FIELDS AND LOWBUSH BLUEBERRY

Manage 350 acres of old fields and lowbush blueberry on Moosehorn NWR (approximately 240 acres on Baring Division, and 110 acres on Edmunds Division) through mowing and using prescribed fire, to maintain the ecosystem over time (e.g., species composition, cover), to support migratory birds (e.g., breeding and migrating landbirds), priority ROCs (e.g., Monarch Butterflies, native pollinators), and maintain native biological diversity and ecological integrity (e.g. reduce invasive species) from 2023 to 2038 with the following attributes (measurement units) and aspirational targets (values):

Maintain the ecosystem over time

- Sixty to 80 percent of fields greater than 5 acres are dominated by grasses (e.g., timothy, rye, fescue) and forbs, 8 to 12 inches in height, with areas of dense (> 75% cover) native low-bush blueberry.
- greater than 80 percent of fields less than 5 acres adjacent to impoundments (i.e., Magurrewock field MSHGR 11S and the dike) are dominated by cool season grasses, less than 8 inches in height, to provide alternate foraging for Canada Geese (reducing over grazing of wetland plants in the impoundment).
- Disturbances (natural or managed) occur frequently enough (i.e., every 2 to 4 years) to sustain a grass- and shrub-dominated system.

Support migratory birds

- American Woodcock are present and use the fields for courtship display during spring (April to May) and for roosting during the post-breeding season (June to September):
    - Maintain 200 acres of grass fields and low-bush blueberry with grasses and forbs less than 8 inches high for roosting areas for American Woodcock.
- Bobolink are annually present during the breeding season on the Former Cox Farm Fields east and west of US Route 1 and the Nat Smith Field at the Edmunds Division, and the Barn Meadow Fields at the Baring Division:
    - Maintain 125 acres of fields with grasses and forbs between 8 and 12 inches high to provide nesting and feeding habitat for Bobolink.

Support refuge priority resources of concern

- At least 40 species of native pollinators (e.g., native bees) and Monarch Butterfly are present annually on 15 old fields or blueberry barrens:
    - A minimum of three native, nectar-producing forbs (e.g., goldenrod, milkweed, and aster species) that bloom during the following three periods: April to May; June to July; and August to October; with a dominate (> 60% cover) forb component.
    - Presence of common milkweed as a larval host plant for Monarch Butterflies.
    - Undisturbed soil, duff, and woody material in areas with full sun, including exposed soil, coarse woody material, herbaceous clumps/tussocks, or hollow plant stems standing through winter for nesting and over-wintering pollinators.

Maintain biological diversity and ecological integrity

Invasive Species

- Containment of medium priority invasive plant species (e.g., smooth bedstraw), by maintaining current occupancy (2021 occupancy = 20%) and 100 percent of occupied areas not exceeding 60 percent cover.
- Containment of low priority invasive plant species (e.g., reed canary grass, thistle spp., Rosa rugosa), by maintaining current occupancy (2021 occupancy < 10%) and no new areas with large infestations (> 60% cover).

Rationale

The historical record is unclear on the abundance and distribution of open lands (such as grasslands and blueberry barrens) and their associated plant and animal communities in New England prior to European settlement (Foster and Motzkin 2003). Scattered large grasslands occurred in coastal areas including the blueberry barrens along the Maine Coast (Askins 1997, Winne 1997). Smaller, temporary grasslands were created when Beavers abandoned their dams or by fires set by lightning or humans (Askins 1997). Some grassland bird species, including Bobolink, may have existed here long before European settlement in coastal barrens, heathlands, and grasslands (Askins 1997). Norment (2002) noted that despite the relatively recent (last 200 years) rise and fall of grassland habitats and associated birds in New England, the region may still be important for these species given their continental decline and habitat loss in the core of their ranges in the Midwest. Rosenberg and Hodgman (2000) highlighted the barrens of Washington County, Maine as locally significant for populations of grassland birds within PIF Physiographic Area 28.

The existing 350 acres of old field and low-bush blueberry fields are scattered across the refuge. Many of these old fields are relatively small, isolated, or surrounded by forested habitat, yet still provide singing

grounds for American Woodcock, foraging areas for Canada Geese, and foraging habitat for post-fledging and migrating birds that nest in forests. The refuge's larger old fields provide some breeding and migration habitat for some grassland-dependent bird species, such as Bobolinks (the only grassland-dependent nesting bird that will utilize fields less than 10 acres), which is a high priority species in BCR 14 (Dettmers 2006). Mixed grasses and forbs 8 to 12 inches in height provide nesting and feeding habitat for Bobolink, Savannah Sparrow, Field Sparrow, and other resident and migratory birds.

In northern regions of their breeding range, woodcock often leave their daytime feeding habitats at dusk and fly to openings such as clearcuts, old fields, pastures, and blueberry barrens, where they spend the night sitting on the ground, seeking protection from predators. The characteristics of these night roosts are open enough so that a woodcock can detect and escape ground predators, such as weasels, while offering some overhead protection against aerial predators, such as owls. Proximity to young hardwood nesting areas and daytime feeding areas (e.g., alder thickets) is ideal (Kelley et al. 2008, McAuley et al. 2020).

MONARCH BUTTERFLY. PHOTO CREDIT: GREG THOMPSON, USFWS

Monarch Butterflies, native bees, and other pollinators are in decline, yet are critical components of native ecosystems. Monarchs are experiencing declining populations in both the eastern and western parts of their North American range, faced with loss of habitat for breeding, migrating, and overwintering. In addition, widespread use of pesticides and a changing climate pose additional threats. Monarchs cannot survive without milkweed as the caterpillars only eat milkweed plants (*Asclepias* spp.), and adults need milkweed to lay their eggs. With shifting land management practices, particularly in the agricultural regions of the country, much milkweed has disappeared from the landscape (Monarch Joint Venture 2019). In December 2020, after a thorough assessment of the status of the Monarch Butterfly, the USFWS found that adding the Monarch Butterfly to the list of threatened and endangered species was warranted but precluded by work on higher-priority listing actions. Based on their listing priorities and workload, USFWS entered into a settlement agreement with petitioners to submit a proposed rule listing the monarch, if listing is still warranted, to the Federal Register by September 30, 2024.

Native bees are also important pollinators of wild plants, as well as cultivated plants, including lowbush blueberries in Maine. Maine has more than 270 species of native bees and many of these species are found in Washington County (Dibble et al. 2017, Stubbs and Coverstone 2014). Scientists worldwide are concerned about declines in bee abundance and species diversity. Factors contributing to declines in wild

bees include loss or conversion of habitat and widespread use of insecticides (Stubbs and Coverstone 2014).

The old fields and blueberry barrens offer the best habitat on the refuge to create and maintain habitat for the range of native pollinators and their associated plants and habitat structure. In 2015 and 2016, bee bowl surveys were conducted in five old field sites; only a few of the many old fields and lowbush blueberry areas of the refuge. The survey results identified 83 species representing 19 genera and 5 bee families. These results reflect approximately 25 percent of the bee fauna that inhabit Maine. Sweat bees dominated bee fauna composition. The high number of common species coupled with limited sampling suggest valuable habitat is available for pollinators (ESI 2019).

Goal 2. Coastal and Freshwater Wetlands and Streams

Perpetuate the biological integrity, diversity, and resiliency of Moosehorn NWR's coastal and freshwater wetlands and streams to sustain plant communities and wildlife native to the Atlantic Northern Forest Region, including species of concern to the FWS.

MIDDLE MAGURREWOCK MARSH, MOOSEHORN NWR. PHOTO CREDIT: USFWS

OBJECTIVE 2.1 FRESHWATER IMPOUNDED WETLANDS

Manage 25 impounded wetlands (950 acres on Baring Division, 38 acres on Edmunds Division) to maintain the ecosystem over time (e.g., water control infrastructure, water quality), support migratory birds (e.g., waterfowl, marshbirds), priority ROCs (e.g., American Eel, Alewife), and maintain native biological diversity and ecological integrity (e.g., reduce invasive species) from 2020 to 2035 with the following attributes (measurement units) and aspirational targets (values):

Maintain the ecosystem over time

- Twenty-five impoundments at Moosehorn NWR have infrastructure (dikes, rock weirs, water control structures, etc.) with the capacity to flood, hold, and draw down the water under average weather conditions.
- Forty to 60 percent open water 6 to 18 inches deep, with 10 to 20 percent cover of submerged and floating aquatic vegetation (e.g., pickerelweed, pondweed, coontail, bladderwort), and 40 to 60 percent native emergent vegetation cover (e.g., wild rice, sedges, cattail, bulrush) with less than 10 percent shrubs (e.g., buttonbush).
- Maintain stable water levels during the waterfowl and marsh and water bird nesting seasons. Periodically conduct drawdowns, from ice out in spring, continuing through summer, and refilling in the fall, every 3 to 5 years.

Support migratory birds

Breeding

- At least five species of breeding waterfowl (e.g., American Black Duck, Wood Duck, Ring-necked Duck) are annually present across 15 managed impoundments.
- At least three species of breeding marshbirds (e.g., American Bittern, Virginia Rail, Sora, Pied-billed Grebe) are annually present across 10 managed impoundments:
    - Perennial vegetation is annually present for breeding marshbirds (e.g., cattails, bulrush, bur-reed, pickerel weed, buttonbush), May to July.

Non-breeding

- At least 12 species of migrating waterfowl are annually present during spring migration (March to May) and fall migration (September to November) with peak counts of individuals (600 birds) occurring in March.

Support refuge resources of concern

- Alewife are annually present during migration from April to September:
    - Stable water levels in impoundments with alewife (Upper and Middle Magurrewock Marshes).
    - Barrier free passage from the fishways on Magurrewock Stream to the spawning areas in Vose Pond and Howard Mill.
    - Fishways maintain a water level and velocity conducive to alewife passage (burst speed of 6 ft. per second, prolonged speed of 3 ft. per second).

Maintain biological diversity and ecological integrity

Invasive Species

- Eradication of high priority invasive plant species purple loosestrife to zero areas occupied.
- Toleration of low priority invasive plant species (e.g., reed canary grass), by maintaining current occupancy (2021 occupancy = < 10%) and no new areas with large infestations (> 60% cover).

Rationale

The Moosehorn NWR once had 52 impounded wetlands, 44 on the Baring Division and 8 on the Edmunds Division. Water control structures were placed on these wetlands between 1950 and 1986, creating the impoundments. Currently only 25 impoundments have water control structures that are functional.

The natural flooding regimes of these wetlands were substantially altered after water control structures were installed, extending hydro periods, reducing hydrologic variation, and increasing maximum flooded depths (Hierl et al. 2004). The structures are used to manipulate water levels to enhance habitat quality for waterfowl nesting and brood rearing, with the goal of increasing annual waterfowl productivity, especially for the American Black Duck. Water level manipulation allows managers to simulate different stages of the natural flood/drought cycle in different impoundments at the same time. This increases the diversity of habitat types and food resources in the wetland complex that is available to ducks and geese, and other migrating and nesting birds.

RING-NECKED DUCK HEN AND DUCKLINGS. PHOTO CREDIT: USFWS

Although Beaver-dammed wetlands provide some of these same conditions, historically managers wanted more control over seasonal water levels to create consistent, stable, and long-term habitat. Water levels in these impoundments can be carefully controlled to prevent waters from rising or falling dramatically during critical periods and can prevent flooding of nests or the excessive subsidence of water around nests that may lead to increased depredation. Water control structures also help protect refuge infrastructure such as roads and trails from flooding and erosion.

However, in the presence of a healthy North American Beaver population, as currently exists on the refuge, controlling water levels in artificial impoundments is extremely labor intensive. Beavers constantly plug water control structures with mud and sticks in attempts to raise water levels so they can increase access to new food sources. In addition, the impoundments are becoming increasingly difficult to maintain due to erosion from storm events and the deterioration of concrete, metal, and wooden water control structure components. Some impoundments are not functional because of needed repairs and deferred maintenance.

As a result of these ecological considerations and the cost of maintaining the impoundment structures, the refuge undertook a study to assess changes in vegetation structure in the impoundments between 1984-85 and 2002, evaluating each impoundment for its value as waterfowl, marsh, and wading bird habitat (Hierl et al. 2004). In 2012, a structured decision-making workshop was held with wetland experts, regional biological staff, and refuge staff. The assessment along with the workshop resulted in the development of

a decision tool for identifying the most productive and highest priority impoundments as habitat for wetland-dependent birds, with a focus on the American Black Duck.

The American Black Duck is one of the FWS's national focal species. It is a highest priority species in the Atlantic Northern Forest Bird Conservation Region (BCR 14) (USFWS, 2021) and a high priority in the North American Waterfowl Management Plan (Hartley and Weldon, 2020). Black Ducks were once the most abundant freshwater duck in North America. However, their populations have dropped steadily since the 1950s, reaching an all-time low in the 1980s. Black Duck populations have stabilized since then, although they are still below the objectives set by the North American Waterfowl Management Plan (ACJV 2019). Typical Black Duck brood habitat contains emergent and floating aquatic vegetation with abundant invertebrates. Females with broods use entire surfaces of shallow, relatively permanent wetlands with emergent vegetation such as reed grasses and sedges, floating-leaved plants, pondweeds, or scrub shrub that support abundant invertebrates.

The 25 high value impoundments will be managed through water level control structures to benefit Black Ducks, other waterfowl, and marsh birds, including American Bittern and Virginia Rail. Specifically, this includes maintaining a diversity of native wetland shrubs and herbaceous plants, such as pickerel weed, wild rice, and sedges in a mosaic of 40 to 60 percent emergent native plant cover to 40 to 60 percent open water. A draw-down in these impoundments every five years will mimic a natural beaver cycle. The impoundments with fish passages will maintain a water flow and level to ensure safe passage by Alewives, Brook Trout, and American Eels. See Appendix C for a list of the high value impoundments.

The following four impoundments are still functional but are not considered as valuable as the 25 we have selected to continue to manage: Eaton Heath, Mahar, and South Ridge at Baring, and Bill's Hill Pond #1 at Edmunds. These impoundments may be restored to their natural hydrology by removing dikes and water control structures, where feasible, or if they fail during storm or other events will not be maintained or replaced. This will improve biological integrity and environmental health and benefit priority fish species, including Eastern Brook Trout, and migratory American Eel and Alewife. Some low value impoundments may be maintained, if critical to the refuge road and trail system or for some other refuge priority. The water control structures will continue to be kept clear of beaver debris if there is a threat of flooding or road erosion.

Unique among East Coast states, Maine waters support 12 native species of sea-run ("anadromous") fish - species that spend most of their lives in the ocean and travel to freshwater rivers or ponds to spawn, or, like the American Eel, spend their lives in fresh water and migrate to the ocean to spawn ("catadromous"). Alewives historically occurred in all major and minor coastal watersheds in the state, but Maine's historically thriving Alewife population plummeted during the last two centuries, a result of industrial pollution, overfishing, and constructing of dams that blocked passage (Maine Department of Marine Resources 2022). Alewives are beginning to recover as more dams and other blockages are removed from the state's rivers.

The American Eel is an important part of the ecosystem, as well as a commercial fishery. In the U.S., the population is at or near historically low levels due to a combination of historical overfishing, habitat loss, food web alterations, predation, turbine mortality, environmental changes, toxins and contaminants, and disease. In 2011, the FWS initiated a status review of American Eel under the ESA to assess the health of the population and the magnitude of threats facing the species. On October 7, 2015, the FWS announced that the American Eel is stable and does not need protection under the ESA. Nonetheless, for the species'

long-term stability, the agency recommends continuing efforts to maintain healthy habitats, monitor harvest levels, and improve river passage for migrating Eels (ASMFC 2022).

ONE OF THE MANY STREAMS AND ASSOCIATED WETLANDS OF MOOSEHORN NWR. PHOTO CREDIT: JENNIFER CASEY, USFWS

OBJECTIVE 2.2 LAKES, STREAMS, AND ASSOCIATED WETLANDS

Manage lakes, streams, and associated wetlands (approximately 12.1 miles and 1,468 acres on Baring Division, 16.7 miles and 410 acres on Edmunds Division), including lakes on Baring Division (Bearce Lake 291 acres, Conic Lake 46 acres) and decommissioned impoundments (130 acres) on Moosehorn NWR to maintain the ecosystem over time (e.g., community composition, hydroperiod), support migratory birds (e.g., Alder Flycatcher, breeding waterfowl and marshbirds), refuge priority ROCs (e.g., native and diadromous fish), and maintain native biological diversity and ecological integrity (e.g. reduce invasive species) from 2020 to 2035 with the following attributes (measurement units) and aspirational targets (values):

Maintain the ecosystem over time

- A closed canopy of native trees and brush buffer consistent with or greater than forestry best management practices located along brook and stream banks.
- Plant species composition and dominance varies spatially and temporally due to Beaver activity.
- Saturated or seasonally flooded peat or muck soils, such as old Beaver meadows, dominated (> 20 to 40% cover) by speckled alder (3 to 9 ft. in height) with a well-developed (> 35% cover) herbaceous layer that is a mixture of forbs, graminoids, and ferns (e.g., cinnamon fern, three-seeded sedge, tussock sedge) with a patchy bryoid layer dominated by peat mosses.
- A range of mixed graminoid-shrub marshes with herbaceous plants (25 to 95% cover), shrubs (0 to 70% cover), and greater than 50 percent cover of graminoids with sparse shrubs (e.g., meadowsweet, hardhack), and the presence of three-way sedge and yellow loosestrife.

- Tussock sedge meadows dominated by hummocks of tussock sedge (> 50%) with bluejoint and other graminoids; strongly hummocked with standing water in-between for most of the growing season; and a shrub layer of greater than 30 percent with meadowsweet.
- Lakes fed by streams and rain events have relatively stable water levels with forested rocky shorelines.

Support migratory birds

Breeding

- Breeding landbirds (e.g., Alder Flycatchers) will be annually present during May to August.
- At least one pair of breeding Common Loons will be annually present during April to November on Bearce and Conic Lakes.
- At least five species of breeding waterfowl (e.g., American Black Duck, Wood Duck, Ring-necked Duck) are annually present.
- At least three species of breeding marshbirds (e.g., American Bittern, Virginia Rail, Sora, Pied-billed Grebe) are annually present:
    - Perennial vegetation (e.g., cattails, bulrush, bur-reed, pickerel weed, buttonbush) is annually present for breeding marshbirds, May to July.

Non-breeding

- At least 12 species of migrating waterfowl are annually present during spring migration (March to May) and fall migration (September to November) with peak counts of individuals (600 birds) occurring in March.

Support refuge priority resources of concern

- Alewife will be annually present during migration April through September on the East and West branches of Magurrewock Stream:
    - Barrier free passage (e.g., no water control structures, dams) through the refuge to upstream spawning areas (Vose Pond and Howard Mill); adults and juveniles return downstream to the ocean.
    - Impoundments with Alewife (Upper and Middle Magurrewock Marshes) have stable water levels.
    - Fishways maintain a water level and velocity conducive to alewife passage (burst speed of 6 ft. per second, prolonged speed of 3 ft. per second).
- American Eel will be annually present during upstream migration (March to June):
    - Minimize barriers (e.g., water control structures, dams) to juvenile (elver) passage upstream through the refuge for maturation to adults (Yellow Eels); adults (Silver Eels) can return downstream to the ocean for spawning.
- Eastern Brook Trout will be annually present on the West Branch Magurrewock Stream, Moosehorn Stream, Barn Meadow, Cranberry and Mahar Brooks at Baring Division and Crane Mill Stream, Barn Meadow Brook, Cranberry Brook, and Hobart Stream, Bog, and Lake on the Edmunds Division:
    - Minimize physical and thermal barriers for fish spawning and rearing.
    - Water temperatures are favorable during the summer growth and survival period in streams that support Eastern Brook Trout (55F to 65F) and a temperature of 40 to 50F in the fall for spawning.
    - Maintain a strip of uncut forest or brush of at least 250 feet adjacent to brooks, streams, and wetlands.

Maintain biological diversity and ecological integrity

Invasive Species

- Eradication of high priority purple loosestrife to zero areas occupied.

Rationale

The refuge includes or abuts portions of ten natural lakes ranging in size from 20 to 295 acres. Bearce Lake, Conic Lake, and Cranberry Lake are located within the Baring Division Wilderness Area and refuge land adjacent to Hobart Lake and Cranberry Pond, on the Edmunds Division, is within the wilderness area. The lake waters and shoreline provide breeding and foraging habitat for Common Loon, Bald Eagle, and Osprey.

Moosehorn NWR contains portions of 20 streams and brooks and 21 miles of riverine habitat. Moosehorn and Magurrewock Streams are the two largest stream drainages in the Baring Division; Hobart Stream is the primary drainage in the Edmunds Division. Thirteen of the refuge's brooks and streams are large enough to support populations of native Brook Trout, a species of conservation concern for the FWS and the State of Maine (MDIFW 2015, USFWS 2009). Self-sustaining populations of Brook Trout occur in several streams on both Divisions.

