Appendix B


©Kevin Fleming

Rough green snake

Habitat Management Plan

Prime Hook National Wildlife Refuge
Habitat Management Plan

Table of Contents

Table of Contents (cont.)

Chapter 1. Introduction

1.1 Scope and Rationale

In 1963, Prime Hook National Wildlife Refuge (NWR) was established to protect migratory birds and preserve coastal wetlands along the Delaware Bay. Lands were later acquired in the early 1970s for the purpose of conserving endangered and threatened species, the protection of natural resources and incidental fish and wildlife-oriented development. In the past, the primary focus of the Refuge has been the restoration of wetland habitats and the management of waterfowl. Although waterfowl management will always be a priority, future habitat management efforts will also ensure the protection, management, and enhancement of native plant communities which will conserve shorebirds, secretive marsh birds, wading birds, landbirds, raptors, the endangered Delmarva fox squirrel, and benefit resident wildlife. Through several CCP scoping and other public meetings our conservation partners and members of the public helped Service and refuge staff develop a future management vision statement. This Refuge Vision Statement serves as a starting point and provides future direction for habitat management planning and implementation.

> *Prime Hook National Wildlife Refuge will comprise a variety of Delmarva coastal plain habitats, such as barrier island beach, freshwater and tidal wetlands, grassland, shrubland and forest. The refuge will manage, maintain, enhance, and where appropriate, restore habitats for native plants and animals, with an emphasis on migratory birds and rare species. A balanced approach will be used to ensure all wildlife-dependent recreational users experience quality opportunities. The refuge will be a leader in conservation, research and community partnerships, adapting to physical and community changes as necessary to maintain the ecological integrity of the refuge and build a stewardship ethic for current and future generations.*

PHNWR is managed by the U. S. Fish and Wildlife Service as part of the National Wildlife Refuge System (NWRS). The mission of the NWRS 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 Refuge's Comprehensive Conservation Plan (CCP) and this Habitat Management Plan (HMP) are the primary tools used to guide refuge staff in achieving refuge objectives and the mission of the System. We have used the most recent refuge biological information and data, scientific literature, and ecological principles in developing this HMP to conserve and protect functional communities of native fish, wildlife, and plants. We view the highest measure of BIDEH as those natural habitats and associated wildlife populations that existed under historic conditions before humans altered the landscape. We have considered a range of habitat management strategies to meet our specific habitat goals and objectives and conducted survey of current refuge habitat conditions using the National Vegetation Classification System (NVCS) community mapping data, scientific reports, conservation partners' professional opinions and Service wildlife management expertise. We will provide for or maintain all appropriate native habitats and species.

This Habitat Management Plan is a dynamic working document with a long-term vision that provides guidance for the management of refuge habitats on an annual basis. The plan will provide direction for the next fifteen years (2010 – 2025), with subsequent reviews every five years, and use of adaptive management principles to assess and modify management activities as required. In the HMP we have considered and incorporated the role that refuge habitats play in international, national, regional, state, and local ecosystem plans. To the extent practicable, we craft our goals and objectives to be consistent with these plans, to assist in attaining the goals and objectives of conservation partners and the larger conservation community, in addition to achieving refuge objectives.

1.2 Legal Mandates

In the early 1960s the southeastern coastal marshes of Delaware were under threat of industrial development from oil refining and manufacturing industries. To help preserve these coastal wetland ecosystems from industrial developmental threats, PHNWR was established under the Migratory Bird Conservation Act (16 U.S.C. 715-715r, as amended on August 8, 1963, "…*for use as an inviolate sanctuary, or for any other management purpose, for migratory birds.*" Approximately 8,356 acres were acquired from sales of Migratory Bird Hunting and Conservation stamps for the purpose of migratory bird management.

Refuge boundaries were later expanded to include lands purchased under the Land and Water Conservation Fund (934 acres) under the authority of the Refuge Recreation Act (16 U.S.C. 460 k --- 460 k-4), as amended for the following purposes "…*suitable for (1) incidental fish and wildlife-oriented recreation development, (2) the protection of natural resources, and (3) for the conservation of endangered species.*"

The National Environmental Policy Act (NEPA) mandates our consideration of the impacts of our habitat management on environmental and cultural resources in planning federal actions. The Comprehensive Conservation Planning (CCP) process ensures compliance with NEPA, and serves as the basis for development of the HMP. In conjunction with the preparation of an Environmental Impact Statement (EIS) under the requirements of NEPA, the CCP process includes intra-Service consultation to fulfill the requirements of the Endangered Species Act (ESA). The Endangered Species Act (ESA) provides a program for the conservation of threatened and endangered plants and animals and the habitats in which they are found.

The Refuge Improvement Act provides the United States Fish and Wildlife Service (Service) the authority to establish policies, regulations and guidelines governing habitat management planning within the System. The Act states that *"… each refuge shall be managed to fulfill the mission of the System, as well as the specific purposes for which that refuge was established…"* {Section 4(a)(3)} and that *"In administering the System, the Secretary shall monitor the status and trends of fish, wildlife and plants in each refuge"* {Section 4(a)(4)}. The Service has established Habitat Management Planning Policy derived from the statutory authority of the RIA and in June of 2002 published Chapter 620: Habitat Management Practices within the NWR System (620 FW 1) in the Service Manual.

The HMP policy delineates strategies and implementation schedules for meeting CCP goals and objectives related to wildlife and habitat management. If a habitat management strategy or activity is required to meet a specific habitat objective in the HMP, and it produces an economic output (like timber harvest or cooperative farming as examples), the requirements for administering refuge management economic activities in the Service's Compatibility policy (603 FW 2) apply, i.e., written compatibility determinations and special use permits. However, compatibility determinations for habitat management activities that do not result in the generation of a commodity are not required. All habitat management activities described in this HMP have been addressed in the CCP.

1.3 Links to Other Plans

Refuge Plans

Habitat goals and objectives developed in the CCP/HMP will provide the groundwork for how the Refuge will conserve, protect, enhance and/or restore functional communities of native plants, fish and wildlife through specific management strategies and prescriptions. These habitat management strategies and prescriptions are linked with national and regional wildlife conservation plans including the Delaware Wildlife Action Plan. These links are explained in this section of the HMP.

Comprehensive Conservation Plan (CCP)
The 1997 RIA requires all Refuges to complete CCPs by 2012. A CCP is an all-encompassing document that guides all biological and public use actions on the Refuge for a 15 year period. Habitat goals and objectives developed in this HMP have been stepped-down from the Refuge's CCP.

Fire Management Plan (FMP)
A FMP is mandated by the Service policy for all Refuges that have *"...vegetation capable of sustaining fire."* The FMP addresses wildland and prescribed fire conditions and events with specific guidelines on the level of protection needed to ensure public safety, protect facilities, refuge resources and property, and restore and perpetuate natural biological processes. Prescribed fire is recognized as an important tool used to mimic ecological processes as an agent of disturbance that releases energy and renews habitats. Other fuels management strategies include mechanical thinning of vegetation and herbicide use. A FMP was completed for PHNWR on 2009. Habitat management goals and objectives developed in the FMP will also be incorprated into this HMP.

Habitat and Species Inventory and Monitoring Plan (HSIMP)
The HSIMP is another step-down plan from the CCP and will be completed 1-2 years after the CCP and HMP have been approved. At that time, habitat condition inventory and monitoring protocols essential to the HMP will be developed in accordance with the Service Manual: Habitat And Wildlife Inventory Monitoring Chapter (701 FW 2).

Monitoring wildlife populations as a sole indicator of wildlife habitat condition is usually not appropriate. However, habitat monitoring in association with wildlife response to habitat manipulations, provide the best measure of achieving HMP objectives (620 FW 1.14). Monitoring will be the primary basis for evaluating the effectiveness of management strategies, prescriptions, and actions to achieve habitat objectives set forth in the CCP/HMP.

Regional and State Plans

USFWS Migratory Bird Program (MBP) Strategic Plan
The MBP completed a 10-year strategic migratory management plan in 2004: A Blue- print for the Future of Migratory Birds - A Strategic Plan for 2004-2014 (USFWS 2004). National Wildlife Refuges provide high quality habitat for many migratory birds. The MBP is seeking to conserve and manage migratory bird populations and their habitats through strategic collaboration with partners committed to the same conservation goals.

Two key strategies of the MBP Plan are bird population monitoring and habitat management. Refuges are currently conducting biological surveys and managing habitat. Prime Hook's HMP will incorporate information from standardized monitoring protocols established while participating in several regional bird studies and from habitat assessments using the NVCS mapping inventories. There is an opportunity for the refuge to contribute to State- and region – wide assessments of bird population trends, and the effects of habitat management activities on migratory birds, by conducting strategies prescribed in this HMP.

North American Bird Conservation Initiative (NABCI)
The NABCI brings together the landbird (Partners in Flight), shorebird, water bird, and waterfowl national plans and consolidates them into a coordinated effort to protect and restore all native bird populations and their habitats of North America. These conservation partnerships reduce redundancy in the structure, planning and implementation of continental conservation goals and objectives. It also utilizes Bird Conservation Regions (BCRs) to guide landscape scale, science-based approaches to conserving birds and their habitats.

PHNWR lies within the New England/Mid-Atlantic Coastal Bird Conservation Region (BCR 30). This area has the densest human population in any region in the country. The highest priority birds of BCR 30 inhabit coastal wetland and beach habitats, especially Saltmarsh Sharp-tailed Sparrow, Nelson's Sharp-tailed Sparrow, Seaside Sparrow, Piping Plover, American Oystercatcher, American Black Duck, and Black Rail. The region also includes critical migration sites for Red Knot, Ruddy Turnstone, Sanderling, Semipalmated Sandpiper, and Dunlin. Other terns and gulls nest in large numbers along with mixed colonies of herons, egrets, and ibis on islands along the Delaware Bay and Chesapeake regions. These birds use Prime Hook NWR for a portion of their life cycle.

Estuarine complexes and salt marsh wetlands created behind barrier beaches in BCR 30 are extremely important to wintering and migratory waterfowl, including 65% of the total wintering American Black Duck population along with large numbers of Greater Scaup, Tundra Swan, Gadwall, Atlantic Brant, and Canvasback.

The Refuge plays an important role in the conservation of habitats for migrating and breeding birds identified in the BCR 30 plan. A comprehensive summary report prepared by Regional Biologist J. Casey (June 2007) collected the most current core information from BCR plans in Region 5 in relation to the bird species found on PHNWR, and this information was used to identify and prioritize specific resources of concern for refuge habitat management.

One hundred thirty-four species have been identified as priority species in the BCR 30 plan (Steinkamp 2008). The majority of these priority species use habitats associated with coastal ecosystems, including beach, sand, mud flats, estuaries, bays and estuarine emergent wetlands. Further review identified priority landbird species of other BCR plans that lie to the north and northwest of BCR 30, which included BCRs 12, 13, 14, and 28. Of the listed ninety-eight priority BCR species in these plans, 83% or 81 priority BCR species use PHNWR during the spring and/or fall migration period (Casey 2007).

The BCR 30 plan has linked bird species of greatest conservation need with their associated habitats that are necessary to sustain their populations. Eleven habitat suites have been identified as critical to conserve highest ranked migratory bird species with associated priority habitat management actions. This information has been incorporated in the Refuge's HMP for identifying Refuge top resources of concern and to establish habitat management priorities for the next 15 years.

North American Waterfowl Management Plan (NAWMP) & Atlantic Coast Joint Venture (ACJV)

The NAWMP outlines strategies in the U.S., Canada and Mexico to protect North America's remaining wetlands and to restore waterfowl populations through habitat protection, restoration, and enhancement actions. Implementation of this plan is accomplished at various regional levels within designated regional habitat "Joint Venture" areas.

The Refuge is part of the Atlantic Coast Joint Venture (ACJV) whose comprehensive conservation approach emphasizes all-bird habitat management. The goal of the ACJV is to *"protect and manage priority wetland habitats for migration, wintering and production of waterfowl, with special consideration to black ducks, and to benefit other wildlife in the joint venture area."*

In order to capture the conservation needs of a diversity of landscapes the ACJV has delineated planning areas into special focus and sub-focus areas. The state of Delaware contains four focus and three sub-focus areas together encompassing over 900,000 acres for waterfowl conservation. PHNWR lies within the Bayshore Focus Area.

The best waterfowl breeding and wintering habitats in the State are found in the Bayshore Focus Area. During the fall and winter hundreds of thousands of waterfowl utilize the areas for feeding and roosting with significant numbers of Canada goose, Snow Goose, Pintail, Black Duck, and Mallard. Over 60% of the Atlantic Flyway's Snow Goose population winters within this focus area. This area also contains concentrations of Northern Shoveler, American widgeon, and Gadwall in the State as well as being notable for the production of American Black Duck and Wood Duck.

The Bayshore Focus Area is also very important for other migratory birds. Located along the eastern coast of the Delaware Bay, it provides some of the most critical habitat (beach, dune, adjacent marshes and impoundments) for migratory shorebirds. This focus area is a major stopover site for over a million shorebirds including 80% of the Western Hemisphere's Red Knot population, along with substantial numbers of Dunlin, Ruddy Turnstone, Semipalmated Sandpiper, Least Sandpiper, Short-billed Dowitcher and others.

Major threats impacting waterfowl and other bird species in the Bayshore Area include sustained resort development, decreasing water quality in natural rivers, streams and bays, and invasive species. Forest and wetland habitats continue to be lost to facilitate agriculture and residential development. AJCV conservation management actions focus on protecting, restoring, and enhancing wetlands and associated upland habitats to form larger contiguous blocks of natural habitats along with connections to undisturbed beach habitats within the Bayshore coastal focus areas. Management recommendations and research priorities are incorporated into refuge habitat management planning and identification of monitoring elements. For example, this HMP places an emphasis on wetland restoration, which is the primary conservation recommendation put forward for the Bayshore Focus Area.

North American Waterbird Conservation Plan and Mid-Atlantic/New England/Maritimes Waterbird Conservation Plan (MANEM)

This plan is a partnership among individuals and institutions with interest and responsibility for conserving waterbirds and their habitats. The primary goal of the plan is to ensure that the distribution, diversity, and abundance of populations of breeding, migratory, and non-breeding waterbirds are sustained or restored.

The regional plan stepped down from the national plan pertinent to PHNWR is the Mid-Atlantic/New England/Maritimes Waterbird Conservation Plan (MANEM) which has compiled and interpreted scientific and technical information on the region's waterbird populations and habitats, assessed conservation status, developed strategies to ensure the persistence of sustainable waterbird populations in the region and identified waterbird priority species and habitat profiles for each state (MANEM Waterbird Plan 2006). This data will be incorporated in the Refuge's HMP.

U.S. Shorebird Conservation Plan and Northern Atlantic Regional Shorebird Plan

These plans are national and regional partnership efforts undertaken to make certain that stable and self-sustaining populations of all shorebird species are restored and protected. The North Atlantic Shorebird Plan listed priority shorebird species by habitat and scoring habitat use in the region with key "focal species" tabulated for each habitat type (Clark and Niles 2000). Shorebird conservation objectives are incorporated in this HMP, primarily through identification of priority resources of concern (ROCs).

Partners in Flight (PIF) Landbird Conservation Plan

The goal of each regional PIF plan is to ensure long-term maintenance of healthy populations of native birds, primarily passerines. Within each physiographic area, the plans rank bird species according to their greatest conservation needs, describe desired habitat conditions, develop biological objectives, and recommend habitat actions for priority birds. PHNWR lies with Physiographic Area 44, the Mid-

Atlantic Coastal Plain. Priority landbird habitats facing the highest threats include salt marshes, forested wetlands, mixed upland forests, and early successional upland plant communities.

Dealing with human population growth and urbanization while maintaining functional natural ecosystems is the greatest conservation challenge recognized in the Partners in Flight Plan for Area 44. The future of wildlife depends on protecting significant habitat patches for priority species. Identification and maintenance of those blocks large enough to support a full array of breeding birds are PIF's Area 44 highest conservation priority.