Eastern Brook Trout are a key indicator of water quality and are a recreationally and culturally important fish. However, populations are declining and greatly reduced or extirpated from nearly half of the watersheds in their historic eastern range from Maine to Georgia (Eastern Brook Trout Joint Venture 2008). Brook Trout require cold, clean, highly oxygenated water. They prefer water temperatures below 68ºF and cannot tolerate sustained water temperatures above 77ºF. Adult fish can tolerate a pH as low as 5, however a pH of 6 or less can cause metals found in soil and rock to dissolve in solution and suffocate and poison aquatic organisms. Since the Brook Trout is so sensitive to water quality and temperature, they serve as an indicator of the health of the ecosystem and the watershed that drains into their habitat (USFWS 2009).

A NET OF ALEWIVES. PHOTO CREDIT: USFWS

Many of the refuge's waterways are impounded with one or more artificial water control structures or are naturally dammed by Beavers, which may impede the passage of some fish species. To help mitigate these impacts, several impoundments have fishways including Middle Magurrewock, Upper Magurrewock, Tyler Flowage, and Howard Mill Flowage. Anadromous fish including Alewives have been documented using the fishways to migrate into the upper waterbodies such as Howard Mill Flowage and Vose Pond, but the degree to which the fishways, beaver dams, and other aquatic connectivity impediments may affect fish movement is not completely understood. Although beavers may negatively affect Brook Trout in lowland streams by inhibiting passage (Salyer 1935, Reid 1952), Brook Trout may benefit from increased food resources in beaver impoundments (Rupp 1954). Several of the most important trout streams on the refuge, including Cranberry Brook and Mahar Brook, depend on a continual outflow from the refuge's impoundments to maintain trout habitat.

Beavers typically inhabit permanent streams of up to 15 percent gradient, with adequate food resources, that do not have major fluctuations in discharge (Allen 1983). Beaver flowages are attractive to many species of dabbling duck, particularly American Black Duck and Wood Duck, as well as other waterfowl, waterbirds, raptors, songbirds, mammals, amphibians, and reptiles. For example, approximately 50 percent of the inland Osprey population in Maine nests on beaver flowages (Joseph 1995).

The riparian areas adjacent to water bodies and wetlands provide important habitat and often have high species richness with dynamic and complex biophysical processes. Riparian areas along rivers and streams provide important structural components including large nest and roost trees for eagles and ospreys and cavity trees for Wood Ducks, Hooded Mergansers, and other migratory birds. Wood Ducks, Common Goldeneyes, and Hooded and Common Mergansers nest in cavities in live trees 18 inches or more in diameter. Riparian areas often contain a mix of native shrubs including alder, elderberry, and viburnum that provide food and cover for nesting and migrating songbirds. The Alder Flycatcher nests in low, damp alder swamps associated with these wetlands and riparian areas (DeGraaf and Yamasaki 2001). In addition, riparian vegetation maintains cool stream temperatures that are important to Brook Trout, Salmon, and other fish.

The refuge will manage streams, wetlands, and riparian areas to ensure clear passage (e.g., lack of physical barriers and thermal barriers) to upstream fish spawning and rearing habitats during key periods of migration by alewives. In-stream habitat will include a mix of pools, glides, riffles, runs, and step-pools. A closed canopy of native trees along brook and stream banks will be maintained to provide shade and materials for the stream to benefit fish and aquatic invertebrates.

PLANTS OF MOOSEHORN BOGS. PITCHER PLANT (LEFT SIDE), CRANBERRY (UPPER RIGHT), *RHODORA* (LOWER RIGHT). PHOTO CREDIT: PITCHER PLANT BY MARY KONCHAR; CRANBERRY BY MIKE HEATH; *RHODORA* BY LIGHTSHEDDER

The FWS assessed all road crossings and culverts along refuge streams for their potential to impede fish and aquatic passage. The assessments included fish surveys above and below road crossings and water temperature monitoring. The results of these assessments will guide the refuge's priorities and actions related to culvert and road crossing upgrades, or in some cases, removal (Craig 2012). Stream-road crossings that most severely limit aquatic connectivity and are at a high risk for failure and are not needed, will be removed. To improve fish, reptile, and amphibian passage on other crossings, failing or insufficient structures and culverts will be replaced with fish- and wildlife-friendly open-bottom box or arch culverts.

OBJECTIVE 2.3 FORESTED WETLANDS AND PEATLANDS

Manage 1,072 acres of forested wetlands and peatlands (i.e. approximately 722 acres on Baring Division, and approximately 350 acres on Edmunds Division) to maintain the ecosystem over time (e.g. soils, species composition, regeneration, size class distribution), support migratory birds (e.g., breeding landbirds, waterfowl), and maintain native biological diversity and ecological integrity (e.g. reduce invasive species) from 2020 to 2035 with the following attributes (measurement units) and aspirational targets (values):

Maintain the ecosystem over time

Northern White Cedar Swamp

- Present on poorly drained basins along stream flowages, or the perimeter of ponds, with alkaline conditions and shallow (< 20 inches) peat (some sites may be deep peat) over mineral soil.
- Less than 60 percent overstory canopy closure (canopies > 16 ft. in height) is sparse with stunted northern white cedar.

- Thirty percent ground layer (canopies < 2 f.t in height) is well-developed and dominated by cinnamon fern (> 50% cover) with a dense carpet of Sphagnum moss, dewberry, and three-seeded sedge, in areas that are not open water.
- Northern white cedar swamp sites may naturally transition to cedar-spruce seepage forest, spruce-fir cinnamon fern forest or spruce-larch woodland bog.
- A minimum of 250 trees per acre greater than 5 inches DBH, 100 to 150 feet2 basal area per acre, and an 11-inch QMD with greater than 250 percent CV.
- A range of tree diameters, including 200 live trees 5 to 10 inches DBH per acre, 48 live trees 11 to 20 inches DBH per acre, 2 live trees 21 to 24 inches DBH per acre, at least 1 live tree greater than 24 inches DBH per acre, approximately2,500 seedlings/acre and 200 to 600 saplings/acre.

Cedar-Spruce Seepage Forest

- Present on gentle, saturated slopes of shallow peat or organic material over mineral soil, with groundwater seepage (water may form rivulets or small brooks).
- Seventy to 95 percent overstory canopy closure (canopies > 16 ft. in height) co-dominated by northern white cedar (30 to 50% cover) and red spruce (30 to 50% cover).
- An open midstory (canopies 6- to 16ft. in height) and understory (canopies 2 to 6 ft. in height).
- Ground layer (canopies < 2 ft. in height) is an herbaceous layer of ferns (e.g., royal, cinnamon, interrupted, and marsh fern), sedges (e.g., three-seeded, longstalked, and boreal bog sedges), and dense bryophyte cover (e.g., shaggy moss, stairstep moss).
- A minimum of 250 trees per acre greater than 5 inches DBH, 100 to 150 feet2 basal area per acre, and a 11-inch QMD with greater than 250 percent CV.
- A range of tree diameters, including 200 live trees 5 to 10 inches DBH per acre, 48 live trees 11 to 20 inches DBH per acre, 2 live trees 21 to 24 inches DBH per acre, at least 1 live tree greater than 24 inches DBH per acre, approximately2,500 seedlings/acre and 200 to 600 saplings/acre.

Red Maple-Sensitive Fern Swamp

- Present on flat or gentle slopes in small basins (floodplains of streams) with mineral soil or well decomposed organic material (muck) over mineral soil (11 to 24 inches deep).
- Twenty to 90 percent overstory canopy closure (canopies > 16 ft. in height) dominated (> 50% cover) by red maple with a component (up to 40% cover) of balsam fir, red spruce, or Northern white cedar.
- Understory (canopies 2 to 6 ft. in height) is a patchy shrub layer with winterberry.
- Ground layer (canopies < 2 ft. in height) is a well-developed herbaceous layer dominated with herbs (> 50% cover) and dwarf shrubs (< 20% cover) and a bryoid layer (< 35% cover) with peat mosses typical but not as deep as in peatlands.
- A minimum of 190 trees per acre greater than 5 inches DBH, 90 feet^2 basal area per acre, and QMD 9.5 inches with greater than 250 percent CV.
- A range of tree diameters, including 150 live trees 5 to 10 inches DBH per acre, 39 live trees 11 to 20 inches DBH per acre, and 4 live trees > 20 inches DBH per acre and approximately greater than 1,000 seedlings/acre and 300 saplings/acre.

Spruce-Larch Woodland Bog

- Present on highly acidic peatland (pH 4.2 to 5.2) sites.
- Twenty to 50 percent overstory canopy closure (canopies > 16 ft. in height) is open, or can be as high as 85 percent closure, dominated (> 50% cover) by black spruce and/or larch with red maple and white pine possibly present.
- Thirty percent understory canopy closure (canopies 2 to 6 ft. in height) of small trees and Labrador tea.

- Ground layer (canopies < 2 ft. in height) is an herbaceous layer of three-seeded sedge with a peat moss layer close to 100 percent cover.

Sheep Laurel Dwarf Shrub Bog

- Present on raised highly acidic (pH 3.9 to 4.6) peatlands where peat is saturated throughout the year.
- Less than 25 percent stunted overstory canopy closure (canopies 6 to 16 ft. in height) of scattered black spruce and larch trees.
- Greater than 75 percent understory canopy closure (canopies 2 to 6 ft. in height) dominated by heath shrubs (e.g., leatherleaf, sheep laurel, rhodora).
- Ground layer (canopies < 2 ft. in height) is a peat substrate containing hummocks and hollows of peat with less than 15 percent cover of sedges (e.g., cotton grasses, three-seeded sedge).

Leatherleaf Boggy Fen

- Present in wetter parts of bogs and acidic nutrient poor fens (pH 4.0) where groundwater contact is maintained.
- Vegetation is dominated (30 to 60% cover) by leatherleaf usually less than 3 feet tall, with a few scattered stunted black spruce (< 15% cover).
- An herbaceous cover of less than 30 percent with cotton grasses and cranberry scattered on a peat moss substrate.

Support migratory birds

- Breeding landbirds (e.g., Northern Waterthrush, Palm Warbler) will be annually present during the breeding season (June to July).
- Breeding waterfowl (e.g., Wood Duck) will be annually present during the breeding season (May to June).

Maintain biological diversity and ecological integrity

Forest Structure

- A presence of dead standing trees (snags) comprising approximately 5 to 20 percent of the total number of trees, the larger the better.
- A presence of hollow trees, living or dead, with cavities comprising approximately 3 to 5 percent of the total number of trees.
- Presence of downed woody material with coarse material (> 5 inches) averaging greater than 10 inches at large end diameter and length greater than 24 feet, the larger the better, and presence of fine material including smaller limbs and branches.

Invasive Species

- Eradication of high priority invasive plant species purple loosestrife to zero areas occupied.

Rationale

Forested wetlands (northern white cedar swamp, cedar-spruce seepage forest, and red maple-sensitive fern swamp) and peatlands (spruce-larch wooded bog, sheep laurel dwarf shrub bog, leatherleaf boggy fen), comprise approximately 5 percent of the refuge. Most of the peatlands are within wilderness or research natural areas, including the 10-acre Hobart Natural Area on the Edmunds Division, one of the few pure stands of northern white cedar. Despite their relatively small area, these sites harbor unique plant communities and habitat features.

Northern white cedar swamps occur in flat, poorly drained basins along streams or around ponds, on alkaline soils (Gawler and Cutko 2018). The swamps are dominated by northern white cedar, a long-lived, slow-growing tree, with a rich ground flora and structure of herbs, sphagnum mosses, dwarf shrubs, fallen logs, and hummocks. Cedar-spruce seepage forests have a closed canopy dominated by northern white cedar and red spruce, with abundant mosses and herb layer. These forests are typically found at the base of saturated slopes with groundwater seepage. Red maple-sensitive fern swamps occur on mineral soil wetlands, where red maple dominates the canopy or is co-dominant with conifers. Sensitive fern and bluejoint are common understory plants (Gawler and Cutko 2018).

The forested wetlands provide optimal habitat for the Wood Duck, a cavity nester and species of concern in BCR 14 (Dettmers 2006). Hunting regulations, the recovery of Beaver that create forested wetlands, and prevalence of mature trees as nest sites, have helped the Wood Duck recover across its range (Hepp and Bellrose 2020). The PIF Physiographic Area 28 supports the highest relative abundance of Northern Parulas, compared to other physiographic areas (Rosenberg and Hodgman 2000). In addition to nesting in mature conifer forest, Northern Parulas occur in wooded riparian habitats, especially where the moss-like lichen, *Usnea* occurs (DeGraaf and Yamasaki 2001). In addition to supporting unique plants and nesting bird species, northern white cedar is a favored browse species for White-tailed Deer, as well as Snowshoe Hare and Porcupine.

Spruce-larch wooded bog is an open canopy peatland with black spruce as the dominant tree species and is the most common type of "forested bog" in Maine. Labrador tea, three-seeded sedge, and a solid ground cover of *Sphagnum* mosses are characteristic. Palm Warbler and Northern Waterthrush breed primarily in this habitat in Maine (Gawler and Cutko 2018). The Palm Warbler usually nests on the surface of bogs deep in a *Sphagnum* hummock or beneath a short conifer (DeGraaf and Yamasaki 2001, Wilson 2013). It is considered a priority species in BCR 14 (Dettmers 2006) and in the PIF Physiographic Area 28 (Rosenberg and Hodgman 2000). Increasing levels of peat-harvesting in boreal forests is considered a threat to this bog-nesting species (Wilson 2020). The Northern Waterthrush prefers cool, brushy areas along edges of forested wetlands, ponds, and bogs. They place their nests among the roots of rotten trees or stumps, in fern clumps, at base of trees, or along banks (DeGraaf and Yamasaki 2001).

The sheep laurel dwarf shrub bog and leatherleaf boggy fen are associated with more open water peatlands. Leatherleaf is the dominant heath shrub in the leatherleaf boggy fen, which typically occurs in settings where groundwater contact is maintained (hence the name "fen") (Gawler and Cutko 2018). Heath shrubs, including sheep laurel, rhodora and Labrador tea, form a dense layer in this highly acidic environment where the plant growth is raised above the water table. Scattered black spruce and larch are typical along with a carpet of spongy *Sphagnum* mosses. It is a common community type in Maine, although on unprotected lands it is impacted by peat harvesting, changes to hydrology, and recreation.

Most of the peatland communities are within the wilderness areas or research natural areas and, as such, no active management is planned. The feasibility and need for active management to facilitate cedar regeneration in northern white cedar swamps will be assessed. If management access is needed or public access desirable in any of these forested wetlands or peatlands, then frozen conditions or use of boardwalks will help minimize impacts.

LOW SALT MARSH ON THE EDMUNDS DIVISION OF MOOSEHORN NWR.
PHOTO CREDIT: RAY BROWN, USFWS

OBJECTIVE 2.4 SALT MARSH

Manage 60 acres of salt marsh at the Edmunds Division to maintain the ecosystem over time (e.g. total marsh extent, vegetation communities, vegetated and non-vegetated marsh, elevation relative to sea level rise, and migration), support migratory birds (e.g., Nelson's Sparrow, American Black Duck), and maintain native biological diversity and ecological integrity (e.g. rare species, reduce invasive species) from 2020 to 2035 with the following attributes (measurement unit) and aspirational targets (values):

Maintain the ecosystem over time

- Less than 10 percent loss of total marsh acreage (6 acres) (e.g., rate of erosion is less than the rate of migration).
- Marsh platform elevation change rate (millimeters per year) greater than or equal to the relative local sea level rise rate (3.02 millimeters per year).
- Un-vegetated marshes (e.g., pools, pannes, creeks and mudflats) comprise 10 to 20 percent of the total marsh acreage (6 to 12 acres).

Low Marsh

- Approximately less than 10 percent of the total marsh acreage is low marsh, typically dominated by smooth cordgrass (*Spartina alterniflora*) and regularly flooded on a daily cycle, with
    - approximately 50 to 80 percent vegetation cover, 20 to 50 percent bare ground, and zero percent open water at low tide.
    - thatch not present and low peat strength (if not on mineral soil).
    - an average height of smooth cordgrass (*S. alterniflora*) of greater than 1-foot.

High Marsh

- Approximately 70 percent of the total marsh acreage is high marsh, typically dominated by saltmeadow cordgrass (*Spartina patens*) and saltgrass (*Distichlis spicata*) (> 80%), and irregularly flooded on a daily cycle, with
    - approximately 80 to 100 percent vegetation cover, zero to 20 percent bare ground, and zero to 30 percent open water at low tide.
    - a thatch layer thickness of 0.8 to 4 inches (2 to 10 cm) *S. patens* and high peat strength (if not on mineral soil).
    - an average height of smooth cordgrass (*S. alterniflora*) of 0.8 to 12 inches (1 to 30 cm).
- Approximately 10 percent of the total marsh acreage is typically dominated by Jesuit's bark (*Iva frutescens*) and seaside goldenrod (*Solidago sempervirens*) and regularly flooded on a lunar cycle, with
    - approximately 100 percent vegetation cover, no bare ground, and no open water at low tide.
    - a thatch layer thickness of 0.4 to 0.8 inches (1 to 2 cm) and high peat strength (if not on mineral soil).

Support migratory birds

- Maximize the number of adult Nelson's Sparrows (median 5-year refuge-level abundance) with greater than 0.91 birds/point as a proxy indicator.
- American Black Ducks will be annually present during spring migration (March to April), fall migration (September to November) and winter (December to February), except during periods when the marsh surface and pannes are frozen.

Maintain biological diversity and ecological integrity

Rare Plant Communities

- Stable or increasing patches of Gaspé arrow-grass (*Triglochin gaspensis*) in Whiting and Denny's Bay (four documented patches identified in 2019).

Rationale

The refuge has only 60 acres of salt marsh on the Edmunds Division in Dennys and Whiting Bays. Despite the small acreage, the refuge salt marsh is an important habitat for many species including American Black Duck, Nelson's Sparrow, and a rare plant, Gaspé arrow-grass. Tidal salt marsh consists of expanses of saltmeadow cordgrass ("high marsh") and smooth cordgrass ("low marsh"), which grows along creeks and just below mean high water (Gawler and Cutko 2018).

Nelson's Sparrow is a species of special concern in Maine and a priority species for the FWS in BCR 14 (USFWS 2021c) and in the PIF physiographic Area 28 (Rosenberg and Hodgman 2000). A secretive and highly localized species, the Nelson's Sparrow is composed of three geographically separated subspecies, all of which inhabit open country, wet meadows, or tidal wetlands. The maritime subspecies, *A. n. subvirgata*, breeds along the coast from the Gulf of St. Lawrence to northeastern Massachusetts. With the loss of coastal salt marsh (and interior grasslands), this species has suffered major habitat loss. Nelson's Sparrows nest in coastal marshes usually placed just above normal high tide mark, and as such, normal fluctuations in rainfall and storm surges can cause high nestling mortality during the breeding season. This species generally requires mature, extensive, and undisturbed marshland habitat to achieve successful nesting and re-nesting. Mowing, draining, plowing, burning, and spraying for insects can

disrupt the breeding cycle as well. The conservation of extensive tidal marsh and interior northern grasslands is critical to the stabilization of Nelson's Sparrow populations. Despite these pressures, Nelson's Sparrows are relatively common, and the population increased between 1966 and 2014, according to the North American Breeding Bird Survey, although they remain vulnerable to habitat loss and sea level rise (Shriver et al. 2020).

Gaspé arrow-grass (*Triglochin gaspense*) is an imperiled plant species in Maine due to its rarity. The plant ranges from Newfoundland south to Prince Edward Island, west to Maine, north to Quebec; in Maine, it is found from eight towns in Washington County in the upper inner tidal zones of salt marshes. The refuge supports a population on Cobscook Bay. Gaspé arrow-grass differs from other arrow-grasses in Maine by forming lawn-like patches (as opposed to clump forming) and the leaves are as long as or longer than the scape. Hydrologic alterations to salt marshes could pose a threat to populations (MNAP 2019).

In New England and the Maritime Provinces of Canada, American Black Ducks use tidal habitats, including salt marsh, exclusively in winter (Jorde 1986). Salt marsh is also an important habitat during migration (Jorde et al. 1989). The salt marshes on the Edmunds Division are in Cobscook Bay, which supports up to 25 percent of Maine’s wintering population of American Black Ducks.

BURNT ISLAND, EDMUNDS DIVISION, MOOSEHORN NWR. PHOTO CREDIT: USFWS

OBJECTIVE 2.5 ROCKY COAST, MUDFLATS, TIDAL CREEKS, AND ISLANDS IN COBSCOOK BAY

Manage 18 miles (approximately 285 acres) of coastal habitats and 5 islands in Cobscook Bay (Denny's and Whiting Bay) on the Edmunds Division to maintain the ecosystem over time (e.g., total extent, dynamic geomorphic settings), support migratory birds (e.g., migrating waterfowl and shorebirds), and maintain native biological diversity and ecological integrity (e.g., reduce invasive species) from 2023 to 2038 with the following attributes (measurement units) and aspirational targets (values):

Maintain the ecosystem over time

- Less than 10 percent loss of coastal islands (ranging from 1 to 50 acres).
- More than 80 percent overstory canopy closure (canopies > 16 ft. in height) on islands is dominated by mature spruce-fir or aspen/birch/maple (> 50% cover) with some white pine and an understory of lowbush blueberry.
- Rocky coastal waters and mudflats have stable or increasing patches of rockweed and clams.