As coastal maritime, inland freshwater, and upland habitats are often adjacent, integrating the conservation objectives of priority land birds with those of waterfowl, shorebirds, and nesting waterbirds is the comprehensive conservation goal of the Area 44 plan. Specific habitat management recommendations pertinent to PHNWR, which are reflected in the objectives and strategies within this HMP, include:

- Continue strict protection of barrier beach and dune habitats to minimize productivity losses of priority species
- Protect salt marsh habitats for black rail, salt-marsh sharp-tailed sparrow, seaside sparrow, and American black duck
- Identify, prioritize, and protect all sites of high salt marsh
- Identify, manage and/or restore open lands > 50 ha with potential to support Henslow's sparrow
- Identify and protect forest blocks that support significant populations of prothonotary warbler, wood thrush, and Acadian flycatcher;

Recovery Plans

The Delmarva fox squirrel (DFS) was extirpated from Delaware by the early 1890s. In 1967 this squirrel was federally listed because it inhabited less than 10 % of its historic range. In accordance with the ESA, a recovery plan has been developed. The DFS recovery plan focused around two action objectives:

- Identify critical DFS habitat requirements
- Translocate DFS into suitable habitat outside areas within their historical range.

Range recovery expansion has occurred through eleven successful translocations conducted in the 1980s, of which one site was on PHNWR. To implement recovery actions in Delaware, Recovery Team Members in the late 1990s made the following Refuge management recommendations: 1) Reforest fallow open areas to add to the Refuge's base acres of forested upland habitats; 2) Augment current DFS Refuge population with additional translocations; and 3) Conduct a Population Viable Analysis (PVA) to estimate the Minimum Viable Population (MVP) needed to mitigate inbreeding and Founder's Effect, prevent problems of genetic drift and loss of heterozygosity, and then manage accordingly (Moncrief 1995). Forest management strategies identified in this HMP are guided by requirements identified in these DFS recovery and research efforts.

State Comprehensive Wildlife Conservation Strategy and Delaware Wildlife Action Plan

The Delaware Division of Fish and Wildlife, Delaware Department of Natural Resources and Environmental Control, has recently completed its Delaware Wildlife Action Plan with funding from the State Wildlife Grants program. The state plan acknowledges development pressure and loss of wildlife habitats as threatening the existence of most of Delaware's species of greatest conservation need (SGCN) such as the American oystercatcher, least tern, hooded warbler, carpenter frog, Delmarva fox squirrel, Coastal Plain swamp sparrow, Bethany firefly and many other species (DNREC 2005).

Fifty different vegetative community types have been delineated; several have been singled out as communities of conservation concern due to their rarity across Delaware's landscape, and featured as 'Key Wildlife Habitats' in Delaware's Wildlife Action Plan (DWAP; DNREC 2005). These communities are rare and underrepresented within the state landscape, have special significance in Delaware, are particularly vulnerable to disturbance, and/or have a high diversity of rare plants. As a result of any of these factors, DWAP's 'Key Wildlife Habitats also harbor SGCN.

For example, large blocks of unfragmented forests and wetlands have been designated as Key Wildlife Habitats because of their importance to area sensitive faunal species. Due to habitat fragmentation in Delaware's wildland landscape, a minimum patch size of 250 acres has been used as the criteria defining a "large block." Key Wildlife Habitats have been assigned to wildland habitats with 1) any SGCN occurrences; 2) rare plants or plant communities on the landscape defined as Habitats of Conservations Concern, 3) forest blocks greater than 250 acres, and 4) wetland blocks greater than 250 acres. Refuge staff has consulted with the Division of Fish and Wildlife and Delaware's Natural Heritage and Endangered Species Program to consider opportunities for the Refuge to conserve, protect, and manage species and critical habitats identified in the state's comprehensive wildlife action plan. State wildlife and habitat goals and objectives have been incorporated into the Refuge's habitat management planning efforts and identification of priority resources of concern (ROCs), as appropriate.

1.4 Guiding Principles of Habitat Management

Within the next 15-year horizon, the management of Refuge habitats will be driven by four factors:

- Conserving biological integrity, diversity and environmental health;
- As climate change alters vegetative communities, species occurrence, and migration chronologies of wildlife, we will allow these changes to occur and avoid maintaining static refuge conditions.
- Basing habitat management goals, objectives, strategies, and prescriptions on focal species management;
- Fulfilling the Refuge's purposes and National Wildlife Refuge System mission and goals.

The central theme guiding Refuge habitat management is the restoration and maintenance of natural habitats to meet refuge objectives, but also allow changes to occur in order to maintain, enhance, and restore biological integrity, diversity, and environmental health (BIDEH). Natural conditions and processes represent the highest measure of biological diversity, ecological integrity, and healthy ecosystems.

Guidance to accomplish this comes from specific Service BIDEH policy (See Section 3.2 of this plan for more details). This policy states that *"we use historical conditions as the frame of reference to identify composition, structure and functional processes that naturally shape ecosystems. We especially seek to identify keystone species, indicator species, and types of communities that occurred during a frame of reference."[601 FW 3.12 (B)].*

Maintaining or restoring existing elements of BIDEH on the Refuge depends on allowing natural processes and communities to develop in response to climate changes and other dynamic conditions. We identify umbrella species, indicator species, and types of natural communities that occurred during historic conditions to represent lost elements of biological integrity and environmental health. Where appropriate and feasible, we also manage for BIDEH by eliminating unnatural biotic and abiotic features and management strategies not necessary to accomplish Refuge purpose(s). We use historic conditions as an initial frame of reference to develop habitat goals and objectives (601 FW 3.15), but with consideration for likely future conditions in response to a changing climate.

Conservation Biology Principles

We have used the concepts of umbrella and indicator species as representatives of biological integrity and/or environmental health conditions (Table 1). These concepts also contributed to our identification of priority resources of concern, as outlined further in Chapter 3. Similar use of focal species has been made by other conservation biologists for site-specific biological planning projects (Chase and Geupel 2005). We have used the concept of umbrella species as appropriate targets for management and the concept of indicator species as representatives of historic biological integrity and/or environmental health conditions. In conservation biology, the protection of an umbrella species with concentrated management of its habitat requirements can extend protection for other priority resources of concern. For example, our decision to manage for larger Delmarva fox squirrel habitat patches makes the squirrel a good candidate umbrella species that benefits many breeding forest interior bird species, migratory landbirds, and a host of other forest-dependent resident wildlife. Similarly, American oystercatchers have been used as an umbrella species representative of overwash and sandy beach habitats.

An indicator species can be used to represent a measure of biological integrity and environmental health. A reliable indicator species can operate as a habitat assessment tool that can save time and money. We have chosen indicator species to be either an individual species or guild whose presence, absence, abundance, or relative well-being in a given habitat type is a sign of the overall health of its environmental condition and ecosystem functioning. For example, presence of the beach dune tiger beetle is indicative of quality, healthy beach and functional panic grass dune grassland habitats. In some cases, a species may serve as both an umbrella species and an indicator species simultaneously. We have chosen certain species or a particular guild as umbrella and/or indicator representatives of a habitat type and used them in developing habitat management objectives and strategies. As such, both groups of identified species are useful as monitoring targets.

Monitoring will be an integral component of biological planning using focal species, such as presence/absence as an inexpensive measure to gauge environmental health, relative abundance, and density of focal species as measures of biological integrity and diversity. Our habitat objectives incorporating specific focal species are based on numerous hypotheses and assumptions using the most recent and best available plant and wildlife survey information. These assumptions will be tested in on-going Refuge monitoring studies where focal species serve as key targets for monitoring endeavors to test the effectiveness of habitat management strategies and conservation actions or to adjust strategies and actions when outcomes do not meet expectations.