Support migratory birds

- At least 10 species of migrating and wintering waterfowl (e.g., American Black Duck) are annually present during spring migration (March to May), fall migration (September to November), and winter (December to February).
- At least 8 species of migrating shorebirds (e.g., Semipalmated Sandpiper) area annually present during spring (April to May) and fall migration (July to September)

Maintain biological diversity and ecological integrity

Invasive Species

- Minimize the effects of invasive Green Crabs by working with partners in trapping and eradication efforts and encouraging research aimed at controlling their populations.

Rationale

Cobscook Bay is noted for its extraordinary natural productivity, diversity of plant and animal species, and importance to wintering Black Ducks, nesting Bald Eagles, migrating shorebirds, and shellfish. The Bay's complex of inlets, bays, tidal creeks, and rivers and approximately 97 miles of shoreline, experiences tidal fluctuations of up to 24 feet, the highest in the United States, creating huge expanses of mudflats, ice-free conditions, and nutrient-rich waters (USFWS 1990). The Maine Wildlife Action Plan (MDIFW 2015) and Atlantic Flyway Shorebird Initiative (2016) recognize Cobscook Bay as a focus area of Statewide Ecological Significance and part of the Maritime Canada and Northeastern United States focus areas, respectively. The refuge's Edmunds Division has more than 18 miles of rocky shoreline along Dennys and Whiting Bays and 5 islands in Cobscook Bay.

The Birch Islands lie about 0.3 miles offshore in Whiting Bay and are part of the Wilderness Area. Both islands are forested and dominated by white pine and white birch; the southernmost island has an active Eagle nest. Cobscook Bay supports the highest density of nesting Bald Eagles in the northeastern United States (MDIFW 2015), and thus played a key role in restoring Eagle populations. The Bald Eagle was removed from the Federal endangered species list in 2007 and from the Maine endangered species list in 2009, though is still protected by the Federal Bald and Golden Eagle Protection Act. Both refuge divisions are used extensively by Bald Eagles throughout the year for feeding and roosting; up to 80 birds were counted at one refuge feeding site in the mid-1980s. There are two active nests on the Baring Division and six along the shore of Dennys and Whiting Bays on the Edmunds Division. Not every nest is active or productive every year.

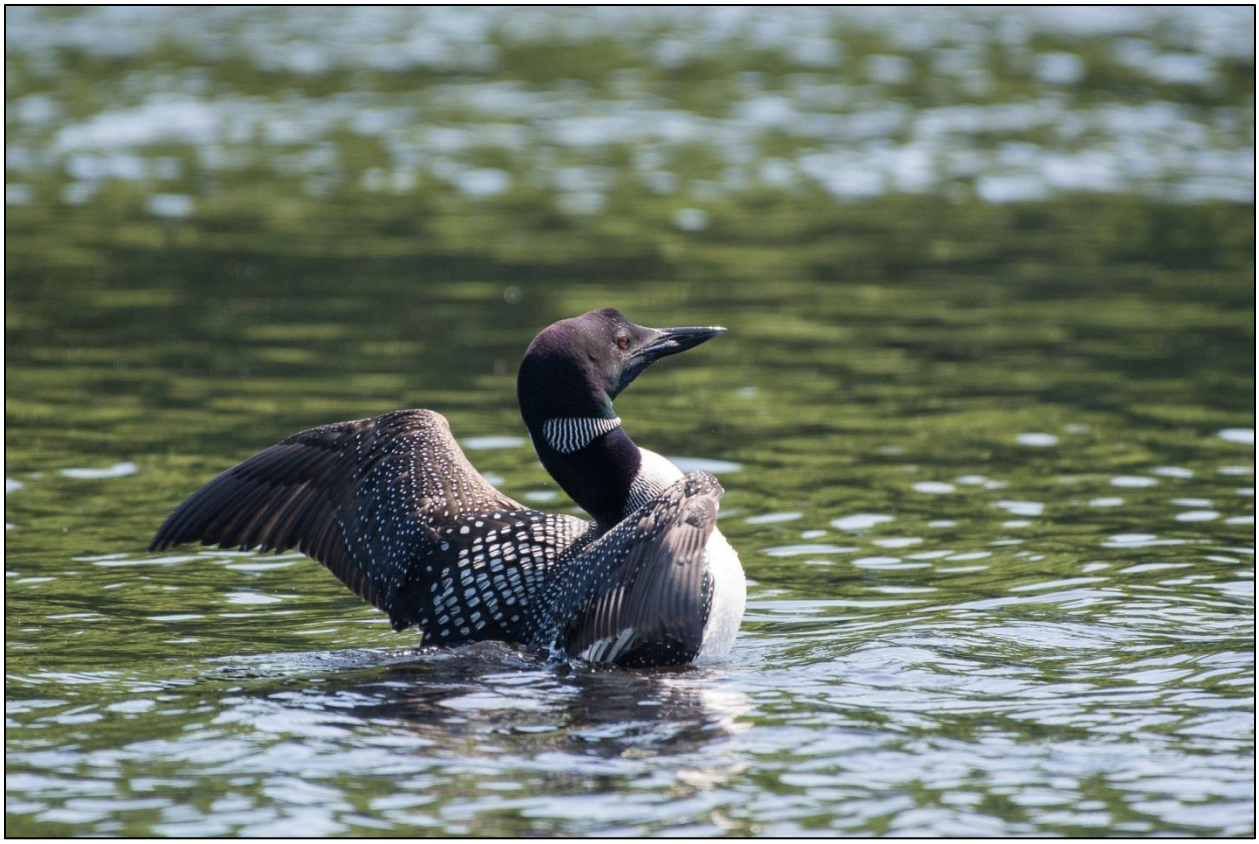
The ice-free bays around Cobscook Bay are wintering habitat for the American Black Duck—up to 25 percent of Maine's wintering population—and other waterfowl (e.g., Common Goldeneye, Bufflehead, Long-tailed Duck) when inland marshes are frozen. The American Black Duck was once the most abundant dabbling duck in eastern North America, but populations began declining steadily in the 1950s and reached an all-time low by the 1980s, having lost more than half of their historical population. Black Duck populations have stabilized since then, although they are still below the objectives set by the North American Waterfowl Management Plan (ACJV 2019) and are considered a "highest" priority species in BCR 14 (USFWS, 2021), Atlantic Coast Joint Venture, and in the Partners in Flight Physiographic Area 28 (Rosenberg and Hodgman 2000).

Cobscook Bay experiences unusually large tides, which bring nutrient-rich water from the Gulf of Maine. Higher concentrations of nutrients in the tidal water stimulate growth of seaweeds and phytoplankton in the Bay. In turn, blooms of phytoplankton provide food for bottom-dwelling shellfish, marine worms, and other important invertebrates--food sources for many other species. The extensive tidal flats of Cobscook Bay provide internationally significant "staging areas" for more than 20 species of migrating shorebirds that stop on their southerly migration to build up fat reserves. The Atlantic Flyway Shorebird Initiative (AFSI 2016) lists many of these species as highest concern (e.g., Red Knot) and high concern (e.g., Semipalmated Sandpiper). Protecting all stopover links along the migratory pathway is a critical component of shorebird conservation, given the multiple threats faced by Atlantic Flyway shorebirds, including habitat loss and change, human disturbance, and predation.

ROCKWEED. PHOTO CREDIT: JEANNETTE S., FLICKR

Rockweed or knotted wrack (*Ascophyllum nodosum*) is a type of large marine algae ("seaweed") and is a major component of intertidal habitat along Maine's rocky coastlines. Up to 60 different marine animals and plants use rockweed at low tide. As the tide comes in, tiny air bladders along the rockweed stem and branches cause the plant to rise and sway with the current, creating an undersea nursery for as many as 31 fish species. Juvenile Herring, Pollock, and Winter Flounder, among other fish species, use rockweed "forests" to escape from predators and feed on invertebrates. Common Eiders use rockweed as brood-rearing habitat, feeding on amphipods and periwinkle snails among the wrack (Daigle and Dow 2000).

Rockweed harvesting has a long tradition in Maine with commercial operations beginning in the 1970s. It is used in food, fertilizer, soil conditioners, animal feed, and other products (Thayer and Schmidt 2013). In 2009, the Cobscook Bay Rockweed Management Area was established by Maine statute to regulate harvesting. In 2014, the State of Maine developed a fishery management plan to provide a holistic approach to coast-wide rockweed harvest and to preserve the ecological functions and stature of rockweed beds, which includes designating sensitive no-harvest areas (MDIFW 2014). Rockweed harvesting is prohibited on the refuge; ownership of coastal lands extends to the low water mark. Some private landowners have added their properties to a registry that lists areas where rockweed harvest is prohibited.



5. MANAGEMENT UNITS AND STRATEGIES

Management Units

Management Unit Priorities

Management Strategies

MANAGEMENT UNITS

Moosehorn NWR has been divided into management units (MUs) to facilitate planning, implementation, documenting, and monitoring purposes. Defining smaller, discrete units makes practical sense when there is a wide diversity of habitat types and management potential. These boundaries are simply an administrative construct for habitat management purposes only. Moosehorn NWR's MUs are clustered in two locations - Baring Division and Edmunds Division. The Baring and Edmunds Divisions were divided into multiple MUs based on geographical location, ecologically recognizable features, roads, trails, and other features. As new lands are acquired, existing MUs will be expanded, or new ones will be designated.

Baring Division Units

The MUs for the Baring Division are the same units delineated and described in the refuge's Forest Management Plan (FMP) for that division, with two exceptions (Table 5-1, Figure 5-1). Lands acquired after the development of the FMP were added to the adjacent MU. The Charlotte Road unit was deleted and habitats within that unit were added to the adjacent MU.

TABLE 5-1. BARING DIVISION MANAGEMENT UNITS AND ACRES

Management Unit	**Size (ac)**
Barn Meadow	2,045
Howard Mill	965
Route 191	3,372
Snare Meadow	2,944
South Trail	3,498
Vose Pond	2,947
*Wilderness (Baring)**	4,763
Total	**20,534**

* Wilderness Area unit includes some areas outside the designated 4,680-acre Baring Wilderness.

Edmunds Division Units

The Edmunds Division of Moosehorn NWR has 11 MUs (Table 5-2, Figure 5-2).

TABLE 5-2. EDMUNDS DIVISION MANAGEMENT UNITS AND ACRES

Management Unit	**Size (ac)**
Belyea Cove/Hobart Stream	830
Bill's Hill	246
Birch Islands (Wilderness)	7
Broad Cove	500
Dodge Road	1,299
Dram Island	9
Edmunds Wilderness	2,709

Management Unit	**Size (ac)**
Hallowell Island	62
Edmunds Managed Interior	2,686
Ox Cove	362
Young's Cove	32
TOTAL ACRES	**8,742**

FIGURE 5-1 EDMUNDS DIVISION MANAGEMENT UNITS.

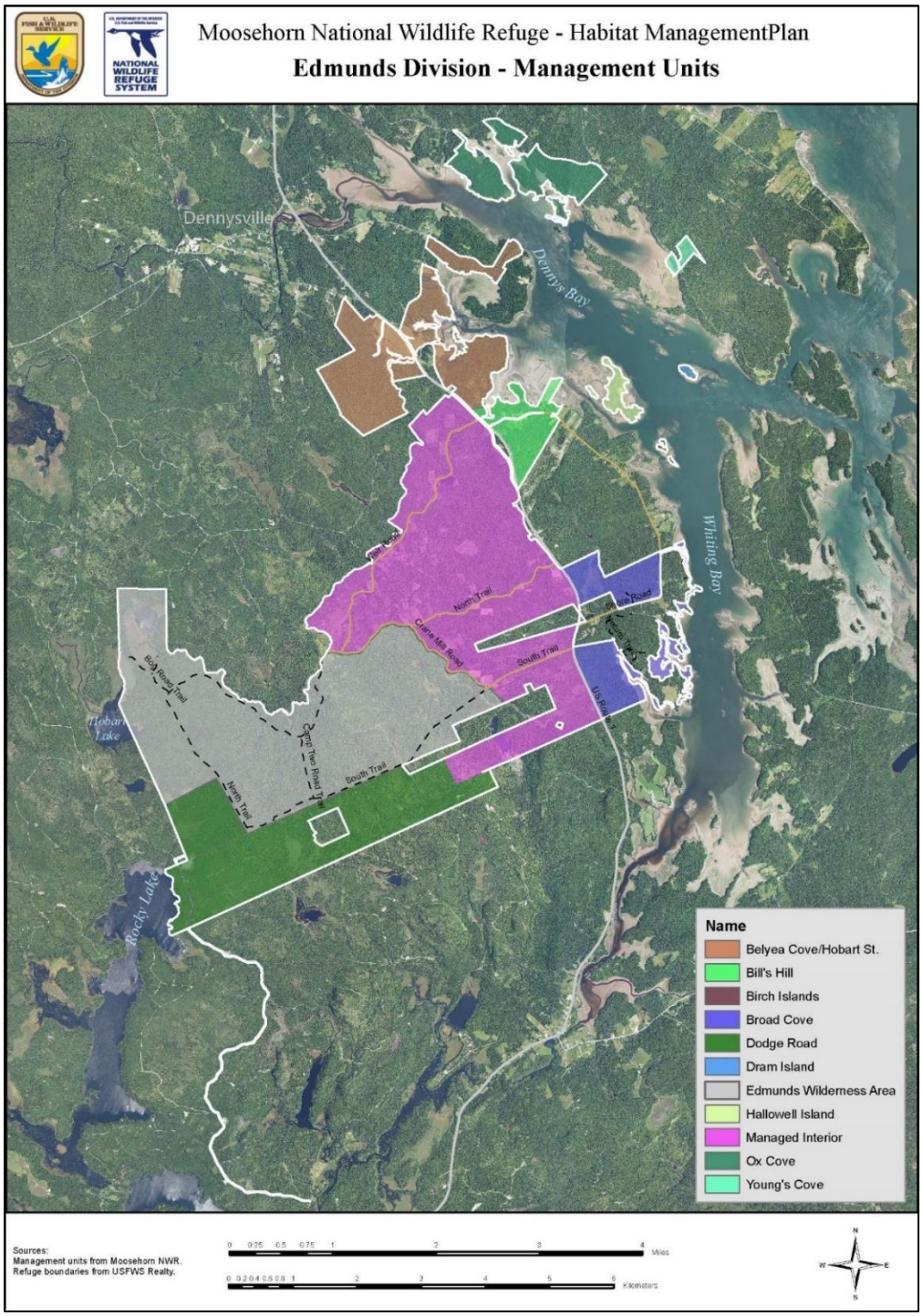
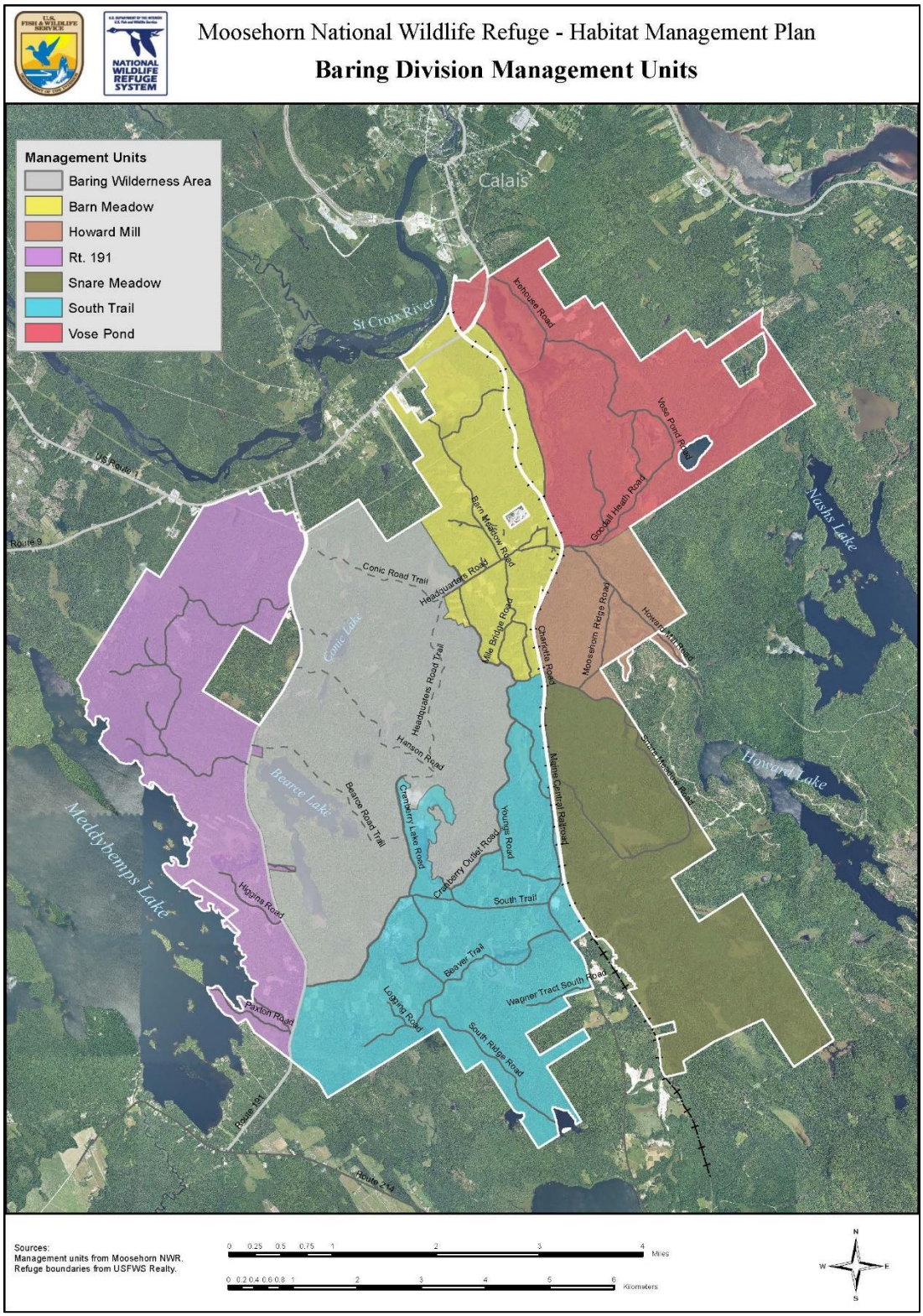


FIGURE 5-2 BARING DIVISION MANAGEMENT UNITS.



MANAGEMENT UNIT PRIORITIES

MUs were prioritized to help guide refuge management capability towards areas with the most potential for meeting refuge goals and objectives (Table 5-4, Table 5-5). Rankings are based on an assessment of where management can achieve its greatest contribution to ROCs, while considering the overall management purpose, HMP goals and objectives, and the need to prioritize annual work plans. Multiple considerations went into the ranking, including the following (in general order of priority):

- Habitat priority (chapter 3, Table 3-3).
- Value or contribution to the ROCs.
- Management capabilities, including access challenges.
- Occupancy by Federal- and State-listed species.
- Habitat quality and potential.
- Spatial patch size and connectivity to similar habitat types.
- Intensity, frequency, and type of management needed.
- Personnel availability and operating costs.

The definitions used to prioritize the MUs:

Priority 1 Management Units

Comparatively large, high-quality units that encompass top priority habitat types and provide habitat for priority resources (Table 5-3). Management actions (e.g., exotic species control or vegetation management) are expected to have beneficial impact and/or connect prioritized habitats. Generally, these units receive more management effort than other MUs. They tend to have higher value for ROCs, have larger habitat blocks, and have good management capability.

Priority 2 Management Units

These units are generally large enough to support minimum ROC patch requirements (Table 5-4). These units provide important habitat for ROC but generally are smaller and not spatially connected to larger habitat blocks. Includes larger areas of jurisdiction on open water habitats. These units still receive active management, but at a reduced level as compared to Priority 1 units. Generally, this reduction is due to increasingly limited management capabilities and challenges of access. These MUs may have a lower value for ROCs. If factors limiting the unit are repaired or upgraded, or as funding becomes available to address management limitations, these units could be reclassified as Priority 1.

TABLE 5-3. PRIORITY 1 REFUGE MANAGEMENT UNITS FOR MOOSEHORN NWR.

Management Unit	Primary Habitats	Size (acres)	Rationale for Ranking
Vose Pond	Early Successional Aspen Birch Forest Freshwater Managed Impoundments Old Fields Streams	2,947	• six early successional focal areas totaling 352 acres. • 387 acres of impoundments, some of the highest quality on the refuge. • 4.2 miles of steam and riparian habitat for migratory fish. • 1,060 acres to be managed for northern hardwoods. • 76 acres of old fields managed for grassland birds.
Barn Meadow	Pine and Mixed Forest Freshwater Managed Impoundments	2,045	• 288 acres of white pine and mixed forest including several oak stands.

Management Unit	Primary Habitats	Size (acres)	Rationale for Ranking
	Old Fields and Blueberry		• 171 acres of impoundments, some of the highest quality on the refuge. • 15 acres of managed blueberry and 131 acres of old field which will be maintained and enhanced for migratory birds.
Howard Mill	Early Successional Aspen Birch Freshwater Managed Impoundments Streams and Associated Wetlands	965	• One early successional focal area totaling 98 acres. • 57-acre Howard Mill Impoundment serves as breeding site for alewives. • 1.5 miles of stream habitat for migratory fish. • 341 acres to be managed for northern hardwoods.
Snare Meadow	Early Successional Aspen Birch Freshwater Managed Impoundments Spruce-northern hardwoods	2,944	• One early successional focal area totaling 169 acres. • Two freshwater impoundments totaling 59 acres. • 983 acres to be managed for northern hardwoods and 878 acres to be managed as spruce northern hardwoods. • 4.3 miles of stream and riparian habitat for brook trout.
Route 191	Early Successional Aspen Birch Freshwater Managed Impoundments Spruce-northern hardwoods	3,372	• Four early successional focal areas totaling 597 acres. • 7 miles of shoreline on Meddybemps Lake. • One high quality freshwater impoundment totaling 70 acres. • 1,237 acres to be managed for spruce-northern hardwoods.
South Trail	Freshwater Managed Impoundments Old Fields Spruce-northern hardwoods	3498	• Six high quality freshwater impoundments totaling 217 acres. • 1,158 acres to be managed for northern hardwoods. • 901 acres to be managed for spruce/northern hardwoods.
Belyea Cove/Hobart Stream	Old Fields and Lowbush Blueberry Salt marsh Rocky Coast, Mudflats, Tidal Creeks Spruce-fir	830	• 669 acres to be managed as spruce-fir forest. • 41 acres of salt marsh. • Nat Smith impoundment (20-acre). • 66 acres of old fields managed for nesting grassland birds.
Bill's Hill	Old Fields and Lowbush Blueberry Salt marsh Rocky Coast, Mudflats, Tidal Creeks Spruce-Fir Forest	246	• 168 acres to be managed as spruce-fir forest. • 21 acres of old field and blueberry. • 16 acres (1.8 miles of shore) of rocky coast, mudflats, and salt marsh.
Broad Cove	Old Fields and Lowbush Blueberry Rocky Coast, Mudflats, Tidal Creeks	500	• 16 acres of old field. • 129 acres (4 miles) of rocky coast, mudflats, and tidal creeks.
Managed Interior	Early Successional Aspen Birch Spruce-Fir Forests	2,686	• 579 acres to be managed as early successional demonstration areas. • 1,426 acres to be managed as spruce-fir forest. • One 18-acre freshwater impoundment to be repaired.

TABLE 5-4. PRIORITY 2 REFUGE MANAGEMENT UNITS FOR MOOSEHORN NWR.

Management Unit	Primary Habitats	Size (acres)	Rationale for Ranking
Baring Wilderness	White Pine-Mixed Conifer Old White Pine Stands (RNA) Spruce-Northern Hardwoods Northern Hardwoods Lakes and Natural Wetlands	4,794	• No active management permitted. • Maintain and monitor Wilderness Character.
Edmunds Wilderness	Spruce-Fir Forest Spruce-Northern Hardwoods Northern Hardwoods Hobart Bog and natural wetlands Cedar Stands	2,709	• No active management permitted. • Maintain and monitor Wilderness Character.
Ox Cove	Spruce-Fir Forest Tidal Salt marsh Rocky Coast, Mudflats, Tidal Creeks	362	• 270 acres to be managed as spruce-fir forest. • 85 acres (5 miles) of rocky coast; protect from illegal rockweed harvest. • Eagle nesting territories.
Young's Cove	Rocky Coast, Mudflats, Tidal Creeks Spruce-Fir Forest	32	• 7 acres (.2 miles) of rocky coast; protect from illegal rockweed harvest.
Hallowell Island	White Pine Mixed Conifer Salt marsh Rocky Coast, Mudflats Spruce-Fir Forest	62	• 8 acres (1.5 miles) of rocky coast; protect from illegal rockweed harvest. • Eagle nesting territory.
Dram Island	Rocky Coast, Mudflats Spruce-Fir Forest	9	• 2 acres (.5 miles) of rocky coast; protect from illegal rockweed harvest. • Eagle nesting territory.
Birch Islands (WA)	Rocky Coast, Mudflats Spruce-Fir Forest	7	• Wilderness Area, no management permitted. • Active Eagle nesting territory. • protect from illegal rockweed harvest.
Dodge Road	Spruce-Fir Forest Northern Hardwoods Forested Wetlands	1,299	• 468 acres to be managed as spruce-fir forest. • 197 acres to be managed as northern hardwoods. • Protect forested wetlands, lakes, and streams.

MANAGEMENT STRATEGIES

The purpose of this section is to describe the management strategies that will be implemented to achieve the habitat objectives at the refuge. We describe strategies that are applied across all MUs and strategies that are tied to a specific objective (see chapter 4). At the regional level, management techniques that are common among refuges and employed to restore and enhance the biological integrity of priority habitats and their associated ROCs are described in some detail in a separate file (*General Land Management Strategies*). These techniques address threats, or are strategies employed on multiple refuges.

All management activities are subject to available funding and staffing. In all cases, with input of additional resources, such as funding, partnerships, or staff, the refuge will:

- Increase intensity and implementation of other strategies.
- Identify/establish systematic monitoring/inventory/assessment protocols to characterize habitats and species across the refuge.

Management Objectives and Locations

For each habitat type (objective), refuge staff have determined the locations where the strategies will be implemented (Figure 5-3 and Figure 5-4). A combination of current conditions, desired future conditions, and site capabilities was used to either maintain the current conditions (e.g., forested wetlands and peatlands), enhance conditions (e.g., spruce-fir forests), or facilitate transition to another objective (e.g., unproductive impoundments). The following maps indicate the general locations where objectives are planned to be implemented.

FIGURE 5-3 LOCATIONS WHERE HABITAT OBJECTIVES AND STRATEGIES WILL BE IMPLEMENTED, BARING DIVISION.

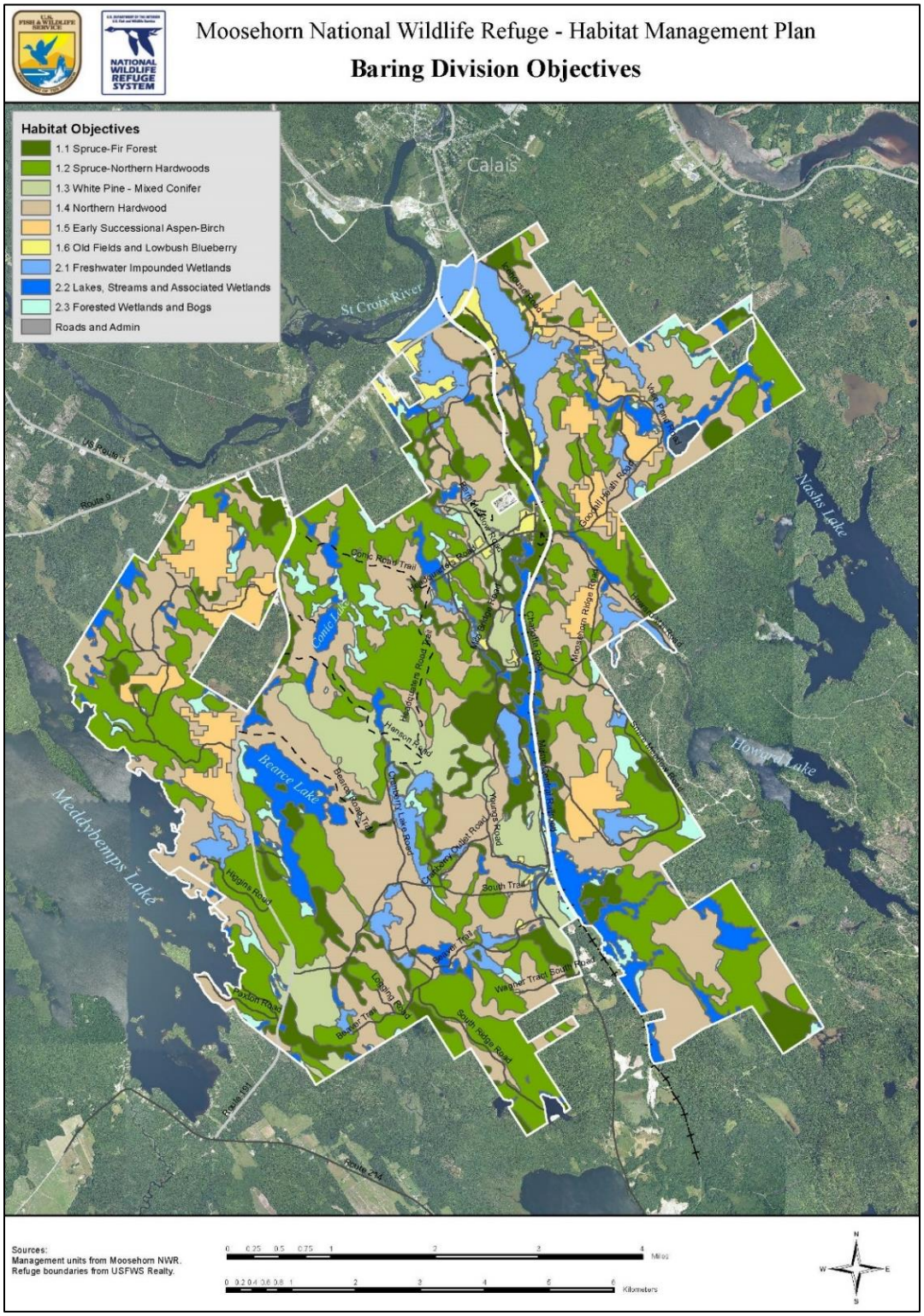
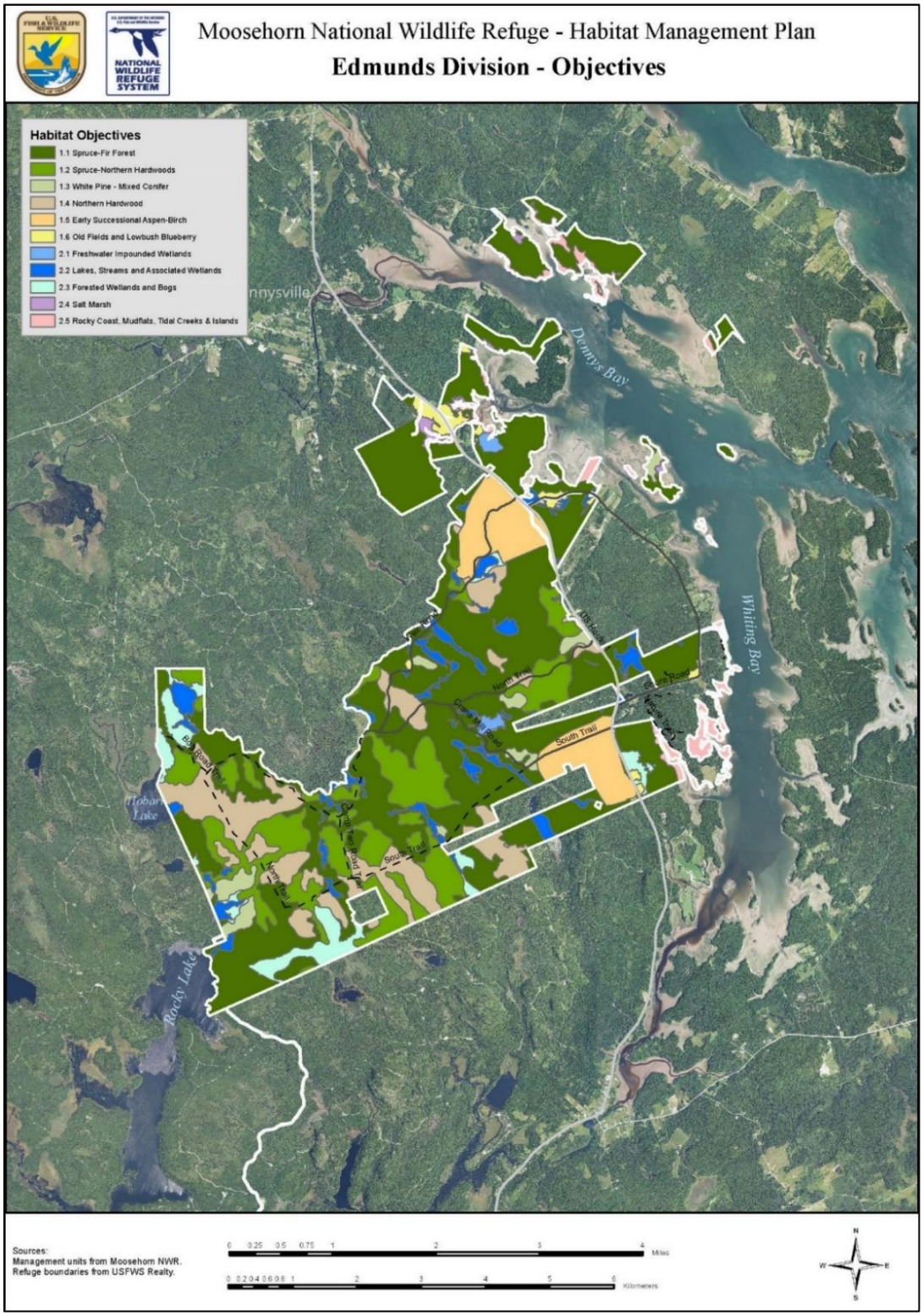


FIGURE 5-4 LOCATIONS WHERE HABITAT OBJECTIVES AND STRATEGIES WILL BE IMPLEMENTED, EDMUNDS DIVISION.



General Strategies Applicable on Multiple Refuges

The following general management strategies are employed on multiple refuges to restore and enhance the biological integrity of priority habitats; they address common threats or are widely employed. See Knutson (2021) for lists of tasks associated with these general strategies.

Make Defensible Decisions in the Face of Uncertainty

The habitat objectives for the priority species and habitats defined in the HMP were designed to be achievable (chapter 4). However, many factors may reduce the ability of the refuge to achieve these objectives. Ecosystems are constantly responding to changing conditions in the surrounding landscape, to new invasive species, new diseases, and, of course, to management actions. Managers respond to environmental changes by employing strategic decision-making.

Adaptive Management

The refuge will employ an adaptive management approach for improving habitat management by learning from management outcomes (Nichols et al. 2011). The refuge manager will be responsible for altering management actions and strategies in response to changes—such as shifts in habitat due to rising sea levels or new invasive plant populations—to produce the desired conditions. Monitoring management actions and outcomes and key resources will be important to implementing an adaptive management process.

Guidance on policy and procedures for adaptive management stems from the 2007 Secretarial Order No. 3270. In response to that order, the Department of Interior developed a technical guidebook to assist managers and practitioners titled "Adaptive Management: The U.S. Department of Interior, Technical Guide" (Williams et al. 2007). It defines adaptive management, the conditions under which managers should consider using it, and the process for implementing it and evaluating its effectiveness.

The guidebook provides the following operational definition for adaptive management:

> "Adaptive management is a decision process that promotes flexible decision-making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders."

Mitigate or Adapt to Climate Change

Climate change magnifies uncertainty about future conditions, creating new challenges for refuge managers (Knutson and Heglund 2011). Changing conditions may require managers to make difficult decisions that will benefit one set of species and reduce habitat quality for another set of species (tradeoffs). Refuge managers are responsible for altering management actions and strategies in response to environmental changes, such as shifts in habitat due to rising sea levels or changes in temperature and precipitation patterns. The effects of climate change on wildlife and habitats are expected to be location- and species-specific, with a predicted general trend of species' ranges shifting northward and sea level

rise pushing habitats and the associated species inland. For specific climate change projections for Moosehorn NWR and vicinity see chapter 2.

General strategies for adapting to climate change have been described elsewhere, including maintenance of genetic diversity, manipulation of disturbance regimes (e.g., fires, floods), and reduction of other stressors (Mawdsley et al. 2009). Tools for implementing these strategies are already widely employed by conservation agencies (e.g., land and water conservation, ecological restoration, species translocation, captive propagation, increasing the extent and connectivity of vulnerable ecosystems, monitoring, natural resource planning, and legislation/regulation). Management options that reduce non-climatic stressors (e.g., habitat modification, overexploitation, pollution, and invasive species) will increase the inherent capacity of ecosystems and help the associated species adapt to a changing climate. Natural resource managers will continue to apply these tools in novel and innovative ways to meet the unprecedented challenges posed by climate change (Carroll and Noss 2021).

Managing under conditions of climate change requires a new approach to decision-making, the resist–accept–direct (RAD) framework (Lynch et al. 2022; Schuurman et al. 2021). Depending upon the risks and benefits, some situations will prompt managers to resist climate change and sustain existing habitat conditions. Other situations will best be addressed by directing ecosystem change, e.g., helping ecosystems to transition to different desired conditions. RAD empowers managers to use familiar techniques associated with adaptive management in the unfamiliar territory of ecosystem transformation (Hansen et al. 2022). RAD involves periodic review and update of management actions and objectives; monitoring, experimentation, and pilot studies; and bet hedging to better identify and tolerate associated risks.

Protect Cultural Resources

As a Federal land management agency, we are entrusted with the responsibility to locate and protect all historic resources, specifically archaeological sites, and historic structures eligible for, or listed in, the National Register of Historic Places. This applies not only to refuge lands, but also to lands affected by refuge activities, and includes any museum properties.

A study by Wheeler et al. (2009) indicated that there are six recorded archaeological sites within the refuge. Considering the topography of the area, and proximity to water bodies, it is likely that additional prehistoric or historic sites may be identified in the future. Archaeological remains in the form of prehistoric campsites or villages would most likely be located along streams and lakes where early inhabitants would have had ample water, shelter, and good fishing and hunting opportunities.

We will continue to evaluate the potential of our management activities to impact archaeological and historical resources as required, including consulting with the Maine State Historic Preservation Office. We will be especially thorough in areas along the lakeshores and streams where there is a higher probability of locating a site. These activities would ensure we comply with *Section 106* of the *National Historic Preservation Act*. That compliance may require one or more of the following: State Historic Preservation Records survey, literature survey, or field survey.

BLACK BEAR IN A MEADOW AT MOOSEHORN NWR.
PHOTO CREDIT: KEITH RAMOS, USFWS

Conserve Wilderness Character in Wilderness Areas

Federal agencies are charged by Congress to preserve wilderness character in designated wilderness areas (*1964 Wilderness Act*). Wilderness character is a holistic concept based on the interaction of (1) biophysical environments primarily free from modern human manipulation and impact, (2) personal experiences in natural environments generally free from the encumbrances and signs of modern society, and (3) symbolic meanings of humility, restraint, and interdependence that inspire human connection with nature. Taken together, these tangible and intangible values define wilderness character and distinguish wilderness from other all lands (Landres et al. 2015).

To operationalize this definition and clarify the stewardship requirements of the 1964 Wilderness Act, these five tangible "qualities" of wilderness character are defined:

- *Untrammeled*—wilderness ecological systems are unhindered and free from intentional actions of modern human control or manipulation.
- *Natural*—wilderness ecological systems are substantially free from the effects of modern civilization.
- *Undeveloped*—wilderness is essentially without structures or installations, the use of motors, or mechanical transport.
- *Outstanding Opportunities for Solitude or Primitive and Unconfined Recreation*—wilderness provides outstanding opportunities for solitude or primitive and unconfined recreation.
- *Other Features of Value*—wilderness may have unique features of ecological, geological, scientific, educational, scenic, or historical value.

As described in the Moosehorn Wilderness Management Plan (USFWS 1979), the Wilderness Areas in the Edmunds Division, Baring Division, and Birch Islands are currently managed under the conditions in Wilderness Stewardship Plan (see MUs for details).

In 1977, Congress acknowledged the uniqueness of the Moosehorn Wilderness Area by naming it as a *Class I air quality area*, providing special protection under the Clean Air Act. The FWS has the responsibility to protect the air quality and air quality related values (AQRVs) - including vegetation,

wildlife, soils, water quality, visibility, odor, and cultural and archaeological resources--from manmade air pollution. The refuge maintains an air quality monitoring station that captures data on air quality, including the amount and type of particulates in samples collected every 3 days. This information is important to the protection of our natural resources and studying long-term trends of forest growth and is available to the public.

Sustain Bald Eagle Populations

Bald Eagles begin courtship and nest repair in February and start laying and incubating eggs in late March or early April. In Maine, mature red spruce, and balsam fir-dominated stands close to foraging habitat are considered preferred eagle nesting habitat. Eagles often nest in large hardwood or white pine trees in or above the surrounding tree canopy. During the nesting season, eagles are sensitive to disturbance and will typically nest in areas with minimal human activity (Buehler 2020). If disturbed, adult Bald Eagles may flush from their nest leaving eggs and young chicks exposed to inclement weather (heat or cold) or susceptible to predation. To protect nesting Bald Eagles on the refuge, we will continue to limit public access near historical and active nests.