Table 1. Prime Hook NWR Indicator and Umbrella Species

Prime Hook NWR: Keystone and Umbrella species or guilds representative of biological integrity, diversity, and environmental health under historic conditions and rare or declining in today's landscape.			
Species or Guild	**Indicator**	**Umbrella**	**Habitat Type**
American Oystercatcher	Yes	Yes	Overwash Dunes
Beach Dune Tiger Beetle	Yes		Sandy Beach & Dune Grassland
Little Wife Underwing	Yes		Red Cedar Woods, Maritime Shrubland
Delmarva Fox Squirrel		Yes	Mixed Hardwood Forest

Prime Hook NWR: Keystone and Umbrella species or guilds representative of biological integrity, diversity, and environmental health under historic conditions and rare or declining in today's landscape.			
Long-Horned Beetle	Yes		Mature, diverse Southern Red Oak Heath Forest
Salt Marsh Passerines	Yes		Spartina High & Low Salt Marsh
Coastal Plain Swamp Sparrow	Yes		Spartina High Marsh, Maritime Shrub, Tidal Creek Shrubland
Henslow Sparrow		Yes	Early Successional (ES) Grasslands
River Herring	Yes		Aquatic Food Webs
Maritime Sunflower Borer Moth	Yes		Early Successional Grasslands
Wetland Lepidopterans	Yes		Peat Bog Communities
Obligate Rare Herptiles	Yes		Impoundments = ES Freshwater Marsh
Obligate ES Lepidoterans and other insect pollinators	Yes		ES Upland Communities

Metrics for indicator species remain to be determined. The best biological parameters to assess healthy habitat types and management actions of indicator species will incorporate biological measures at various levels to include a single metric and/or combination of:

- Presence/absence
- Index of Abundance
- Numbers per unit time
- Absolute density (Numbers per unit area)
- Nest densities, nest success, etc.
- Metrics to assess habitat diversity and heterogeneity
- Other population parameters

These habitat quality measures will be developed and refined over time and incorporated into a refuge Inventory & Monitoring plan. They will be used to monitor progress in achieving Refuge habitat restoration and management objectives.

Historic Range of Variability

Historic range of variability (HRV) is a method of restoration ecology describing natural ecosystems as having a range of historic conditions where they were self-sustaining and beyond which they move to a state of disequilibrium or unsustainability, due to degraded ecological integrity caused by anthropogenic stressors (Egan & Howell 2001).

Consideration of HRV can be used as a management tool to understand the dynamic nature of ecosystems, the processes that sustain and change them, the current state of the ecosystem in relationship to the past, and the possible range of conditions that are feasible to maintain and manage for in the future. It is a useful tool for determining a range of desired future habitat conditions (Landres et al 1999). This variability represents the variance of ecological and biological parameters over a specified temporal frame of reference. Our frame of reference has been set for approximately 400 years ago (European Settlement), when their disturbances started having significant influence on biological condition of natural habitats. Using a HRV management approach considers a range of past habitat conditions when BIDEH elements were maximized and human stressors were minimal. Managing for HRV means restoring historic habitat conditions and maintaining an appropriate representation of those conditions that will ensure both short and long-term maintenance of BIDEH.

Historic conditions of Refuge habitats at this established frame of reference includes native Delmarva Coastal Plain plant communities dominated by mixed upland forests, swamps and emergent wetlands interspersed with transitional (grassland & shrubland) upland habitats. These transitional habitats were represented by small openings of grasslands and thickets influenced by a combination of fires set by aboriginal people, storms and beavers.

The current state of the Delmarva Coastal Plain ecosystem sustained a loss of 75% or more of mature forests, 50% or more loss of wetland habitats, and contains few to no acres of transitional or early successional upland habitats. Remaining fragments of natural areas on Refuge are considerably degraded (Sections 2.2, 2.3, and 2.4).

Managing for HRV for an ecosystem requires the selection of habitat and biological parameters necessary to sustain habitat goals and management objectives for target conservation species, called resources of concern (ROCS). See Chapter 3 for more information on ROCS. Through HRV, the refuge will select variables at all levels of biological organization and habitat classifications such as community type, patch size, tree size, tree density, canopy cover, population size, species composition, water depth and temperature, gene flow, etc., and use them in habitat objectives.

Chapter 2. Background

2.1 Refuge Location, Description and Geographic Setting

Prime Hook National Wildlife Refuge is located within the Atlantic Coastal Plain (BCR 30 and PIF Physiographic Region 44) along the southwestern shore of the Delaware Bay in Sussex County, Delaware. It is a Refuge within the Coastal Delaware NWR Complex (HMP Map 1). The Refuge, established in 1963, historically consisted of tidal marshes and agricultural lands with both habitats heavily grazed by cattle. The landscape surrounding the Refuge was dominated by small farms producing vegetables and small grains. From the 1990s to present day, resort and residential development and intensive agricultural operations (corn, soybean and chicken production) are the dominant land uses bordering the Refuge.

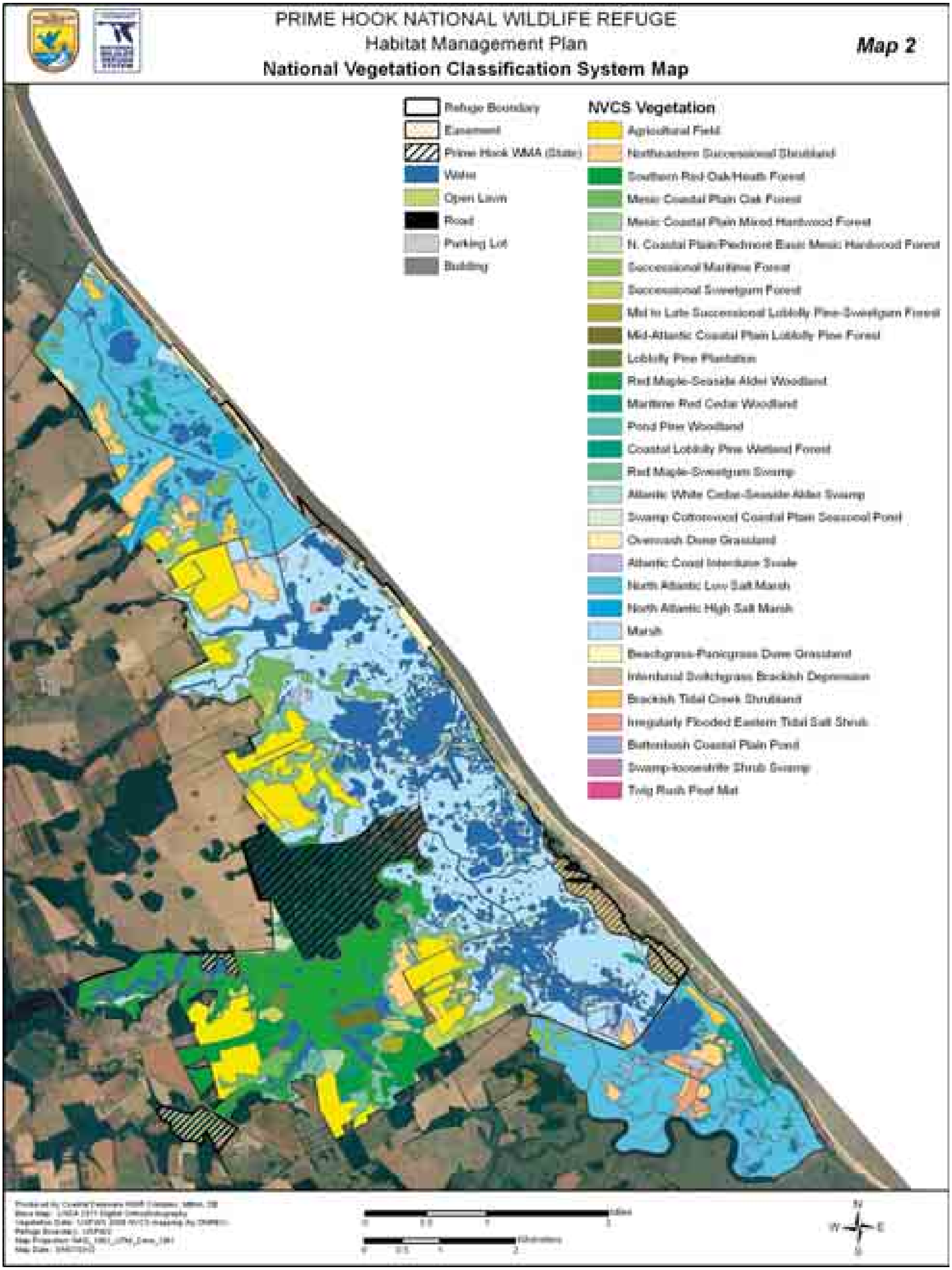
Natural habitats are dominated by emergent wetlands interspersed with swamp and upland forests representative of the Delmarva Coastal Plain ecosystem. Eighty percent of PHNWR's vegetation cover types are influenced by tidal and freshwater creek drainages that discharge into the Delaware Bay with associated coastal marsh habitats. The remaining twenty percent are composed of upland habitats. NVCS cover typing of the Refuge has resulted in the delineation of 37 land cover types including vegetation and anthropogenic communities and water surface coverages (HMP Maps 2–7).