Sustain Vernal Pool Habitats

According to the MDEP, "*Significant vernal pool habitat*" includes the vernal pool itself and the area within a 250-foot radius of the spring or fall high water mark of the pool, which is considered critical terrestrial habitat. The refuge will continue to protect vernal pools following the appropriate habitat management guidelines (Calhoun and De Maynadier 2004) for protecting and managing vernal pools.

In recent years, the refuge has been collecting data on 20 ‘focal’ pools annually, visiting each pool 2 to 3 times during the vernal pool species’ breeding seasons. Mapping of other vernal pools has only been done for a small portion of the Baring Division due to limited staff and the short season when egg masses are present.

SPOTTED SALAMANDER. PHOTO CREDIT: USFWS

General Strategies Applicable Refuge-wide

The following strategies are employed across many habitat types (objectives) at Moosehorn NWR.

Minimize Invasives

Control invasive plants

- To the extent possible, physically remove invasive species where they are encountered (Casey et al. 2020).
- Only herbicides approved for the use on target species will be used, and at the approved rates, concentration, and timing for application to enhance effectiveness and to reduce exposure for bees and butterflies.
- See Appendix B for a prioritized list of species.

Control other invasive taxa

- Continue to monitor the populations of Spruce Budworm--a native species that occurs in 40-year cycles--in partnership with the U.S. Forest Service and the Maine Forest Service.
- Work with partners and researchers to survey the refuge for other types of invasive species, including insects, crayfish, and marine plants and animals and monitor for other emerging invasive insect pests including Hemlock Woolly Adelgid and Asian Longhorn Beetle.

Prevent new infestations

- Properly care for all refuge equipment to avoid introduction or transport of invasive plants.
- Prevent new invasive species from becoming established by using EDRR (Early Detection Rapid Response) techniques to identify newly established invasive species and immediately control them using the appropriate methods.
- Work with State agencies to prevent introduction of invasive species to all water bodies on the refuge. Increase enforcement to check boats and equipment to protect against invasive plant transport.

Sustain Bald Eagle Population

Nest protection

- Evaluate all future land acquisition for potential to provide nesting habitat for Bald Eagles. Any additional Bald Eagle nest sites acquired in the future by the FWS would receive the same level of protection as current refuge nest sites.
- Maintain the one artificial nesting platform (at junction of Route 1 and Charlotte Road, Eagles have consistently nested there for over 20 years) and the opportunity it provides for wildlife viewing.
- Protect the seven active Bald Eagle nesting territories along the shores of Dennys and Whiting Bays.

Reduce disturbance

- Implement seasonal public access restrictions on the active and historic Bald Eagle nesting sites: historic eagle nesting islands and other historic nesting sites are closed from February 15 to May 15; active eagle nesting islands (or portions thereof) and other active nesting sites are closed from February 15 to August 31.
- Continue to use news releases or social media posts (such as Facebook) to make people aware that disturbing nesting eagles could result in the loss of a chick, and that human disturbance is illegal under state and federal law.

Protect Vernal Pool Habitat

Provide forest features

- Maintain a mostly closed forest canopy to provide the cool, moist conditions preferred by vernal pool obligate species.

- Maintain coarse, woody material by leaving dead and dying trees and fallen logs in place and protecting the forest floor by maintaining intact litter and duff layers, and a diverse herbaceous understory to provide adequate cover for those species that use the vernal pools.
- Establish criteria and rank vernal pools as to their conservation concern and need for management based on size, location, threats, productivity, seasonality, species diversity, and other factors.

Protect Vernal Pools from disturbance and contaminants

Follow the guidelines recommended by the Maine Forest Service in "Forest Management and Vernal Pools " (*https://www.maine.gov/ifw/docs/Vernal%20Pool%20Factsheet.pdf*), and "Forestry Habitat Management Guidelines for Vernal Pool Wildlife" (*https://maineaudubon.org/wp-content/uploads/2017/03/Forestry-Habitat-Management-Guidelines-for-Vernal-Pool-Wildl.pdf*) including, but not limited to, the following:

- Maintain a uniformly distributed stand of trees, at least 20 to 30 feet tall, with at least 75 percent canopy cover within 100 feet of the pool perimeter.
- Maintain a uniformly distributed stand of trees, at least 20 to 30 feet tall, with at least a 50 percent canopy cover, in the area between 100 and 400 feet of the pool perimeter.
- Avoid the use of chemicals in proximity to vernal pools because amphibians are particularly sensitive to toxins.

Strategies by Objective (Habitat Type)

The following strategies are employed in specific habitat types, wherever they occur. If a strategy applies to a specific MU or units, they are identified.

General Strategy for All Forest Types

The forest management activities proposed may be conducted in several ways. If the area proposed for management contains marketable forest products, we will attempt to achieve our objectives through the use of individual certified logging professionals or a logging company, where the refuge will realize some economic benefits from the harvest in the form of stumpage payments or a lump sum sale. On sites which don't contain trees large enough for a commercial harvest management may be conducted by refuge staff using FWS-owned equipment such as a brontosaurus (excavator with rotary chipping head) or FECON (forestry mulching machine), or the work may be contracted out.

General Strategies for All Mature Forest Types

Includes objectives 1.1 Spruce-Fir Forest, 1.2 Spruce-Northern Hardwood Forest, 1.3 Pine and Mixed Forest, and 1.4 Northern Hardwood Forest. See the refuge's Forest Management Plans (USFWS 1985a, 1993) for details.

Maintain no-cut areas

- Prohibit forest management in wilderness areas, as detailed in the Wilderness Stewardship Plan.
- Prohibit active forest management in Research Natural Areas and designated no-cut zones, other than to control infestations of invasive species.
- No cutting of trees or other forest management will be permitted in permanent "No Cut' or "No Management Areas" except under unusual circumstances. These areas were not suitable for harvest due to steep slopes or they have important scenic value.

Apply best management practices

- Meet or exceed State of Maine forestry regulations using *The Forestry Rules of Maine 2017: A Practical Guide for Foresters, Loggers and Woodlot Owners–2nd Edition* (MFS 2017b).
- Consult with State of Maine's *Best Management Practices for Forestry: Protecting Maine's Water Quality–Third Edition* to minimize management impacts (MFS 2017c).

- Consult *Forestry for Maine Birds–A Guidebook for Foresters* to employ bird-friendly forest management practices. Guidance on the application of specific management techniques to benefit birds has been developed by Maine Audubon in consultation with a variety of forest management specialists working in Maine. (Gallo et al. 2017)

Implement forestry prescriptions

- Most of the refuge's forest habitats will be allowed to develop naturally into late successional stages.
- The recent forest inventory assessment will be used in conjunction with USGS ecological site information to determine the areas with the greatest potential for each forest objective and the forestry needed to attain the desired future conditions.
- Promote multi-aged (uneven-aged) silvicultural systems of three or more age classes of trees in the same general area or stand using one or more of the following techniques:
- Single Tree Selection–trees are removed to enable upward recruitment of lower canopy stems into the future overstory, and three canopy levels uniformly distributed throughout the stand.
- Group Selection–trees are removed to form openings in a range of 1/10 to 2 acres, typically less than one acre, to create a range of canopy levels and densities.
- Irregular Shelterwood–promotes regeneration of shade tolerate species under partial shade by promoting two-storied stands where dense understories are established beneath partial overstory canopies using a variety of tree removal techniques.
- Maintain the integrity of closed-canopy habitat within the stand, by limiting the total area in gaps to no more than 20 percent of the stand area in any 20-year period.
- Identify how prescribed fire could be used to support forest management objectives and reduce fuel hazards.

Increase diversity

- Maintain a mix of snags and live cavity and/or decaying trees distributed throughout the stand. Good candidates to retain for future snags include aspen and red maple, as well as others with broken tops, large dead limbs, or other signs of potential decay.
- In older stands with few snags or cavity trees, girdling of a few trees will be used to create snags and/or decaying trees that will develop into cavity trees and snags will be retained.
- To increase the amount of course and fine woody material, treetops and occasional large logs will be left during mechanical logging.

Promote under-represented tree species

- Conduct landscape-level assessment using ecological land units, historic photographs, modeling, and predictions of historic and potential natural vegetation to determine where site conditions would favor native red spruce.
- Retention of clusters of softwoods and individual large-crowned softwoods in the overstory.
- Enhance tree species diversity by using silvicultural practices to promote species such as red oak, ash species, sugar maple, and yellow birch, which are under-represented on the refuge.
- Where appropriate, enhance cedar and hemlock stands to provide potential wintering habitat for White-tailed Deer, especially in areas where other components of wintering areas are present.

General Strategies for Early Successional Aspen-Birch

Maintain no-cut areas

- Prohibit early successional management in wilderness areas, as detailed in the Wilderness Stewardship Plan.
- Prohibit early successional management in Research Natural Areas and designated no-cut zones, other than to control infestations of invasive species.

Apply best management practices

- Meet or exceed State of Maine forestry regulations using *The Forestry Rules of Maine 2017: A Practical Guide for Foresters, Loggers and Woodlot Owners–2nd Edition* (MFS 2017b)
- Consult with the State of Maine's "Best Management Practices for Forestry: Protecting Maine's Water Quality–Third Edition" to minimize management impacts (MFS 2017c)
- Consult the guidelines and best management practices outline in *American Woodcock: Habitat Best Management Practices for the Northeast* (Williamson 2010)

Implement forestry prescriptions

- Promote even-aged silvicultural systems that result in a single age class of trees across an entire area using clearcutting techniques to promote intolerant hardwood species such as aspen and birch with the removal of all trees.
- Approximately 1,900 acres will be a mosaic of early- (0 to 15 years) and mid- (16 to 50 years) successional aspen and birch.
- Openings of variable patch sizes ranging from one, 5, or 10 acres with different configurations (e.g., 100-ft-wide strips of various length and edge design placed along the moisture gradient) will be created with an alder thicket or forested wetland near the center of the mosaic of successional stages.
- Develop a management plan for the demonstration areas that identifies which areas will be managed over the next 15 years, and the silvicultural practices to be employed.
- Prioritize areas that require active management, including conducting 20-year rotation cuts with 4-year entry intervals, or conducting understory prescribed burns.
- Reevaluate management within the demonstration areas as needed in the event of large-scale natural disturbance.

General Strategies for Old Fields and Lowbush Blueberry

Rotational mowing

- Maintain grass fields and blueberry barrens using mowing and prescribed fire on an established rotation. Control native sweet fern in some areas.
- Mow areas with priority grassland-nesting birds, such as bobolink and savannah sparrow, after August 1 and when pollinators are not active.
- Maintain 125-acres of fields with grasses and forbs between 8 and 12 inches high to provide nesting and feeding habitat for bobolink.
- Maintain 200-acres of grass fields, and low-bush blueberry with grasses and forbs less than 8 inches high for roosting areas for Woodcock.
- Mow less than a 2-acre area next to Magurrewock Dike, at the intersection of Charlotte Road and Upper Magurrewock Dike, every 2 to 4 weeks to draw resident Canada Geese away from the impoundment. Mowing will commence as early in the spring as conditions permit.
- Mow lanes (after July) in Woodcock roost areas to concentrate birds and facilitate night capture and banding of Woodcock.

Enhance fields for butterflies and bees

- Increase the abundance and distribution of common milkweed habitat for the Monarch Butterfly.
- Maintain a minimum of three native, nectar-producing forbs (e.g., goldenrod, milkweed, and aster species) that bloom during the following three periods: April to May; June to July; and August to October, to benefit pollinators.
- Maintain sparse vegetation in sandy soils to provide nesting areas for ground nesting bees.
- Allow some standing dead wood, brambles, plant stems, rotting logs, and tufts/clumps of grasses and leaves to remain in fields to provide nesting and overwintering habitat for a variety of bees.
- Prescribed fire to benefit pollinators will be conducted on only a portion or half of a site.

- Mowing intervals of 2 to 3 years will benefit pollinators, with mowing heights adjusted to leave more stems for stem nesting bees will also promote faster re-flowering.
- Control of invasive species will consider the availability of native flowering species during the same flowering period. In areas where only invasive plants are providing a source of nectar (for a specific time of year), native species will be increased before elimination of the invasive plants.

General Strategies for Freshwater Impoundments

Enhance habitat for wetland birds

- Maintain stable water levels throughout the spring and summer months to provide nesting and brood rearing habitat for waterfowl and marsh and water birds. Some impoundments may be periodically drawn down to mimic the natural cycle of a Beaver influenced wetland, and to provide habitat for migrating shorebirds.
- Optimal water levels will be set to encourage the growth of desirable vegetation and to approximate the open water to vegetated surface ratio of the hemi-marsh.
- Seasonally or permanently restrict public access to high use waterfowl and wading bird habitats.
- For all the impoundments identified as high priority:
- Develop specific management objectives and strategies for each impoundment and incorporate them into Annual Habitat Work Plans (AHWPs).
- Use adaptive management to refine management, including determining appropriate water levels and vegetation management.
- Evaluate the potential to manage impoundments to mimic natural processes such as a natural beaver pond cycle.
- Implement the continued maintenance and operation or removal of water control structures as guided by a decision support tool created by refuge staff.
- Install staff gauges to measure water levels, as needed.
- Conduct routine annual maintenance, including use of "beaver deceivers" (fence and pipe), as needed.

Manage furbearers

- Manage furbearers as warranted to protect infrastructure. Continue to implement annual trapping programs to limit damage to refuge roads, culverts, dikes, and water control structures.
- Conduct reconnaissance of Muskrat and Beaver damage to water control infrastructure and embankments to determine areas to target for the annual trapping program.
- In accordance with the refuge's Trapping Plan (USFWS 1985b), conduct an annual trapping program to reduce Beaver and muskrat populations that damage dikes and reduce the population of Beavers in areas where they cause problems with refuge water management.

Provide fish passage

- Assure that fishways are clear of debris and accessible to migrating fish by the first week of May.
- Maintain a steady water level in impoundments with Alewives.
- Impoundments with fishways, maintain a water level and velocity that supports a burst speed of 6 feet per second and prolonged speed of 3 feet per second to be conducive to Alewife passage.
- In partnership with the St. Croix International Waterway Commission, the Passamaquoddy and Penobscot Tribes, and the FWS Fisheries Office (Orland, ME), evaluate the existing fish passages in the impoundments and assess use and potential use of these areas by native fish (e.g., Alewife and American Eel) and identify seasonal windows of use that may be critical.

Evaluate infrastructure

- Prohibit the active maintenance or replacement of water control structures on wetlands in the wilderness areas or Research Natural Areas.
- For all the impoundments identified as lower priority:

- Evaluate the feasibility and options of removing structures and restoring free-flowing streams.
- Retain and maintain infrastructure if critical to the refuge road and trail system or for some other refuge priority; continue to keep these structures free of beaver debris if there is a threat of flooding or road erosion.

General Strategies for Lakes, Streams, and Associated Wetlands

Maintain fish passage

- On the Baring Division, maintain the fishways on the Upper and Middle Magurrewock Marshes and Howard Mill Flowage to provide optimal flow rates in the fishway and downstream areas during migration seasons.
- Remove or breach blockages between fishways, primarily Beaver dams, to allow fish passage upstream and downstream.
- In partnership with the St. Croix International Waterway Commission, the Passamaquoddy and Penobscot Tribes, and the FWS Fisheries Office (Orland, ME), evaluate the existing fish passages in the impoundments and assess use and potential use of these areas by native fish (e.g., Alewife and American Eel) and identify seasonal windows of use that may be critical.
- Improve fish, reptile, and amphibian passage by replacing existing structures and culverts with fish- and wildlife-friendly arch culverts or similar devices. Use the USFWS Maine Fishery Resource Office's 2012 summary report on stream-road crossing surveys to help identify which structures to remove (Craig 2012). Prioritize the removal of stream-road crossings that most severely limit aquatic connectivity and are at a high risk for failure.
- Enhance partnerships with local and regional Federal and State fishery personnel.

Enhance habitat for fish

- Maintain a closed canopy of native trees and brush along streams to help prevent water temperatures from exceeding 70 degrees F.
- Use adaptive management as needed to maintain the mixed graminoid-shrub vegetation in the wetlands associated with streams.
- Work with the Maine Department of Marine Resources Bureau of Sea Run Fisheries and Habitat, the FWS's Maine Fisheries Office, and other partners to improve Atlantic Salmon and Brook Trout habitat in Hobart Stream, and other brooks and streams with Salmon and Brook Trout habitat.

Protect lakeshores

- Maintain lakeshore forest cover to provide nesting opportunities for Bald Eagles and Osprey and protect the watershed by retaining a 1,500-foot no-cut buffer along the shore of Meddybemps Lake, James Pond, and Ledge Pond.
- Enforce area closures, as needed, to limit disturbance to loons and other water birds.
- The buffer zone along Rocky Lake will follow recommendations of applicable Best Management Practices.

General Strategies for Forested Wetlands and Peatlands

Protect forested wetlands and peatlands

- Maintain a buffer of 25 to 100 feet around wetlands if forest management activities are planned near these areas to prevent any damage to the wetland or the local hydrology.
- Prior to employing forest management, the areas to be impacted will be surveyed for potential vernal pools and other significant wetlands. Additional strategies for vernal pool protection are listed in the table of Strategies Across all MUs.
- Encourage needed research on the forested wetlands:

- USGS scientists are working on developing test wells to monitor the groundwater around freshwater forested wetlands and have installed a prototype on the Baring Division.

Enhance northern white cedar

- Develop a forest implementation plan and prescriptions to improve and enhance areas of northern white cedar, if silvicultural treatments are needed to restore or rehabilitate them.
- Encourage needed research on peatlands:
- In 2019, a graduate student from the University of Maine at Orono began assessing the cedar stands on Moosehorn and Sunkhaze Meadows NWRs.

General Strategies for Salt Marsh

Sustain natural processes and protect rare species

- Allow natural processes to maintain the salt marsh community.
- Protect the known populations of Gaspé arrow grass (*Triglochin gaspense*) that are scattered around the intertidal zone in multiple locations in Cobscook Bay.

General Strategies for Rocky Coast, Mudflats, Tidal Creeks, and Islands in Cobscook Bay

Reduce rockweed harvesting

- Prevent the illegal harvest of rockweed by documenting violations and filing official reports to appropriate law enforcement officials.
- Encourage patrols of refuge coastal properties by FWS Law Enforcement Officers.
- Maintain communications with other conservation organizations in the area regarding rockweed harvests.
- Contact individuals who will be harvesting in parts of Cobscook Bay and provide them with maps of refuge lands to prevent accidental harvest.
- Post the boundaries of all refuge islands and coastal properties.
- Encourage research to survey waterfowl and other waterbird use of Cobscook Bay to determine if increased commercial fishing activity (rockweed, scallops, crabs) is affecting the use of the bay by wintering waterfowl.

AN EXAMPLE OF A FORESTRY STRIP CUT AT BARING DIVISION, A FOREST MANAGEMENT STRATEGY. PHOTO CREDIT: USFWS

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APPENDIX A. ENVIRONMENTAL ASSESSMENT FOR MOOSEHORN NWR

This Draft Environmental Assessment (EA) evaluates the effects associated with this proposed action and complies with the National Environmental Policy Act (NEPA) in accordance with Council on Environmental Quality regulations (40 CFR 1500-1509) and Department of the Interior (43 CFR 46; 516 DM 8) and FWS (550 FW 3) regulations and policies. NEPA requires examination of the effects of proposed actions on the natural and human environment.

A list of laws and executive orders evaluated through this Environmental Assessment is included at the end of the document.

PROPOSED ACTION

With this EA, the U.S. Fish and Wildlife Service (FWS) is proposing to implement the Habitat Management Plan (HMP) for Moosehorn National Wildlife Refuge (NWR). The FWS has prepared the HMP, which is incorporated herein by reference and contains this EA, to provide more details regarding the Proposed Action for habitat management on the refuge. The FWS discloses anticipated effects for each alternative, pursuant to the NEPA of 1969, as amended. Where possible, the HMP aligns with State conservation priorities outlined in the Maine State Wildlife Action Plan (ME WAP 2015). Combined, these efforts provided clarity about the desired future conditions we aim to protect, enhance, and/or restore on the refuge over the next 15 years. Two alternatives were prepared for this EA: a No Action alternative and a Proposed Action alternative. For details on the specific components and actions constituting the alternatives, see the 'Alternatives Considered' section of this EA.

The draft Proposed Action alternative may be modified depending on the comments received from the public and other agencies and organizations. The FWS's Northeast Region Refuge Chief will decide which alternative will be implemented. The refuge prepared this HMP to guide implementation of management actions for a period of 15 years.

The analysis in this EA will inform the decision of whether a Finding of No Significant Impact (FONSI) can be reached. The FONSI will identify the alternative selected for implementation and the rationale behind the decision. If a FONSI cannot be reached, an Environmental Impact Statement (EIS) will be prepared.

BACKGROUND

National wildlife refuges are guided by the mission and goals of the National Wildlife Refuge System (Refuge System), the purposes of an individual refuge, FWS policy, and laws and international treaties. Relevant guidance includes the Refuge System Administration Act of 1966, as amended by the Refuge System Improvement Act of 1997 (Improvement Act), Refuge Recreation Act of 1962, and selected portions of the Code of Federal Regulations and FWS Manual.