Other natural wildland habitats and managed wetlands immediately adjacent and/or near PRIME HOOK NWR include:

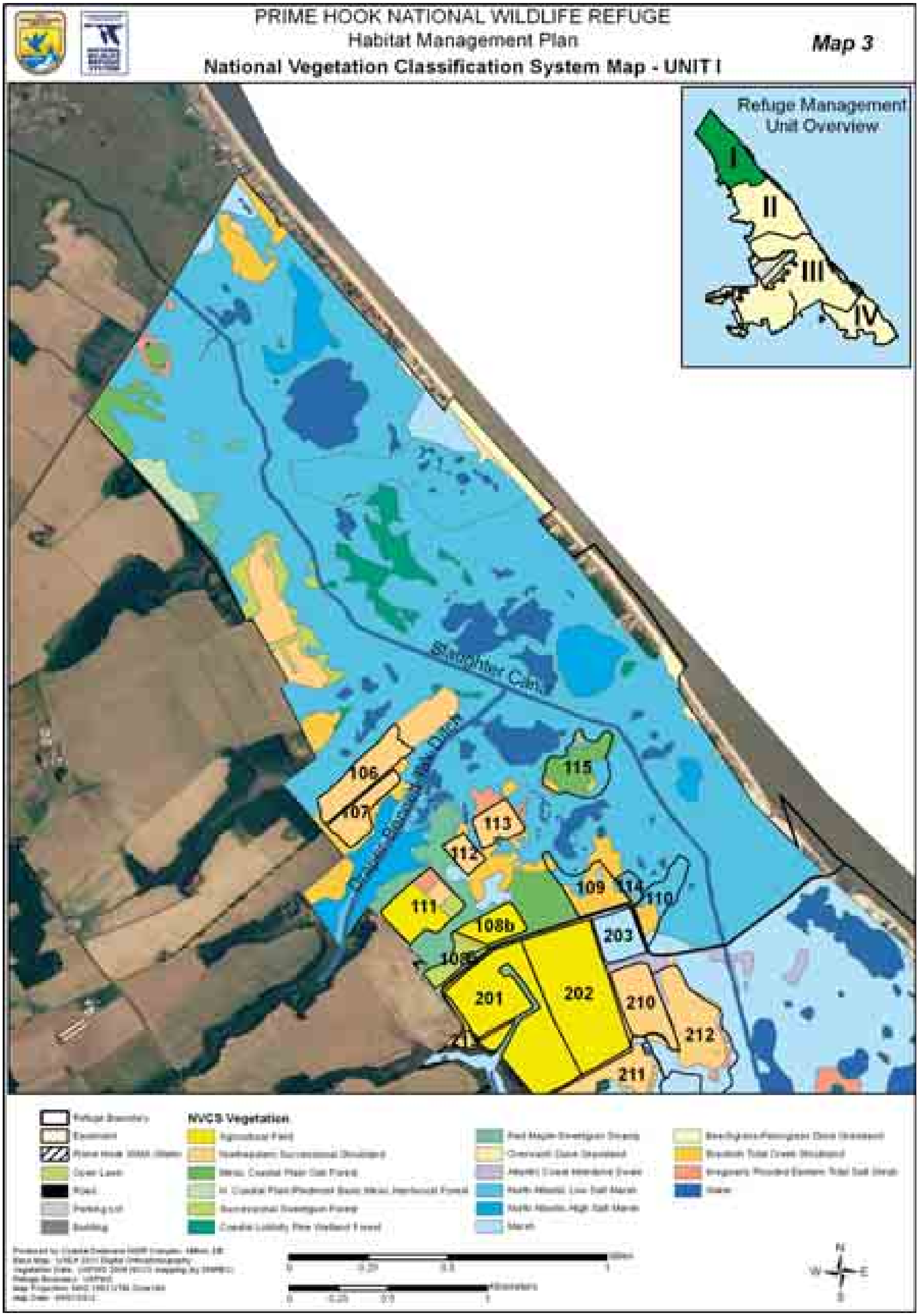
1) The Great Marsh (1,000 acres of salt marsh, owned by the town of Lewes) located just south of the Refuge,
2) Milford Neck WMA (5,459 acres), 3 miles north of the refuge above Mispillion Inlet;
3) Ted Harvey Conservation Area (2,661 acres), 9 miles north of the refuge above Bower's Beach;
4) Little Creek WMA (4,721 acres), 15 north of Prime Hook NWR above Port Mahon;
5) Prime Hook WMA (698.2 acres), adjacent to Prime Hook NWR
6) Bombay Hook NWR (16,000 acres), 25 miles north of the refuge.

Map 1. Delmarva area National Wildlife Refuges

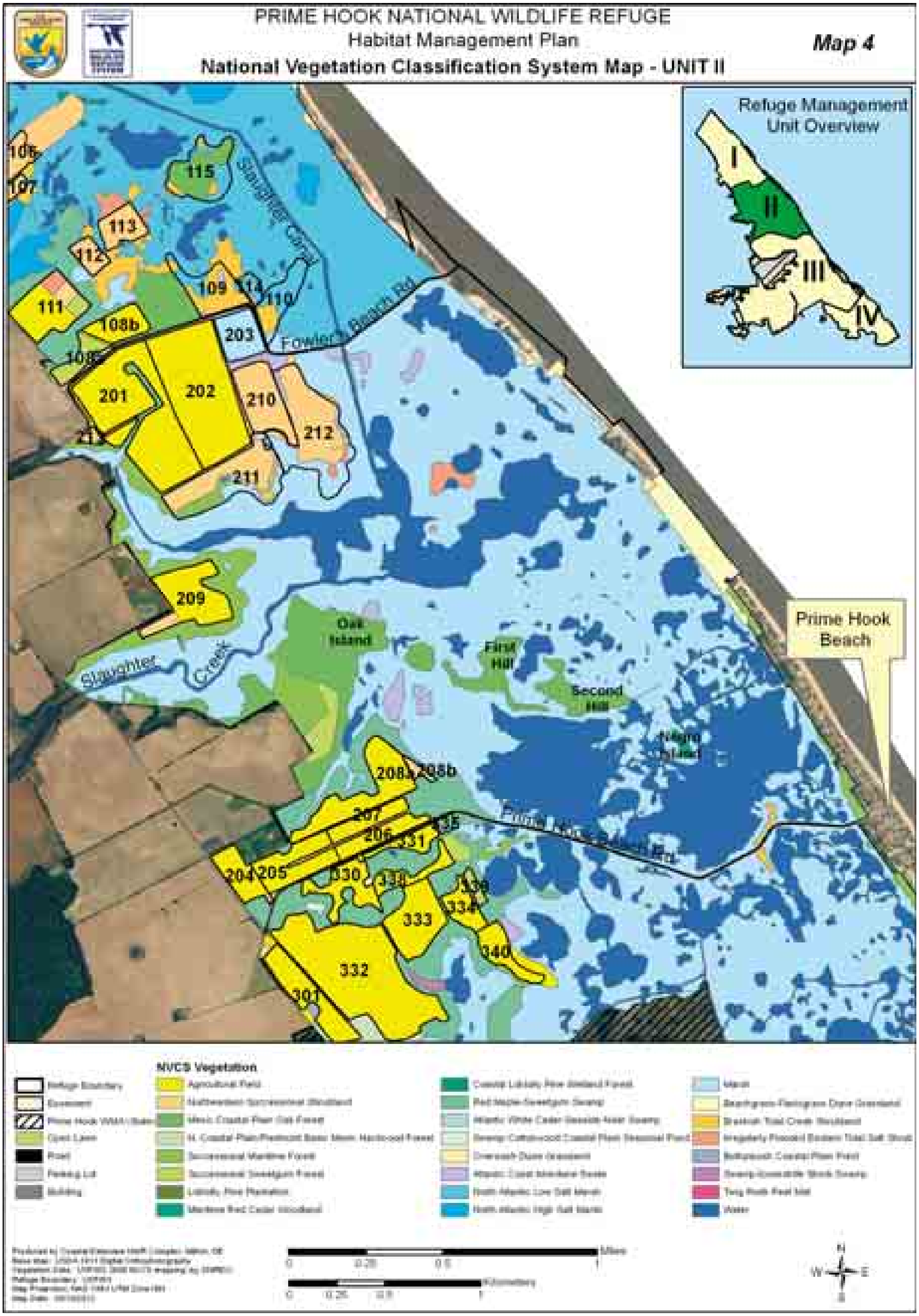
Map 2. National Vegetation Classification System Map - Overview (2006)



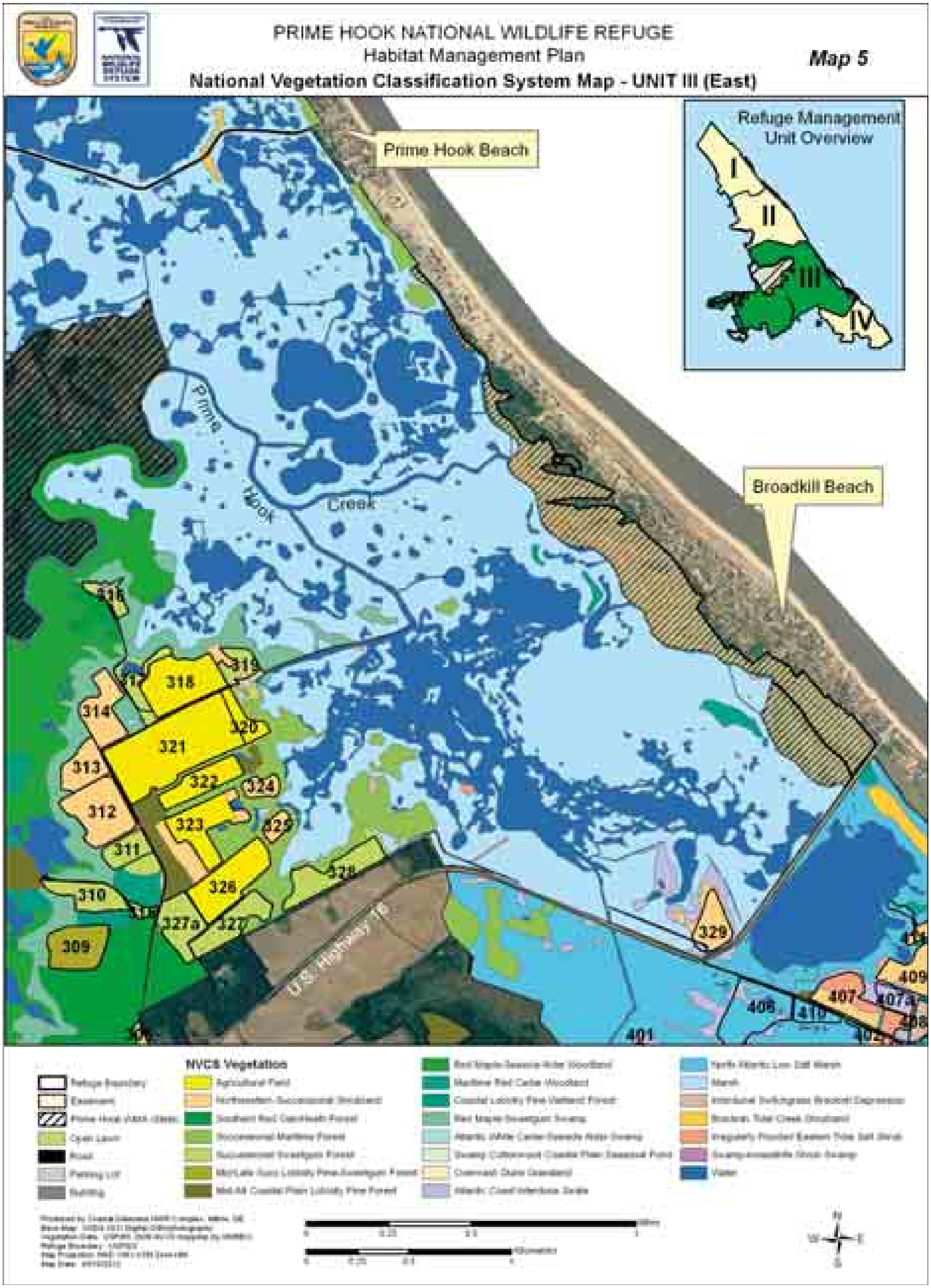
Map 3. National Vegetation Classification System Map - Unit I



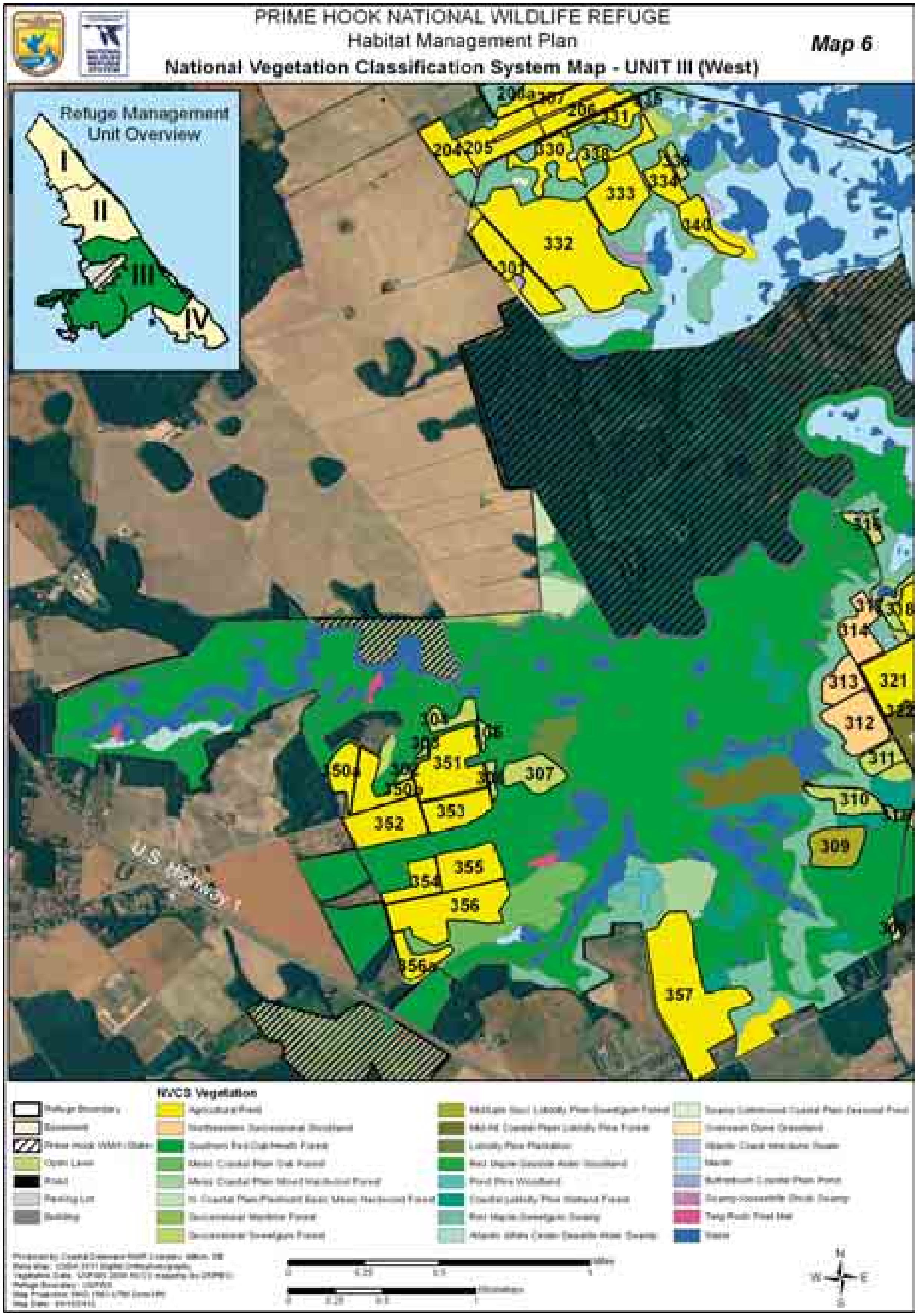
Map 4. National Vegetation Classification System Map - Unit II