The mission of the Refuge System, as outlined by the National Wildlife Refuge System Administration Act (NWRSAA), as amended by the National Wildlife Refuge System Improvement Act (Refuge System Improvement Act; 16 U.S.C. 668dd et seq.), is:

"... to administer a national network of lands and waters for the conservation, management and, where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans."

We derive our statutory authority to conduct habitat management planning from the Improvement Act. Section 4(a)(3) of the Improvement Act states: "*With respect to the System, it is the policy of the United States that -- (A) each refuge shall be managed to fulfill the mission of the System, as well as the specific purposes for which that refuge was established ...*" and Section 4(a)(4) states: "*In administering the System, the Secretary shall -- (N) monitor the status and trends of fish, wildlife, and plants in each refuge.*" The Refuge System Improvement Act provides the FWS the authority to establish policies, regulations, and guidelines governing habitat management planning within the Refuge System. Habitat management planning is guided by FWS policy, primarily 620 FW 1.

Moosehorn NWR has two divisions, the 20,532-acre Baring Division, about 3 miles southwest of Calais, Maine and the 8,822-acre Edmunds Division, about 3 miles south of Dennysville, Maine. Moosehorn NWR is part of the Northern Maine NWR Complex, which includes Aroostook NWR, Sunkhaze Meadows NWR, and Carlton Pond WPA.

Table A-1 summarizes the establishment of the refuge, including the enabling legislation and authority, purpose, and management directives since inception of the NWR.

TABLE A-1. ENABLING LEGISLATION FOR MOOSEHORN NWR.

Enabling Legislation	**Purpose**
Executive Order 7650	"...as a refuge and breeding ground for migratory birds and other wildlife..." [dated July 1, 1937]
16 U.S.C. 715d Migratory Bird Conservation Act	"...for use as an inviolate sanctuary, or for any other management purpose, for migratory birds."
16 U.S.C. 460k-1 Refuge Recreation Act	"...suitable for - (1) incidental fish and wildlife-oriented recreational development, (2) the protection of natural resources, (3) the conservation of endangered species or threatened species..."
16 U.S.C. 3901(b), 100 Stat. 3583 Emergency Wetlands Resources Act of 1986	"...the conservation of the wetlands of the Nation in order to maintain the public benefits they provide and to help fulfill international obligations contained in various migratory bird treaties and conventions..."
16 U.S.C. § 742f(a)(4) 16 U.S.C. § 742f(b)(1) Fish and Wildlife Act of 1956	"... for the development, advancement, management, conservation, and protection of fish and wildlife resources ..."and "... for the benefit of the United States Fish and Wildlife Service, in performing its activities and services. Such acceptance may be subject to the terms of any restrictive or affirmative covenant, or condition of servitude ... "
16 U.S.C. § 668dd(a)(2) National Wildlife Refuge System Administration Act	"... conservation, management, and restoration of the fish, wildlife, and plant resources and their habitats for the benefit of present and future generations of Americans..."
16 U.S.C. § 1131 Wilderness Act	"... wilderness areas ... shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and

Enabling Legislation	**Purpose**
	enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness: …"

Consisting of 29,354 acres, the refuge is comprised of early successional aspen-birch, pine and mixed forests, pure spruce-fir forests, second-growth northern hardwood-conifer forests, and salt marsh. Numerous streams, beaver flowages, bogs, impoundments, and scrub-shrub and forested wetlands are nestled within the largely forested landscape. These communities support a variety of migratory birds, interjurisdictional fishes, and resident wildlife.

Purpose and Need for the Proposed Action

The purpose of the Proposed Action is to implement the 2024 HMP, which provides a long-term vision and specific guidance on managing priority species and their habitats. Implementing the HMP will guide strategic habitat management that will benefit breeding and migrating landbirds, shorebirds, and waterfowl, interjurisdictional fishes, and other species of conservation concern on the refuge.

The need for this Proposed Action is to meet the FWS's priorities and mandates as outlined by the Refuge Administration Act, as amended by the Refuge System Improvement Act of 1997. The Administration Act directs the FWS to ensure that the BIDEH of the Refuge System are maintained for the benefit of present and future generations of Americans. To meet this mandate, the FWS developed the BIDEH policy to provide refuges with guidance for consideration and protection of the broad spectrum of native fish, wildlife, and habitat resources on refuges and in associated ecosystems. This policy provides refuges with a process for evaluating the best management direction to prevent the additional degradation of environmental conditions, and to restore lost or severely degraded ecosystems or ecosystem functions. In evaluating these factors, the FWS looks at historical conditions and compares them to the current conditions. Along with considering plausible climatic and ecosystem futures for the refuge, this approach provides a way to compare the relative intactness of ecosystem functions and processes, as well as an assessment of the opportunities and limitations to restoring BIDEH.

ALTERNATIVES CONSIDERED

This EA evaluates two alternatives:

- Alternative A: No Action—Continue Current Management
- Alternative B: Proposed Action—Strategic Habitat Management

Alternative A: Current Management (No Action alternative)

The No Action alternative is presented in this EA in accordance with 40 CFR 1502.14(d) to represent the environmental baseline against which to compare the impacts of the Proposed Action. The No Action alternative represents a continuation of existing management, which focuses on control of invasive, nonnative plant species, some silviculture practices to manage forests and early successional habitats, and manipulation of water levels in impoundments. Management would continue to be guided by separate, previously approved plans (HMP chapter 1. Refuge Plans) that address management of forest, marsh, water, and wilderness. Because these separate plans span a large timeframe in their development, they did

not always provide consistent management direction or cohesive management objectives, as management priorities and available science were changing over time.

Alternative B: Strategic Habitat Management (Proposed Action)

Under the Proposed Action, FWS staff will work to achieve the objectives and implement the strategies in the 2024 HMP. The HMP also identifies goals and objectives aimed at supporting key life cycle requirements of priority species and their required habitats. This Proposed Action will help the refuge achieve the purpose and need described earlier. The HMP goals to provide strategic habitat management on the refuge are as follows:

Goal 1. *Perpetuate the biological integrity, diversity, and resiliency of Moosehorn NWR's upland habitats to sustain plant communities and wildlife native to the Atlantic Northern Forest Region, including species of concern to the FWS.*

Goal 2. *Perpetuate the biological integrity, diversity, and resiliency of Moosehorn NWR's coastal and freshwater wetlands and streams to sustain plant communities and wildlife native to the Atlantic Northern Forest Region, including species of concern to the FWS.*

Objectives to support each of these goals were developed as well. Under this alternative, the refuge would establish larger blocks of mature, late successional forests, decrease extent but increase quality of early successional habitats, restore nonfunctional impoundments to naturally functioning wetland systems, increase functionality of remaining impoundments, increase barrier free aquatic organism passage along refuge streams and rivers, and continue exploring options for increasing the resiliency of vulnerable coastal habitats.

Specifically, the refuge would:

- Enhance the biological integrity of all the refuge's ecosystems by continuing to work to control invasive species, by eradicating, minimizing, or containing these species based on their priority ranking.
- Expand the coverage area and enhance the quality of the refuge's *late-successional forest habitat*, by using a combination of silviculture practices, natural processes, and managing towards the ecological site descriptions of each management area.
    - Continue to prohibit forest management in Wilderness Areas, in Natural Research Areas, and designated no-cut zones.
    - Promote multi-aged (uneven-aged) silvicultural systems of three or more age classes of trees in managed stands.
    - Conduct landscape-level assessment using ecological land units, historic photographs, modeling, and predictions of historic and potential natural vegetation to determine where site conditions would favor native red spruce.
    - Enhance tree species diversity by using silvicultural practices to promote species such as red oak, ash species, and yellow birch, which are under-represented on the refuge.
    - Continue to allow approximately 18,327 acres (this includes 3,106 acres of aspen-birch woodland) of early mid successional forest habitats to succeed into late-successional mature forest habitat.
- Decrease the extent but enhance the biological integrity of the refuge's *early successional habitat* for American Woodcock and other early-successional species by selecting only those areas that would result in aspen-birch or alder stand regrowth (and that weren't exempt from silviculture techniques).

- Continue to prohibit early-successional management in Wilderness Areas, in Natural Research Areas, and designated no-cut zones.
- Promote even-aged silvicultural systems that result in a single age class of trees across an entire area using clearcutting techniques to promote intolerant hardwood species such as aspen and birch, with the removal of most trees.
- Approximately 1,900 acres will be a mosaic of early (0 to 15 years) and mid- (16 to 50 years) successional aspen-birch and alder stands.

- Protect the biological integrity of the refuge's *old fields and blueberry barren habitat*, while enhancing habitat for native pollinators through native plant restoration efforts.
  - Continue to maintain old fields and blueberry barrens by mowing and/or burning on a rotational basis.
  - Continue to introduce milkweed, and other native, nectar-producing forbs (e.g., goldenrod, and aster species) that bloom during the following three periods: April to May; June to July; and August to October, to benefit pollinators.
- Decrease the number of impounded wetlands by restoring low priority *impoundments* but enhance the biological integrity of the refuge's highest priority Impoundments, for the benefit of several of the refuge's highest priority species.
  - On 25 impoundments (988 acres) that have been identified as high priority, the refuge will increase impoundment functionality (though infrastructure replacement, increased maintenance, and improved adaptive management techniques), allowing for more active management for high priority waterfowl, marshbirds, shorebirds, and some diadromous fishes.
  - For impoundments identified as low priority (2 impoundments - totaling 19 acres), the refuge will evaluate the potential for restoration efforts to minimize stream/river barriers to upstream passage by migratory fishes.
  - For those impoundments that host the diadromous Alewife and American Eel, the refuge will ensure that functional fishways are maintained to ensure safe passage to complete their life cycle.
- Enhance the biological integrity of the refuge's *streams and associated wetlands habitat*, some of the most critical habitat for migratory fishes that travel from the Gulf of Maine to spawn or complete their life cycle.
  - Maintain the fishways on the Upper and Middle Magurrewock Marshes and Howard Mill Flowage to provide optimal flow rates in the fishway and downstream areas during migration seasons.
  - Remove or breach blockages between fishways, primarily beaver dams, to allow fish passage upstream and downstream.
  - Improve fish, reptile, and amphibian passage by replacing existing structures and culverts with fish- and wildlife-friendly arch culverts or similar devices. Prioritize the removal of stream-road crossings that most severely limit aquatic connectivity and are at a high risk for failure.
- Protect the biological integrity of the refuge's *forested wetlands and peatland habitat*, while continuing to prevent any damage to the wetland or the local hydrology.
  - If silviculture treatments are needed to restore or rehabilitate northern white cedar forests, the refuge will develop a forest implementation plan and prescriptions to improve and enhance this habitat.
- Protect the biological integrity of the refuge's *salt marsh habitat*, by allowing natural processes to maintain the system and preventing any alterations to the marsh platform that would negatively impact tidal flow.
  - Continue to protect and monitor known populations of Gaspé arrow grass (*Triglochin gaspense*) that are scattered around the intertidal zone in Cobscook Bay.

- Protect the biological integrity of the refuge's *coastal areas and islands* in Cobscook Bay, which are increasingly vulnerable to commercial fishing activity.
    - Increase coordination with law enforcement division to prevent illegal rockweed harvest.
    - Continue to post clear boundary signs on all refuge islands and coastal properties to inform the public of refuge ownership and accompanying restrictions.

More information on the goals, objectives, and strategies can be found in chapter 4 of the HMP.

This alternative best meets the purpose and need described above. The HMP provides comprehensive management direction, along with identifying clear metrics for assessing what successful conservation delivery looks like at Moosehorn NWR for the next 15 years. This plan, when implemented, will help achieve the refuge purpose, fulfill the Refuge System's mission, and comply with all applicable laws, regulations, and policies governing the management of FWS lands.

Alternatives Considered, But Dismissed from Further Consideration

The Planning Team considered the evaluation of a separate "intensive management" alternative, which would increase the involvement, frequency, and number of management actions across all habitats. This alternative represents a scenario where increased or unlimited resources (funding, staff, or partners) would be available to achieve (or exceed) the objectives more rapidly for all refuge habitats, simultaneously. Because the refuge operates at a relatively constant and predictable level of allocated resources, this alternative was determined by the Planning Team to be unrealistic.

AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

The refuge consists of approximately 29,354 acres in two separate divisions in eastern Maine (see HMP Figure 1-1), providing a wide diversity of species and ecosystems.

The HMP chapter 2.0 (Existing Conditions) summarizes pertinent refuge background information, including a description of existing conditions such as physical environment (water quality, topography and soils, geology and hydrology, climate, and air quality); the biological environment (terrestrial, wetland, and aquatic habitats, and fish and wildlife); the socioeconomic environment (geographic setting, history and archaeology, land use, and recreational use); historic and current ecosystem influences; and current threats. This information presented was chosen specifically to inform future management actions.

The following section analyzes the affected environment and environmental consequences of the two alternative actions on each affected resource, including direct, indirect, and cumulative effects. This EA focused on the written analyses of the environmental consequences on a resource when the impacts on that resource could be more than negligible and therefore considered an "affected resource," or are otherwise considered important as related to the proposed action. Resources that would not be more than negligibly impacted by the action may be dismissed from further analysis (Table A-2).

The following section contains:

- A brief description of the affected resources in the proposed action area.
- Impacts of the proposed action and any alternatives on those resources, including direct and indirect effects.
- A brief description of the past, present, and reasonably foreseeable other actions affecting these resources, and the cumulative impacts of the proposed action and any alternatives.

Impact Types:

- *Direct effects* are those that are caused by the action and occur at the same time and place.
- *Indirect effects* are those that are caused by the action and are later in time or farther removed in distance but are still reasonably foreseeable.

- *Cumulative impacts* result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions.

TABLE A-2. POTENTIAL FOR ADVERSE IMPACTS FROM PROPOSED ACTION AND THE ALTERNATIVE.

Resources	**Not Applicable:** Resource does not exist in project area	**No/Negligible Impacts:** Exists but no or negligible impacts	Greater than Negligible Impacts: Impacts analyzed in this EA
Wildlife and Aquatic Species	☐	☐	☒
Threatened and Endangered Species and Other Special Status Species	☐	☐	☒
Upland Vegetation	☐	☐	☒
Wetlands	☐	☐	☒
Geology and Soils	☐	☒	☐
Air Quality	☐	☒	☐
Wilderness*	☐	☒	☐
Visitor Use and Experience	☐	☐	☒
Cultural Resources*	☐	☒	☐
Land Use	☐	☐	☒
Socioeconomic and Environmental Justice	☐	☒	☐

See chapter 4 of the HMP for more detail regarding the anticipated impacts on resources.

*Although these resources were determined to have negligible impacts, for compliance with the National Historic Preservation Act (Section 106) and the Wilderness Act of 1964, all resources were identified, and any potential impacts were addressed. Additionally, in compliance with Section 106, actions identified within the EA will be consulted with the State Historic Preservation Officer (SHPO) prior to implementation.

As stated above, this section predicts the foreseeable impacts of implementing the habitat management program in each of the alternatives. When detailed information may be deficient or unavailable, we base

our comparisons on professional judgment and experience. We usually identify potential impacts within a long-range timeframe (i.e., 15 years). Beyond that timeframe, they become more speculative.

Please keep in mind the relatively small total land mass of the refuge in comparison with the entire Atlantic Flyway or the breeding ranges of the many birds and wildlife that use it. We recognize that the refuge is not isolated ecologically from the lands around it; however, we may have overstated positive or negative impacts in that larger geographic context. Nevertheless, many of the actions we propose conform to other regional landscape plans, and provide positive, incremental contributions to those larger landscape goals.

Wildlife and Aquatic Species

Affected Environment/Existing Condition

The refuge supports a diversity of game and nongame wildlife species across 11 broad habitat types, including 252 species of birds, 20 species of mammals, 21 species of reptiles and amphibians, 37 species of fish, and diverse but largely uninvestigated populations of invertebrates (*ROC Tables*).

Portions of Moosehorn NWR are situated along the Atlantic Ocean and within the Atlantic flyway migration corridor. The strong tides of Cobscook Bay keep water open in winter, vital to wintering waterfowl along the Atlantic Flyway. A quarter of Maine's wintering American Black Duck population is found in Cobscook Bay. The ducks follow the tide in, foraging on invertebrates in the intertidal rockweed and the mudflats as the tide recedes. The Maine Wildlife Action Plan (2015) and Atlantic Flyway Shorebird Initiative (2015) recognize Cobscook Bay as a focus area of Statewide Ecological Significance and part of the Maritime Canada and Northeastern United States focus areas, respectively.

At the regional level, Moosehorn NWR plays a role as part of the North Atlantic planning region within the Atlantic flyway migration corridor. The Atlantic flyway encompasses some of the hemisphere's most productive ecosystems, including salt marsh and coastal habitat. In 2017, researchers from the University of Delaware used weather radar technology to identify key stopover sites for landbirds and determined that both divisions of Moosehorn NWR are marked as areas of highest importance for landbird stopover sites (Buler et al. 2017).

Alternative A

The ongoing management of refuge habitat is generalized to each land cover and does not specifically designate focal species and manage toward ecosystem attributes specifically benefiting them. Existing management outcomes are generally limited to single species (i.e., invasive species spot treatment) without defined long-range targets. The refuge would continue to meet its mandate as stewards to trust resources but may not optimize management efforts that benefit a range of species assemblages.

Because this alternative does not consider a landscape-scale approach to threat mitigation, certain habitats and species may be vulnerable to the incremental impacts of threats, such as sea level rise (SLR), coastal erosion, and other variables affected by climate change.

Alternative B (Proposed)

The strategic, adaptive approach to land management outlined in the HMP and the prioritization of habitats would streamline available resources to maximize benefits for priority species and ecosystems. The specific, measurable, science-based ecosystem endpoints are tied specifically to priority resources of concern (ROCs) requirements and are designed to promote ecosystem health in support of priority ROCs, other candidate ROCs, and associated wildlife (*ROC Tables*). We anticipate that the Proposed Action would increase the dependability of the refuge as a sanctuary for target resident and migratory wildlife

and aquatic species; would support the recovery, stabilization, or growth of target populations; and would promote the resiliency and adaptability of required habitats in the face of climate change and other ecosystem threats.

Potential minor adverse impacts may occur to some species as certain habitats are transitioned across the refuge. Specifically, local populations of American Woodcock and other early successional species may decline as 3,106 acres of Aspen-Birch Woodland transition to late-successional mature forests. However, adverse impacts may be offset to some degree by the increase in American Woodcock habitat suitability by employing geospatial habitat models that incorporated vegetation and soil conditions to determine where this habitat should occur on the refuge. Additionally, some of this habitat is intended to serve as a demonstration area, resulting in its strategic placement in easily observable areas of the refuge. This may result in potential minor beneficial impacts to early successional species if local landowners and/or partners begin to employ similar techniques to off-refuge lands.

Likewise, the restoration of two low priority impoundments (totaling 19 acres) is likely to benefit diadromous fishes as streams and naturally functioning wetlands are restored and aquatic connectivity is improved. Meanwhile, 15 impoundments (totaling 936 acres) will be improved, resulting in higher functionality that will allow the refuge to actively manage, increasing biodiversity and productivity on the impoundments. These are the only places some wetland species are found on the refuge, such as Sora, Virginia Rail, and Pied-billed Grebe. They also provide nesting and brood rearing cover for American Black Ducks and several other priority species, resulting in potential minor beneficial impacts to these species.

Improvement of in-stream and riparian habitat within the refuge and working with partners on off-refuge stream habitat may result in potential minor beneficial impacts to aquatic species. The Proposed Action will also improve aquatic connectivity along streams and rivers which may result in potential major beneficial impacts to migratory fishes.

Consideration and planning for threats (HMP chapter 2) through adaptive management techniques would be implemented to either actively reduce threat risk or assist in a gradual transition to a new condition as unavoidable threats progress. For example, focusing on forest diversity may help habitats maintain resiliency or adapt to changing climatic conditions.

Threatened and Endangered Species and Other Special Status Species

Affected Environment/Existing Condition

The federally endangered Northern Long-eared Bat has been recorded in small numbers on the refuge, primarily in areas with old spruce-fir habitats.

The federally endangered Atlantic Salmon historically occurred in Hobart Stream (on the Edmunds Division). The last known sighting of a wild Salmon was in the mid/late 1980's. An experimental reintroduction program began in 2006 and ended in 2009. Atlantic Salmon are now believed to use the Dennys River, which is adjacent to refuge lands and not part of the refuge's jurisdiction.

The State endangered Little Brown Bat and the state threatened Eastern Small-footed Bat both occur on the refuge.

The State rare (S3) showy lady's slipper (*Cypripedium reginae*), a species of Special Concern, occurs on the refuge in one area.

The State imperiled (S2) Gaspé arrow grass (*Triglochin gaspensis)* occurs on the refuge.

Alternative A

No appreciable change to existing condition anticipated. The refuge would continue to meet its mandate as stewards to these Trust resources but may not optimize management efforts that benefit these species.