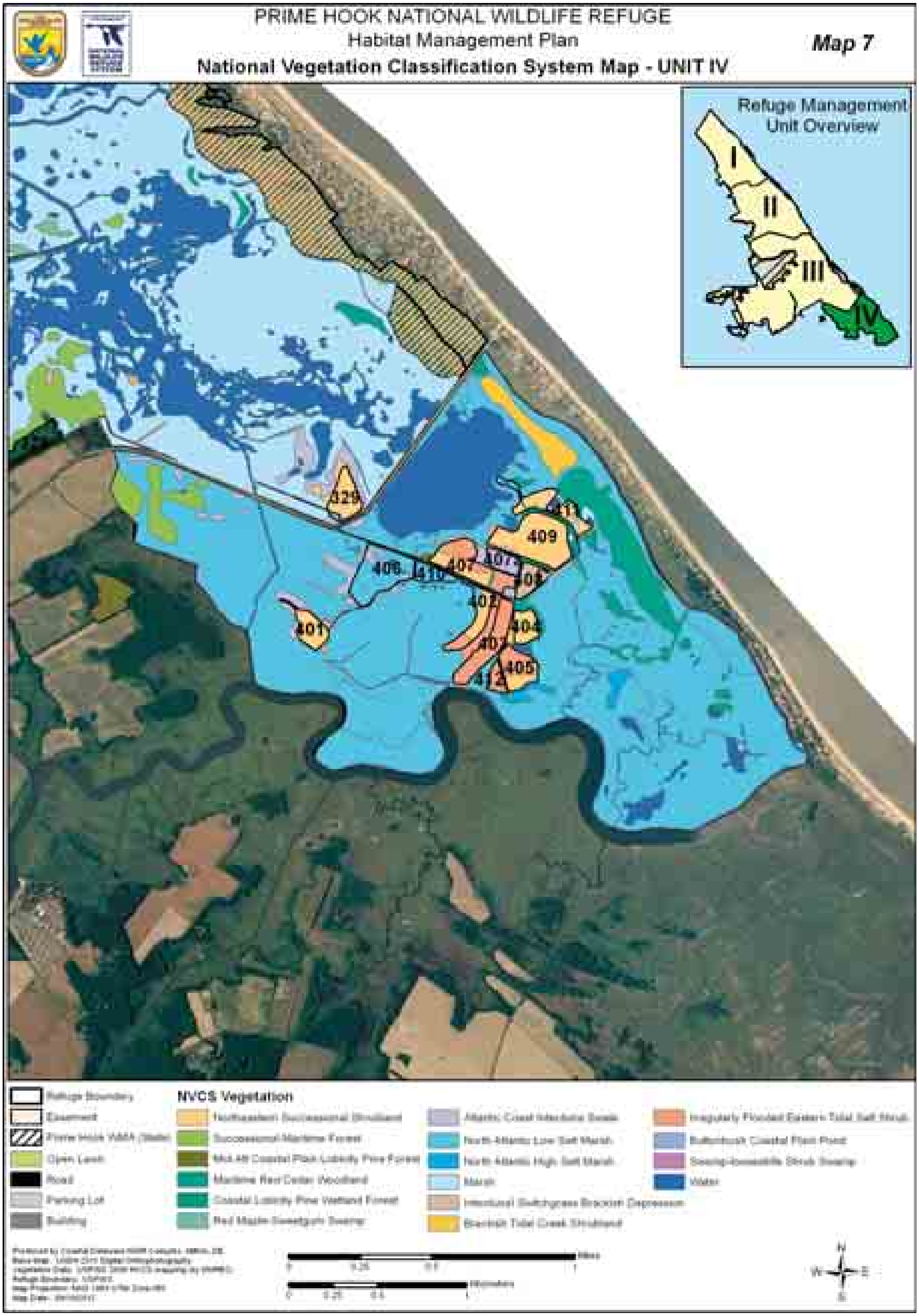
Map 5. National Vegetation Classification System Map - Unit III (East)



Map 6. National Vegetation Classification System Map - Unit III (West)



Map 7. National Vegetation Classification System Map - Unit IV



2.2 Management Units: Geographic Description, Topography, Soils and Historical Perspective

Prime Hook NWR can be described as an elongated coastal strand of ten thousand acres that lies parallel to the Delaware Bay. For management purposes, the Refuge has been divided into four management units transected by four state roads which run perpendicular to the Bay. All managed fields on the refuge and other place names referenced in the HMP are labeled in HMP Maps 3–7. Fields with numerical names in the one-hundreds are located in Unit I, two-hundreds in Unit II, etc.

UNIT 1 (HMP Map 3)

This area comprises the northern most end of the refuge and is delineated by Slaughter Beach Road as its northern boundary, overwashed barrier dunes and a portion of the Slaughter Beach community houses on the east, Fowler's Beach Road on the south, and an upland fringe of scrub-shrub areas on the western boundary.

Hydrology

There is currently no water level management capability in Unit I, which contains about 1,400 acres of salt marsh. Tidal salt water is the primary source of water for the unit, which flows approximately two miles from the DE Bay through the Misspillion Inlet and into Slaughter Canal entering through Slaughter Canal.

Attenuated tidal flow provided by Slaughter Canal bisects Unit I and receives its afflux from the ditches and creeks within the salt marshes in Unit I. The Draper-Bennett Tax Ditch drains the southwestern portion of this unit, which ultimately feeds into the Slaughter Canal. Daily tidal action has a 4.4 foot range and salinities range from 5 to 25 ppt in the Canal. During drought periods, the salinity can get as high as 30 ppt. Rainfall, new and full moon tides, and spring and neap tides maintain the salt marsh community within Unit I. Natural formations of inlets from overwash events along the Bay shoreline rejuvenate tidal marsh habitats in Unit I through maintenance of salinity levels and deposition of nutrients and sediments carried by tidal flow. During the past 30 years several of these mini-inlets have opened and closed along this shoreline. Currently, a breach in the southern portion of Unit I has restored tidal flow into the unit east of the Slaughter Canal.

Soils and Topography

Unit I is dominated by Transquaking and Mispillion soils (TP) which, along with a smaller proportion of Sunken mucky silt loam (SuA), constitute most of the salt marsh habitats. Other soil types found in upland areas include Hammonton sandy loam (HnA) and loam sand (HmA), Carmichael loam (CaA), Hurlock sandy loam (HvA) and loamy sand (HuA), Ingleside loamy sand (IeA and IeB), Marshyhope sandy loam (MdA), Pineyneck loam (PyA), and Unicorn loam (UlA).

Management History – Upland Fields 1978 – 2008 (HMP Map 3).

- **Fields 101-105:** not tilled during this period and have reverted to brush (*Morella, Iva, & Baccharis*). This area was hydro-axed in late 1980s to set back succession. No management has taken place since the late 1980's. These fields are not depicted on the map.
- **Field 106/107:** farmed in early 1970s but Refuge lacks access to this area.
- **Field 108a**: tilled in early 1970s, but farming was ceased in 1972 because field was too wet.
- **Field 108b**: planted until 2006 alternating between corn and soybeans.
- **Field 109** planted in wildlife mixture 5 times in past 30 years.
- **Field 110** reverted to Brush mostly bayberry (*Morella)*; too wet to cultivate.
- **Field 111:** farmed until 2006; 10 acres removed in 1990s, too wet to cultivate.
- **Field 112:** managed as grasslands.

- **Field 113:** managed as grasslands.
- **Field 114:** reverted to brush.
- **Field 115:** reverted to brush and saplings.

Current Vegetation

We have listed the National Vegetation Classification System community associations and habitat descriptions that apply to each of the four management units. Acreages presented in habitat objectives reflect approximations from NVCS mapping.