Alternative B (Proposed)

Management actions within the refuge are geared towards helping priority resources of concern and federally listed species (HMP chapter 3). These priority species were chosen based on several different metrics. Although these selections are used to guide habitat management decisions on the refuge, there are several tradeoffs that must occur because of conflicting habitat needs by all species using the refuge. These conflicts have been analyzed by the planning team and the current priorities, objectives, and strategies outlined in the HMP are believed to result in the highest biological contribution by the refuge.

- Atlantic Salmon: Improvement of in-stream and riparian habitat within the refuge and working with partners on off-refuge stream habitat may result in potential minor beneficial impacts to the species. Improving aquatic connectivity along streams and rivers may result in potential minor beneficial impacts to the species.
- Northern Long-eared Bat, Little Brown Bat, Eastern Small-footed Bat: Increasing the quantity and quality of late successional hardwood trees, with large amounts of standing and downed dead wood, and diverse vertical structure may result in potential minor beneficial impacts to the species.
- Showy lady's slipper (*Cypripedium reginae)*: In the one small area where this rare species exists, the refuge will continue to cut back woody growth to allow for suitable habitat, resulting in potential minor beneficial impacts to the species.
- Gaspé arrow grass (*Triglochin gaspensis)*: Because this rare species is found in areas with little potential for human disturbance, there should be negligible impacts due to current management strategies.

Upland Vegetation

[see HMP chapters 2-3]

Affected Environment/Existing Condition

Moosehorn NWR's upland is dominated by northern hardwood forests (Table 3-1). The forest composition at the refuge is a mix of aspen-birch, spruce-fir, hemlock, northern hardwoods, and northern white cedar forest types. The two most common forest types on both the Baring Division and Edmunds Divisions are aspen-birch and spruce-fir forests (Table 2-4). The forests on Moosehorn NWR are generally older and contain larger trees than most forests in Maine, particularly in the two wilderness areas (Table 2-5). These forests are critical to several high priority nesting landbirds.

Moosehorn NWR's early successional aspen-birch and alder stand habitat has exceptional value for early successional species (e.g., American Woodcock, Chestnut-sided Warbler). This habitat must be maintained through disturbance events (e.g., fire, harvest, natural disturbance) to keep it in the young forest (aspen-birch) or alder stand successional stage.

Alternative A

No change to existing condition anticipated. Invasive species would continue to be spot treated reactively rather than under a proactive, systematic adaptive management approach.

Alternative B (Proposed)

In general, native target vegetation species would benefit from the Proposed Action, as it is intended to increase the natural attributes of all ecosystems and reduce impacts of and risks from known threats, such as the presence of invasive species.

The Proposed Action sets the stage for increased coverage and health of contiguous late-successional mature forest habitat into the future. Potential minor adverse impacts may occur to early successional habitats as they transition to late-successional forests across the refuge. Specifically, aspen-birch woodland will decline as 3,106 acres transition to late-successional mature forests.

Wetlands

[HMP chapter 4–Goal 2]

Affected Environment/Existing Condition

Moosehorn NWR is approximately 20 percent wetland, with 1,072 acres of forested wetland and peatlands, 1,103 acres of freshwater impoundments, 130 acres of decommissioned impoundments, 29 miles of streams, 1,880 acres of associated stream wetlands, 60 acres of salt marsh, and 18 miles of coastal habitats (e.g., rocky coast, mudflats, and tidal creeks) (HMP chapter 4–Goal 2).

This includes frontage on parts of 10 natural lakes, beaver ponds, impoundments, marshes, streams, brooks, and peatlands. There are 32 unmanaged natural marshes and bogs on the refuge. The open-water lakes range in size from 20 to 295 acres. Moosehorn has 15 functional high priority freshwater impoundments; at one point, there were over 50. The wetlands support a mix of open water and aquatic vegetation including sedges, pondweeds, and cattails. Alder and willow species are common wetland shrubs, while leatherleaf, sweet gale, and sphagnum moss are common in refuge bogs. Forested wetlands are dominated by small black spruce, northern white cedar, red maple, cinnamon fern, sphagnum, and some tamarack.

Moosehorn NWR has approximately 20 streams, 13 of which are large enough to support populations of native Brook Trout. Several important trout streams, including Cranberry Brook and Mahar Stream, depend on a continual outflow from refuge impoundments. Refuge streams are under threat from water quality issues, degraded riparian habitat, and in-stream blockages.

The Edmunds Division of Moosehorn NWR has more than 18 miles of rocky shoreline along Dennys and Whiting Bays in Cobscook Bay with tidal fluctuations up to 24 feet twice a day. Although the refuge has a relatively small portion of shoreline, it is a vitally important component of the Cobscook Bay ecosystem. The diversity and abundance of marine life in Cobscook Bay is a result of the tremendous tides bringing in nutrient rich water from the Gulf of Maine. Cobscook Bay was listed as a priority for protection in the Regional Concept Plan under the Emergency Wetlands Resources Act of 1986 (specifically the intertidal and subtidal habitats of Dennys and Whiting Bays), and in the U.S. Environmental Protection Agency's (U.S. EPA) Priority Wetlands of New England. The ACJV identified Cobscook Bay as the highest priority focus area for resource protection within Maine and it was the first project in Maine to be approved for a North American Wetlands Conservation Act (NAWCA) grant.

The minimal salt marsh habitat on the refuge supports a few priority resources of concern, including the Nelson's Sparrow and the American Black Duck. This habitat is under constant threat of sea level rise

(projected to rise at least 5 to 15 inches in the next 100 years) and development of the uplands that border the marsh.

Alternative A

No change from existing condition anticipated.

Alternative B (Proposed)

The Proposed Action will allow for impoundments identified as ‘high priority’ to have their infrastructure improved to allow the refuge to better manipulate water levels. This will allow the refuge to create more suitable habitat for waterfowl, marshbirds, shorebirds, and some diadromous fishes. This action may result in major beneficial impacts to these impoundment systems and the species they support.

The Proposed Action will allow for impoundments identified as ‘low priority’ to potentially be restored to more natural conditions to minimize stream/river barriers to upstream passage by migratory fish. This action may result in major beneficial impacts to stream ecosystems and aquatic connectivity. The impoundment systems and the species that rely on them may have minor negligible impacts due to these restoration efforts; however, overall, it is believed that this will have a net benefit to the health of the natural wetland communities on the refuge.

The refuge has identified nine projects that would improve aquatic connectivity by replacing up to 11 existing water control structures, and 9 culverts, with arch culverts or bridges and rock weirs.

Improvement of in-stream habitat within the refuge and working with partners on off-refuge stream habitat may result in potential minor beneficial impacts to in-stream habitat. The Proposed Action will also improve aquatic connectivity along streams and rivers by removing blockages, allowing fish passage upstream and downstream. This action may result in potential major beneficial impacts to migratory fish species, including diadromous fishes.

The Proposed Action will increase coordination with the law enforcement division to prevent illegal rockweed harvest in coastal ecosystems, resulting in potential minor beneficial impacts to the biotic community.

The Proposed Action for Forested Wetlands and Peatland habitat and Salt marsh habitat will be similar to the No Action alternative.

Health and function of all wetland systems, and value to migratory bird species and migratory fishes, would improve due to strategic focus on hydrologic restoration and increased coastal protection measures.

Geology And Soils

[HMP chapter 2–Geology and Soils]

Affected Environment/Existing Condition

Typical of this part of New England, the refuge has rolling terrain with elevations between sea level and 480 feet above mean sea level (MSL). The relief of the Baring Division ranges from 80 to 480 feet above MSL, while the Edmunds Division ranges from sea level to 200 feet above MSL. The rolling hills, large rock outcrops, and stream valleys reflect the impacts of the late Pleistocene Wisconsin glaciation. Glacial deposits of till, outwash, and marine clay underlie the local soils. Bedrock in the Edmunds Division is mostly volcanic rock and is exposed in less than 2 percent of the area.

A total of 54 different soil types occurs in the Baring Division and 44 have been identified at the Edmunds Division. Soils vary from sandy loam to clay and peat. The two major soil associations include Lyman-Scantic-Peru group and the Marlow-Peru-Lyman group. The deep, well-drained, stony Marlow soils and the shallow, well-drained Lyman soils occur on crests and upper slopes of ridges. Peru soils are deep, moderately well drained, and developed in very firm glacial till. The deep, poorly drained Scantic soils have a seasonal high-water table and are considered wetland soils (USFWS 1990).

Alternative A

No change from existing condition anticipated.

Alternative B (Proposed)

Same as No Action alternative.

Air Quality

[HMP chapter 2–Air Quality]

Affected Environment/Existing Condition

Maine has the fifth-best air quality in the Nation, with an air quality index of 36.1 - indicating that air quality conditions are good and that there is subsequently little or no human health risk. Since 2018, Maine has seen a large improvement in air quality; however, some residents live in areas where the air is unhealthy due to emissions from power plants (U.S. Air Quality Index State Rank 2022).

One of the nearby potential sources of regional air pollution is the pulp and tissue mill in Baileyville (Woodland), Maine. In 1989, the U.S. EPA formally attributed visibility impairment to the Georgia Pacific (now owned by International Grand Investment Corporation [IGIC]) paper mill in Baileyville. To establish that the plume from a nearby paper mill was periodically impairing the visibility over the Baring Wilderness Area, a time-lapse video camera was installed in 1994. Although no enforcement action was taken, Georgia Pacific modified their process to improve visibility. Currently, most of the visible plume from the paper mill is steam. There are still issues with the liquid wastes that the paper mill produces and the subsequent odors from the settling ponds, which do impact the refuge.

IMPROVE samplers that the refuge has deployed have helped determine that much of the particulate matter measured on the refuge is originating from air pollution sources in the Midwest. During the winter months, these elemental carbon measures increase - likely resulting from increased wood stove use in adjacent lands to the refuge.

In 2022, the American Lung Association gave Washington County, ME a C Grade for Ozone. Warming temperatures from climate change are expected to result in more ozone-high level days and unhealthy air days.

Alternative A

No change from existing condition anticipated. The refuge would continue to maintain early successional habitat and blueberry fields by burning on a rotational basis. We believe that the small acreage requiring burn maintenance will potentially result in negligible direct impacts on particle pollution.

Alternative B (Proposed)

Same as No Action alternative.

Wilderness

[HMP chapter 2–Vegetation–The Moosehorn Wilderness Area]

Affected Environment/Existing Condition

On October 23, 1970, Congress designated a 2,712-acre portion of the Edmunds Division, including the Birch Islands (6-acres in size) in Whiting Bay, as a Wilderness Area. This was followed on January 3, 1975, with the designation of 4,680 acres on the Baring Division as a Wilderness Area (USWFS 1979). Collectively, these 7,392 acres are known as the Moosehorn Wilderness (HMP Table 2-5; Figure 2-6).

Alternative A

As described in the Moosehorn Wilderness Management Plan (USFWS 1979), the Wilderness Areas in the Edmunds Division, Baring Division, and Birch Islands are currently managed under the following conditions:

- No mechanized equipment or vehicles including conventional and e-bikes, snowmobiles, and outboard motors are permitted.
- Non-motorized boats are permitted on Bearce Lake and Conic Lake.
- No commercial logging or other forest management.
- No camping.
- Hunting, fishing, skiing, snowshoeing, research, and nature study are permitted if they are compatible with refuge purposes.
- Unrestricted public access to all parts of the Wilderness Areas is permitted, day use only, no wheeled vehicles.
- Fire suppression is permitted under "appropriate response" protocols.
- No maintenance of or improvements to water control structures.

Alternative B (Proposed)

Same as No Action alternative

Human Environment—Visitor Use and Experience

Affected Environment/Existing Condition

Moosehorn NWR is open to all six priority public uses (hunting, fishing, wildlife observation, photography, environmental education, and interpretation). Except for a few areas closed to public entry (Closed Areas) to prevent wildlife disturbance and/or provide for visitor safety, the entire refuge is open to the public.

The refuge has 43 miles of gravel service roads that are open for the public to walk or bike on during the spring, summer, and fall months, and snowshoe and cross-country ski on during the winter months. There are 12 miles of trails in the Wilderness Areas and 3.5 miles of interpretive trails near refuge headquarters on the Baring Division. Auto tour routes at Baring and Edmunds (5 and 4.7 miles respectively) are open to the public from late spring to the end of the firearms deer season. Total visitation averages 40,000 per year, with most visits occurring during the summer and early fall. Hunting visits total approximately 860 per year, making up only 2 percent of total visitation. Hunting is a common recreational activity in Maine and is a longstanding use on the refuge. In addition to other refuges, there are numerous Wildlife Management Areas and private lands open to hunting near the refuge.

In August 2021, the refuge released a Final Hunting and Fishing Plan, which continued to provide opportunities for big game (Black Bear, Moose, White-tailed Deer), upland game (Ruffed Grouse, Gray and Red Squirrel, Snowshoe Hare, Woodchuck, Red Fox, Coyote, Bobcat, and Raccoon), and migratory bird (duck, goose, American Woodcock, and Wilson's Snipe) hunting. The Plan adopts State hunting and fishing regulations for the areas open for those uses, with some additional refuge-specific regulations to minimize conflicts with other refuge objectives and visitor activities.

Alternative A

No change from existing conditions anticipated. The refuge would continue to manage habitats for the greatest benefit to wildlife, which would continue to support wildlife-dependent recreation. The refuge would continue to manage all assets that support recreation activities, such as roads and trails, to the greatest beneficial use and for the continued health and safety of all users. We anticipate that as the population continues to grow, and wild areas become increasingly scarce in the landscape, the refuge would continue to support a gradual but consistent increase of visitors through time.

Alternative B (Proposed)

In addition to the impacts of alternative A, the Proposed Action's forest management demonstration areas near roadways are anticipated to enhance visitor services activities. This may result in potential minor beneficial impacts to partner lands (in terms of both early and late successional management) if these practices are applied to their lands. The demonstration areas should also enhance habitat quality for early successional species, such as the American Woodcock, as well as species that require late successional forests, such as Bay Breasted Warbler and other wildlife and should increase the quality of the hunting and viewing experience.

Cultural Resources

Affected Environment/Existing Condition

Moosehorn NWR lies within a potentially rich area of early human activity; however, very little historical or cultural evidence has been unearthed within its 29,000-acre boundary. The refuge has not conducted a comprehensive inventory of cultural resources. To date, two arrowheads are on file with the Maine State Museum and two historical cemeteries are located on the Edmunds Division. Two archeology surveys have been completed in the past, a Fire Line clearing project, and a proposed Liquefied Natural Gas (LNG) Pipeline study. Neither study found anything of historical or cultural significance. Adjacent areas of interest include the Lincoln House (1787) in Dennysville and closer to the Baring Division, along U.S. Route 1, St. Croix Island, and site of the first French settlement in the New World. The nearest known archaeological site, known as N'tolonapemk, which means "Our Ancestor's Place" (Passamaquoddy), is located near the town of Meddybemps approximately 10.5 miles from the refuge's headquarters office. Archaeologists have known about the site since the 1960s, and it has produced artifacts that date back 8,000 years.

Section 106 of the National Historic Preservation Act of 1966, as amended, requires the FWS to evaluate the effects of any of its actions on cultural resources (historic, architectural, and archeological properties) that are listed or eligible for listing in the National Register of Historic Places (NRHP). In accordance with the regulations under Section 106, the FWS consulted with the SHPO of Maine. The SHPO indicated that there are five recorded archaeological sites along the Cobscook Bay shoreline. All are prehistoric sites that have not yet been professionally investigated in detail but have potential as sites

worthy of listing in the NRHP. There are no known archaeological sites within the Baring Division. The soils are mostly fine-grained glaciomarine and till derived soil, poorly drained, and not attractive for prehistoric settlement. Archaeological remains in the form of prehistoric campsites or villages would most likely be located along the coastline and streams where early inhabitants would have taken advantage of water supply and fishing and hunting opportunities.

Alternative A

No adverse impacts would occur under this alternative.

Ongoing refuge management does not impact historic, architectural, archaeological, and cultural resources. Any earth moving activities associated with habitat management (i.e., mowing, prescribed fire, field maintenance) affect only shallow, superficial soil layers and are unlikely to encounter unknown artifacts and are within previously disturbed areas. However, in the event an unanticipated discovery of previously unidentified archaeological resources is made during normal maintenance activities, all activities near the discovery would stop and all reasonable measures would be taken to avoid or minimize harm to the property until the FWS concludes consultation with the SHPO.

Alternative B

Same as No Action alternative.

Coordination with the SHPO is not applicable at this time. Should additional projects tiered from the HMP require earth moving activities or affect known historic properties, further coordination with the SHPO and potentially interested tribes would occur.

Land Use

Affected Environment/Existing Condition

The St. Croix International Waterway Commission (SCIWC) was established in the late 1980s through legislation and a memorandum of understanding between the Province of New Brunswick and the State of Maine. Thereafter, the SCIWC provides co-operative management of the unique and distinctive St. Croix Heritage River acting as a natural border between Canada and the United States. The SCIWC has a management plan intended to preserve heritage, environment, and economy of the region.

The Maine Department of Marine Resources has developed a rockweed management plan for Cobscook Bay. Any landowner (Federal, State, or private) may register their tidal lands in a rockweed no-cut registry.

The refuge currently owns roads, occupied buildings, trails, and infrastructure. Areas with occupied buildings and public roads are protected by State regulations. Refuge lands are also adjacent to and crisscrossed with well-traveled roads. Refuge land use and land cover is described in the Wildlife, Vegetation, and Recreation sections above. The refuge does some commercial timber harvests, and the major land uses in the watershed are recreation and logging (Dennys River Watershed Council 2005).

Alternative A

Although the refuge would continue to uphold its responsibilities as a steward of trust resources and fulfill its designated mission, without a long-term strategy that identifies threats and prioritizes resources and strategies, achievement of habitat goals and objectives for the effective longer-term function of refuge ecosystems may be at risk from inconsistencies in potential funding and other threats. Habitats would

persist, but the refuge may not be able to support designated land use to be the most effective for and greatest value to identified ROCs.

Alternative B (Proposed)

The refuge would continue to uphold its responsibilities as a steward of trust resources and fulfill its designated purpose and the Refuge System's mission. The HMP will provide an approved long-term strategy that identifies habitat goals and objectives for the effective longer-term function of refuge ecosystems, while simultaneously identifying threats, prioritizing resources, and determining appropriate management strategies. The BIDEH of wildlife habitats would continue to be protected, enhanced, and/or restored to support priority ROCs. The desired endpoint is management efficiency and land use optimization for all targeted priority ROCs.

Socioeconomic And Environmental Justice

Affected Environment/Existing Condition

Moosehorn NWR is in Washington County, ME. The county consists of 3,258 square miles and has a population of 31,379 (in 2019) making it the third least populated county in Maine. The population in Washington County has declined 4.5 percent since 2010. The 2018 population levels for five of the towns that contain refuge lands were Baring Plantation (237 people), City of Calais (3,005 people), Town of Charlotte (317 people), Town of Meddybemps (147 people), and the Town of Pembroke (788 people). (USCB 2019). Edmunds is an unorganized township and population data at the individual township level is not available.

From an economic perspective, Moosehorn NWR provides a variety of environmental and natural resource goods and services used by people either directly or indirectly. Spending by refuge staff and visitors in the general area of the mainland divisions supports economic activity in the Downeast region of Maine.

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, requires all Federal agencies to incorporate environmental justice into their missions by identifying and addressing disproportionately high or adverse human health or environmental effects of their programs and policies on minorities and low-income populations and communities.

Alternative A

No change from existing conditions anticipated. The refuge does not disproportionally impact minority or low-income populations; rather, the refuge provides a low-cost natural experience to all visitors and strives to be a good neighbor in the local community.

Alternative B (Proposed)

Same as No Action alternative

CUMULATIVE IMPACTS

Cumulative impacts are defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR 1508.7). Implementation of this HMP will prioritize species and habitats of greatest conservation need at

the landscape scale, employing robust and scientifically defensible strategies. Strategic Habitat Conservation (SHC) involves both cross-programmatic FWS groups and non-FWS conservation partners. Within the limits of established regulations and policies, the refuge will support a unified and coordinated approach by which the FWS, states, and conservation partners collaborate to provide important stopover sites for migrating landbirds and shorebirds in the Atlantic flyway and increased aquatic connectivity for migratory fishes. The HMP will sustain and restore habitat for species of greatest conservation need and conserve habitats identified as regional priorities.

Moosehorn NWR is currently managed as part of a Complex that includes two other refuges and a waterfowl production area. Moosehorn NWR is an active participant on several State of Maine plans/projects. For example, the refuge has a partnership with the St. Croix International Waterway Commission, the Passamaquoddy and Penobscot Tribes, and the FWS Fisheries Office (Orland, ME), working to evaluate the existing fish passages in the impoundments and assessing use and potential use of these areas by native fishes (e.g., Alewife and American Eel). As shown in this example, the refuge works in coordination with several other Federal, State, Tribes, and local governments to improve the ecological integrity of the refuge.

Climate Change

The major climate predictions for Maine include increasing water and air temperatures, longer growing seasons, changes in precipitation and moisture levels, more frequent and intense storm events, rising sea levels, and more frequent pest and disease outbreaks (MCC STS 2020). Temperatures are increasing statewide. Average annual temperature has increased 3.2 degrees Fahrenheit (°F) in the last 124 years, and the rate of warming has increased most notably since 1960. The six warmest years on record have occurred since 1998. The Northeast is warming faster than any other region in the U.S. and is projected to warm 5.4 °F when the rest of the world reaches 3.6 °F (Fernandez et al. 2020). The growing season (the period between the last frost and first frost) on the refuge is more than 2 weeks longer than it was in 1950, mostly due to later frosts in the fall (Fernandez et al. 2020).

Ocean surface temperatures are also projected to increase between 4 and 6° F by 2100. Additionally, over the next 100 years, sea level is projected to rise at least 5 to 15 inches, with some estimates as high as 45 inches. As sea level rises, the severity and frequency of coastal flooding and erosion will likely also increase (Whitman et al. 2010). Consequently, one primary concern for Moosehorn NWR is the impact of SLR on marsh elevation. This is causing marsh migration and marsh inundation. These habitat changes may dramatically reduce the amount and quality of salt marsh for migratory birds and many other species. As a result, wildlife could be forced into reduced amounts of available habitat. Concentrating birds in smaller areas also has potential to more readily allow disease to spread within overwintering waterfowl populations, resulting in increased bird mortality.

Precipitation levels are projected to increase approximately 2 to 14 percent in winter, spring, and fall, while summer precipitation is predicted to change very little. Winter precipitation is estimated to increase the most (8 to 16 percent) with a greater amount falling as rain. These changes in precipitation could also lead to shifts in hydrology if Maine’s rivers and streams transition from a snowmelt-dominated system with peak runoff in the spring to a rain-dominated system with peak runoff in the winter. The frequency and severity of heavy rainfall events is also estimated to increase, and the number of short-term droughts will also increase (Whitman et al. 2010). Increased frequency of droughts may also lead to a higher risk of wildfires (Kunkel et al. 2020).

Global climate change models developed by the U.S. Forest Service Northern Research Station predict the range of spruce-fir forest cover types will recede substantially beyond the refuge boundaries to the north by 2100, and that beech-birch-maple and/oak-hickory types will dominate this ecoregion (Iverson et al. 2008).

We anticipate that the management actions described in the HMP will have positive effects. Collectively, the goals, objectives, and strategies in the HMP aim to increase the resilience and health of the refuge's habitats in the face of climate change. This will restore and maintain natural processes and functions and allow for adaptive management as environmental conditions change from year to year, and sometimes in unpredictable ways.

Late successional forests sequester large amounts of carbon and for demonstration areas that are managed as early successional habitat, the new growth of young trees will remove carbon from the atmosphere as they grow.

Descriptions of Anticipated Cumulative Impacts

The refuge would use an adaptive management approach for its habitat management program, reviewing the program annually and revising as needed. To ensure sound wildlife management, the refuge will monitor the wildlife populations and habitat conditions. The proposed monitoring and re-evaluating will help to ensure that the habitat management program continues to contribute to the biodiversity and ecosystem health of the refuge, and that habitat management activities on the refuge do not contribute to any cumulative adverse impacts to habitat or wildlife from climate change, population growth, and development, or local, state, or regional wildlife management.

The Proposed Action was developed from a landscape perspective, where the refuge recognizes its critical placement in the landscape, especially relative to other wildlife refuges, core habitat, and connectors. Enhancing the availability of quality habitat in the region, especially the addition of larger, contiguous mature forest habitat, would benefit breeding and migrating species, support genetic diversity, and provide natural areas that may be more suitable for adaptation in the face of changing climate. The Proposed Action has also acknowledged that vegetative communities are also expected to shift with climate change, and as a result, desired future conditions may also need to shift.

Uncertainty about the future effects of climate change requires refuge managers to use adaptive management to maintain healthy ecosystems. Adaptive management involves improving or adjusting policies and practices based on the outcomes of monitoring or management activities and may result in changes to regulations, shifts in active habitat management, or changing management objectives. Some adaptive management recommendations are to manage for diverse and extreme weather conditions (e.g., drought and flood), maintain healthy, connected, genetically diverse wildlife populations, and protect coastal wetlands to accommodate sea level rise.

MONITORING

A primary component of the implementation of the HMP will include implementing the IMP, establishing baseline data, and establishing procedures to evaluate effectiveness of management actions. Implementation of projects in this HMP will occur simultaneously with annual activities (e.g., water management, invasive species control) documented in the annual habitat work plan (AHWP), and both plans will be integrated with the refuge IMP. Refuge staff will use this plan as a working document to

apply management-through-learning concepts, including adaptive management as needed. Periodic revisions are expected as projects are implemented, and the response of the system is monitored.

SUMMARY OF ANALYSIS:

The purpose of this EA is to provide sufficient evidence and analysis for determining whether to prepare an EIS or a FONSI.

Alternative A–No Action Alternative

The No Action alternative means that the refuge will continue to manage the habitat following the guidance put forth by separate, previously approved plans (HMP chapter 1, Table 1-1) that address management of forests, wetland ecosystems, streams and rivers, early successional habitat, and coastal habitats. Habitat management has been limited to control of invasive, nonnative plant species, limiting coastal ecosystem disturbance, some forest management efforts, manipulation of water levels in impoundments, and burning and mowing fields used by American Woodcock. It is likely that the refuge would continue to uphold its responsibilities as a steward of trust resources and fulfill its designated mission; however, without a long-term strategy that identifies threats and prioritizes resources and strategies, achievement of habitat goals and objectives for the effective longer-term function of refuge ecosystems may be at risk from inconsistencies in potential funding and other threats. Habitats would persist, but the refuge may not be able to support designated land use to be the most effective for and greatest value to identified Priority ROCs. Overall, the No Action alternative would not improve the FWS's ability to meet its legally mandated mission to protect other trust resources and preserve and enhance wildlife habitat.

Alternative B–Proposed Alternative–Implementation of the HMP

As described above, the Proposed Action is to implement the HMP and associated strategies. These strategies are aimed at increasing the dependability of the refuge as a sanctuary for target resident and migratory wildlife and aquatic species; supporting the recovery, stabilization, or growth of target populations; and promoting the resiliency and adaptability of required habitats in the face of climate change and other ecosystem threats. Early successional habitats will be managed more deliberately, to improve vegetation community diversity and quality and promote a mosaic of early (0 to 15 years) and mid- (16 to 50 years) successional aspen-birch and alder stands, for the benefit of American Woodcock and other early successional wildlife. Most forest communities will be allowed to mature into late successional forests - increasing the value for forest interior-dwelling landbirds and other species. Streams and river aquatic connectivity will be improved, allowing for improved access to migratory fishes, including diadromous species. Priority freshwater impoundment functionality will be improved to allow for higher quality habitat for priority waterfowl, shorebirds, marshbirds, and diadromous fishes.

Potential minor adverse impacts may occur to some species as certain habitats are transitioned across the refuge. Specifically, populations of pollinators and other early successional upland-obligate species may decline as the gradual transition of 3,106 acres of such habitat to late successional forests occurs. However, adverse impacts may be offset to some degree by the increase in early successional habitat value and quality through proposed management actions to increase diversity and extend available bloom in remaining locations and through strategic placement of such habitat in areas where habitat suitability is advanced. Likewise, the continued succession of 18,327 acres of early mid successional forest habitat to contiguous mature late successional forest habitat is likely to benefit interior forest-dwelling species. This

Proposed alternative helps meet the purpose and needs of the FWS as described above because the strategic, adaptive approach to land management outlined in the HMP and the prioritization of habitats would streamline available resources to maximize benefits of management efforts. This will result in improved habitat for priority resources of concern, including migratory birds, fishes, and resident wildlife.

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- Austin Rizzo–Conservation Planner
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STATE COORDINATION

Moosehorn NWR coordinates conservation efforts with state biologists regarding state-listed species.

PUBLIC OUTREACH

Public notifications of the EA and the draft HMP are being made available to the public through the refuge website and social media notices, and a hardcopy is available for review at refuge headquarters. There is a 30-day public comment period.

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OTHER APPLICABLE STATUTES, EXECUTIVE ORDERS AND REGULATIONS

Cultural Resources

- American Indian Religious Freedom Act, as amended, 42 U.S.C. 1996–1996a; 43 CFR Part 7.
- Antiquities Act of 1906, 16 U.S.C. 431-433; 43 CFR Part 3.
- Archaeological Resources Protection Act of 1979, 16 U.S.C. 470aa–470mm; 18 CFR Part 1312; 32 CFR Part 229; 36 CFR Part 296; 43 CFR Part 7.
- National Historic Preservation Act of 1966, as amended, 16 U.S.C. 470-470x-6; 36 CFR Parts 60, 63, 78, 79, 800, 801, and 810.
- Paleontological Resources Protection Act, 16 U.S.C. 470aaa–470aaa-11.

- Native American Graves Protection and Repatriation Act, 25 U.S.C. 3001-3013; 43 CFR Part 10.
- Executive Order 11593–Protection and Enhancement of the Cultural Environment, 36 Fed. Reg. 8921 (1971).

Fish and Wildlife

- Bald and Golden Eagle Protection Act, as amended, 16 U.S.C. 668-668c, 50 CFR 22.
- Endangered Species Act of 1973, as amended, 16 U.S.C. 1531-1544; 36 CFR Part 13; 50 CFR Parts 10, 17, 23, 81, 217, 222, 225, 402, and 450.
- Fish and Wildlife Act of 1956, 16 U.S.C. 742 a-m.
- Lacey Act, as amended, 16 U.S.C. 3371 et seq.; 15 CFR Parts 10, 11, 12, 14, 300, and 904.
- Migratory Bird Treaty Act, as amended, 16 U.S.C. 703-712; 50 CFR Parts 10, 12, 20, and 21.
- Executive Order 13186–Responsibilities of Federal Agencies to Protect Migratory Birds, 66 Fed. Reg. 3853 (2001).

Natural Resources

- Clean Air Act, as amended, 42 U.S.C. 7401-7671q; 40 CFR Parts 23, 50, 51, 52, 58, 60, 61, 82, and 93; 48 CFR Part 23.
- Wilderness Act, 16 U.S.C. 1131 et seq.
- Wild and Scenic Rivers Act, 16 U.S.C. 1271 et seq.
- Executive Order 13112–Invasive Species, 64 Fed. Reg. 6183 (1999).

Water Resources

- Coastal Zone Management Act of 1972, 16 U.S.C.1451 et seq.; 15 CFR Parts 923, 930, 93.
- Federal Water Pollution Control Act of 1972 (commonly referred to as Clean Water Act), 33 U.S.C. 1251 et seq.; 33 CFR Parts 320-330; 40 CFR Parts 110, 112, 116, 117, 230-232, 323, and 328.
- Rivers and Harbors Act of 1899, as amended, 33 U.S.C. 401 et seq.; 33 CFR Parts 114, 115, 116, 321, 322, and 333.Safe Drinking Water Act of 1974, 42 U.S.C. 300f et seq.; 40 CFR Parts 141-148.
- Executive Order 11988–Floodplain Management, 42 Fed. Reg. 26951 (1977).
- Executive Order 11990–Protection of Wetlands, 42 Fed. Reg. 26961 (1977).

APPENDIX B. INVASIVE SPECIES

SETTING PRIORITIES FOR INVASIVE SPECIES

General management strategies employed to restore and enhance the biological integrity of priority habitats and their associated ROCs are described in some detail in a separate file: *https://ecos.fws.gov/ServCat/Reference/Profile/132859*. These general strategies address threats, or are strategies employed in multiple units and habitat types.

Preventing the establishment and spread of invasive species is a national priority for the Refuge System (USFWS 2003). The unchecked spread of invasive plants threatens the biological diversity, integrity, and environmental health of refuge habitats. In many cases, these plants have a competitive advantage over native plants and can dominate an area, reducing the availability of native plants as food and cover for wildlife. The FWS uses the following definition for invasive species (620 FW 1.4E):

> "Invasive species are alien species whose introduction does or is likely to cause economic or environmental harm, or harm to human health. Alien species, or nonindigenous species, are species that are not native to a particular ecosystem. We are prohibited by Executive Order, law, and policy from authorizing, funding, or carrying out actions that are likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere."

The National Wildlife Refuge System Invasive Species Management Strategy released in May 2004 (USFWS 2004b) described tools, processes, and strategies for managing invasive species. The 2004 report was complemented by a technical report issued in May 2005 by USGS, titled "The Invasive Species Survey: A Report on the Invasion of the National Wildlife Refuge System" (Simonson et al. 2005). This report gives both a status review and a management strategy for combating invasive species.

Every year, refuges are faced with new species, expanding infestations, new control methods and ongoing surveillance, as well as declining staffs and budgets. As invasive species problems increase and staff time is constrained, refuges must become more strategic in addressing their invasive plant challenges. A strategic approach to invasive species involves (1) prevention, (2) early detection and rapid response, (3) control and management, and (4) rehabilitation and restoration (Ries et al. 2004).

The threat to habitats and ROCs from invasive species varies by species. We describe objectives for eradicating, minimizing, containing, or tolerating certain species (Casey et al. 2018).

- Eradication–eliminate the species.
- Minimize–reduce the current level of infestation over time to some percent level of coverage (coverage within the unit or habitat; coverage of current level of infestation; coverage of an area; etc.).
- Contain–will not allow the current coverage of infestation to spread (e.g., control all plants that occur outside of the current infestation).
- Tolerate–allow the current level of infestation to occur; species has become 'naturalized'.

Management priority is assigned to each invasive species, based on capacity and the level of effort the refuge can provide (Casey et al. 2018).

- High Priority–The refuge will give this species the most attention, the refuge will treat this species with current staff and funding. The species is threatening high priority habitat, or the species can be efficiently controlled/eliminated.

- Medium Priority–The refuge will treat this species if more personnel or funding become available. The species is not threatening high priority habitat, or the species requires more personnel or funds than are available, or treatment will contain but not eliminate the species.
- Low Priority–The refuge will not treat this species for one or more of the following reasons:
  - The species is not currently threatening high priority habitat.
  - The species is not spreading.
  - The species has become so prolific that treatment would not be successful.
  - The species has infested the local landscape creating a constant seed source.

At Moosehorn NWR the threat of invasive species is currently low compared to other refuges in the Northeast Region, although 16 invasive plant species have been documented on the refuge. Our objective is to ensure that no new invasive plant species become established, and we will manage to control the spread of the species that do exist. See

We developed a list of priority invasive species to control on the refuge, and we prioritize areas for monitoring, and establish monitoring and treatment strategies (Table B-1)(Mills 2023). The combination of the species *Level of Spread*, *Ecological Threat* and *Management Difficulty* are used to determine the Management Priority, which is explained in the Justification. The following are the definitions used in Table B-1.

LEVEL OF SPREAD

The rate with which the species' infestation is expanding.

- Stable (S)–The infestation is not expanding due to site conditions or slow growth, and/or is not entering new areas.
- Expanding (E)–The infestation is increasing and/or spreading to other areas.

ECOLOGICAL THREAT

The level of threat that the species has to the native community.

- High (H)–The invasive plant is known to have severe detrimental effects to native plants/biota/ecology.
- Medium (M)–The invasive plant has some detrimental effects to native plant species and/or ecosystem.
- Low (L)–The invasive plant has little detrimental effect to the ecosystem.

MANAGEMENT DIFFICULTY

The level of management needed to control or eradicate the species and/or prevent new infestations.

- High (H)–Management of the invasive plant and maintenance of the ecosystem requires substantial time (multiple years), effort (> 2 treatments) and funding.
- Medium (M)–Management of the invasive plant and maintenance of the ecosystem can be obtained quickly (one year) with moderate amount of effort (1 to 2 treatments) and funding.
- Low (L)–The invasive plant can quickly be eliminated with minimal effort, or it does not need to be managed because it is not spreading or is not a threat to the ecosystem.

MANAGEMENT PRIORITY

The overall priority rating based on level of spread, ecological threat, and management difficulty.

- EDRR (early detection, rapid response)–Vigilant observation for new infestations and rapid removal of plant.
- High (H)–High priority for treatment.
- Medium (M)–Medium priority for treatment; treat High species first.
- Low (L)–Low priority for treatment, little to no treatment planned. If treatment is planned, treat High and Medium species first.

TABLE B-1. INVASIVE PLANT SPECIES AT MOOSEHORN NWR, BY RISK LEVEL AND RECOMMENDED TREATMENTS.

Level of Establishment	Plant Species	Location	Spread*	Threat	Difficulty	Priority	Treatment
Peripheral, not on refuge yet	Purple Loosestrife (*Lythrum salicaria*)	No known established stands; common along roadsides.	-	H	H	EDRR	One or more plants/clumps found and removed and/or sprayed with herbicide. None detected 2022.
Peripheral, not on refuge yet	Phragmites (*Phragmites australis*)	No known stands on the refuge. One stand along Rt 1 near Pembroke/Perry line.	-	H	H	EDRR	
Peripheral, not on refuge yet	Japanese Knotweed (*Polygonum cuspidatum*)	No known occurrences on the refuge; extensive stands near refuge boundaries.	-	H	H	EDRR	None detected in 2022
Minimal Extent	Bell's and Morrow's Honeysuckles (*Lonicera x bella; Lonicera morrowii*)	A few trees on the railroad between Lower Barn Meadow and Lower Magurrewock Marshes; Route 1 and main track (no jurisdiction)	-	M	M	EDRR	None planned.
Minimal Extent	Japanese Barberry (*Berberis thunbergii*)	No known current infestations; 2 or more over past 30 years.	-	L	L	EDRR	One clump in 2019 in buckthorn area
None	Autumn Olive (*Elaeagnus umbellate*)	No known current infestations	-	L	L	EDRR	
None	Multiflora Rose (*Rosa multiflora*)	No known current infestations		M	M	EDRR	
New, low % cover	Glossy Buckthorn (*Frangula alnus*)	Between Ice House Road and the eastern edge of Middle Marurrewock Marsh.	E	H	H	H/EDRR	Ongoing, hand pulling smaller plants; herbicide larger plants.
New, low % cover	Spotted Knapweed (*Centaurea stoebe*)	Small section in Middle Barn Meadow Field.	S	M	H	H	Sprayed annually; mowed in 2022.

Level of Establishment	Plant Species	Location	Spread*	Threat	Difficulty	Priority	Treatment
New, low % cover	Black Locust (*Robinia pseudoacacta*)	Large trees off the South Edmunds Road (Edmunds Division); small saplings along road and in Bill's Hill Fields.	E	M	H	H/EDRR	Bill's Hill Fields mowed to removed seedlings; large trees removed, and stumps treated; ongoing
New, low % cover	Climbing Nightshade (*Solanum dulcamara*)	Only a few instances known.	S	L	L	EDRR	All known infestations have been removed.
New, low % cover	Garden Heliotrope (*Valeriana officinalis*)	Individual plants in the larger fields.	S	L	L	L	No treatment planned; impacts un-documented.
New, low % cover	Cypress Spurge (*Euphorbia cyparissias*)	One infestation in Bill's Hill Field along South Edmunds Road; one infestation near intersection of Belyea Road and Route 1 in demolition area.	S	L	L	EDRR	Treated with herbicide; None detected in past 5 years.
New, low % cover	Coltsfoot (*Tussilago farfars*)	One area found along north side of Two Mile Meadow Road; hand pulled early summer 2022	S/U	L	M	EDRR	Staff will be alert for new infestations and remove any found
New, extent not known	Smooth Bedstraw (*Cruciata laevipes*)	Fairly widespread along roadsides and in some fields.	E	H	H	H	Not treated as of Nov 2022.
Established, limited distribution	Canada Thistle (*Cirsium arvense*) and other Thistle	Populations variable year to year.	S	M	M	EDRR	No treatment planned.
Well established, widespread	Reed Canary Grass (*Phalaris arundinacea*)	Common on and off refuge.	E	M	H	M	Limited control; impacts to native plants un-documented.
Well established, widespread	Common Mullein (*Berbascum thapsus*)	Widespread in un-vegetated areas.	S	L	L	L	Hand pulling of plants.

*Key: SPREAD: Stable (S), Expanding (E); THREAT: High (H), Medium (M), Low (L); DIFFICULTY: High (H), Medium (M), Low (L); PRIORITY: Early detection rapid response (EDRR), High (H), Medium (M), Low (L)

Appendix C. Priority Impoundments

Table C-1 Priority Impoundments at Moosehorn NWR

Impoundment Name	Map Reference	Size (acres)
Upper Magurrewock	1	141
Middle Magurrewock	2	144
Lower Magurrewock	3	57
Upper Barn Meadow	4	29
Middle Barn Meadow	5	74
Lower Barn Meadow	6	49
Lower Goodall Heath	7	19
Seeley Flowage	8	40
Howard Mill Flowage	9	57
Snare Meadow	10	48
Hatton	11	27
Bearce Flowage	12	70
Cranberry Lake	13	106
Daly	14	22
McGaughlin	15	4
Boundary	16	11
Dudley Swamp	17	8
Sawyer Flowage	18	3
Firehole	19	8
MacDougall	20	15
Nat Smith (Edmunds Division)	21	20
Hallowell (Edmunds Division)	22	18
Barn Meadow #2	23	3
Barn Meadow #1	24	1
Cranberry Outlet	25	14
Total		**988**