Management Unit I is the northernmost unit at Prime Hook and totals 1,624.9 acres [657.5 ha (Table 2 and HMP Map 3). Of the total acres, 1,504.7 acres (608.9 ha) are natural communities and 120.2 acres (48.6 ha) are anthropogenic communities. This management unit receives tidal, brackish water inputs from Slaughter Creek which results in the development of *Spartina* Low Salt Marsh, the largest vegetation community in Unit I. A small Wax-Myrtle Shrub Swamp located at the south end of the Unit is the smallest vegetation community mapped. Part of this unit experienced an arson-set marsh fire under high wind conditions (45 + mph) on March 10, 2002 that burned approximately 1,300 acres.

Table 2. Acreage of Natural and Anthropogenic Communities in Management Unit I

Natural Community	UNIT I acreage (ha)
Atlantic Coast Interdune Swale	0.3 (0.1)
Beachgrass-Panicgrass Dune Grassland	12.5 (5.1)
Brackish Tidal Creek Shrubland	73.9 (29.9)
Coastal Loblolly Pine Wetland Forest	34.2 (13.8)
Coastal Plain Depression Swamp	39.9 (16.1)
Marsh	33.2 (13.4)
Mesic Coastal Plain Oak Forest	49.6 (20.1)
Mesic Rich Forest	10.6 (4.3)
Mid-Atlantic Maritime Salt Shrub	10.8 (4.4)
Overwash Dune	5.1 (2.0)
Successional Sweetgum Forest	31.2 (12.6)
Spartina High Salt Marsh	75.2 (30.4)
Spartina Low Salt Marsh	982.0 (397.4)
Open Water	146.2 (59.2)
Natural Community Total	**1,504.7 (608.9)**
Anthropogenic Community	
Agricultural Field	25.6 (10.4)
Northeastern Successional Shrubland	90.1 (36.4)
Road	4.5 (1.8)
Anthropogenic Community Total	**120.2 (48.6)**
UNIT 1 Total	**1,624.9 (657.5)**

UNIT II (HMP Map 4)

This management unit is just south of Unit I and is an impounded wetland system. It is bounded on the north by Fowler's Beach Road, barrier dunes and sand dike plus the Prime Hook beach community on the east, Prime Hook Road on the south, and an upland interface on the west. Prior to 2009, when large breaches formed along the eastern barrier dunes, this unit was managed solely as a freshwater impoundment through the manipulation of water levels at water control structures and the exclusion of tidal flow. Presently, the unit is subjected to daily tidal influence through the breaches and consists of a larger expanse of open water than is reflected in the 2005 vegetation mapping acreage.

Hydrology

During storm tides this sand dune system has been breached several times and washouts have deposited sand and salt water into the Unit II impoundment. Freshwater input is from Prime Hook Creek, which flows from the west. Delaware Bay's normal tidal ranges are from 3 to 3.5 feet except for storm surges and spring tides (± 6.5 ft). Tidal flow enters Slaughter Canal from the Delaware Bay through Unit I salt marshes into the northern portion of Unit II and fresh water flow enters Unit II on the west from Slaughter creek.

Soils and Topography

The area is relatively flat with the exception of four upland islands surrounded by wetland habitats. The dominant soil type of 1,500 acres in Unit II Transquaking and Mispillion soils (TP) which, along with Sunken mucky silt loam (SuA), which together constitute most of the wetland habitats. Negro Island consists of Hurlock loamy sand (HuA). Second Hill soils are Glassboro sandy loam (GoA). First Hill consists of Ingleside sandy loam (IgA) and Glassboro sandy loam (GoA). *Oak Island is made up of (SaB) Sassafras sandy loam with 2 to 5 percent slopes.* The remaining 600 acres of upland forest, croplands and grasslands consist of Pineyneck loam (PyA), and Unicorn loam (UlA), Carmichael loam (CaA), and Glassboro sandy loam (GoA).

Management History – Wetlands

Until 1900, Unit II marshes remained unchanged, consisting of a freshwater system dominated with cattails and sedges. Landowners had the marsh drained and dug Slaughter Canal in the early 1900s to improve drainage of their upland areas by channelizing water north to Cedar Creek. In 1906 the Slaughter Canal dredging reached into Unit II and ended at Oak Island. Portions of Unit II were also heavily grid ditched during the 1930's for mosquito control. To maintain water on the marsh during the fall and winter for muskrat trapping and waterfowl hunting, private owners built water control structures at Fowler's Beach Road, Oak Island and near the bridge at Slaughter Creek to hold water.

The construction of Slaughter Canal in the 1930's vastly increased drainage in Unit II marshes and lowered water tables in upland areas. It significantly altered tidal exchange, leaving only a narrow band of tidal marsh along the edge of the canal and around Oak Island. The dredging of the canal also contributed to Phragmites colonization. By the 1980s, Unit II had completely reverted to a Phragmites jungle, with dense stands covering 1,000 acres (See Prime Hook's Environmental Assessment for Chemical Control of Phragmites and Proposed Marsh Rehabilitation-March 21, 1983).

In 1934, a dike was dug by dragline, along the eastern edge of the marsh from Slaughter Beach to Prime Hook Beach to prevent the bay from washing into the marshes. The deep borrow ditch is still evident today but several sections have been filled by washouts. Until the early 1950s, access to Prime Hook Beach was possible only by boat or during the dry summer by horse or vehicle. In 1953, a gravel roadway was constructed across the marsh and today this roadway is paved (Prime Hook Beach Road). It has effectively acted as a dike between Units II and III with small culverts under the roadway resulting in some limited flow of water between the units. All of these activities have significantly altered the hydrology of Unit II wetlands (USFWS 1986).

In 1963, the Service proposed a water management plan to the public, which outlined marsh management needs for the entire refuge including Unit II. The plan was designed to impound refuge marshes without backing water against upland areas. Local residents expressed strong opposition to the proposal and the state Drainage Engineer felt that it had the potential to flood or waterlog contiguous agricultural lands as occurred at Bombay Hook NWR. A revised plan with inland canals to provide drainage of uplands was also strongly opposed. Subsequently, a “No Management” policy was adopted which resulted in a severe decline in the quality, quantity, and productivity of the Unit II marshes over the ensuing years (USFWS 1986).

From the establishment of the refuge in 1963 to 1986, Unit II had no water level management capabilities. In 1987 a large concrete water control structure was put into place and partially funded by the first DU Donor Project in the country (J. Howard Isaacs). The project cost about $350,000 to install a concrete multi-bay water control structure with 11 separate bays, spanning 46 feet across the Slaughter Canal serving to impound 1,500 acres. Saltwater intrusion into Unit II is held in check by this structure located on the northern boundary at Fowler’s Beach Road. After water level management capability was restored, salinities within this impoundment range from 0 to 8 ppt year round.

The Environmental Assessment documentation (August 1986) for the reestablishment of water control in Unit II provide important information in linking the past with the present. The title of the EA itself is historically interesting “Reestablishment of Water Control in Unit II.” Prior to the refuge acquiring this area, both private land owners and the state mosquito control agency used timber sheeting to construct small water control structures throughout Unit II to manage water levels (USFWS 1986).

Historically, the majority of Unit II wetlands were formerly freshwater marsh. Slaughter Creek was the most significant watercourse in the unit, flowing southeasterly across the entire Unit II to Prime Hook Creek south to Prime Hook Road. The hydrology of Unit II was changed with the installment of water control infrastructure as water flows northward to Unit I from First and Second Hills to Fowler’s Beach Road but from Oak Island south, water flows in a southerly direction to Prime Hook Road.

Unit II restoration of water level management in 1987 significantly increased the water table of these marshes. Water sources which affect the hydrology of this unit today come from tidal action, runoff from Slaughter Creek, excess water from the Unit III, rainfall and local runoff. Tidal and freshwater exchange would also at the site of the water control structure when abnormal tides and storm surges cause water to flow over the top of stoplogs. Today, large breaches along the barrier dune permit daily tidal flow of brackish water from the Delaware Bay into Unit II, preventing water level management through the water control structures as was conducted for over two decades and resulting in an increased amount of open water relative to the acreage estimated during 2005 vegetation mapping.

Management History – Upland Fields 1978 – 2008 (HMP Map 4)

- **Field 201:** Tilled until early 1990s. Removed from farming, too wet to till. Returned to corn/ soybean cultivation in 2006.
- **Field 202:** Tilled until 1991, then field was split into 2 section 202a managed as 64 acre areas in grassland; and 202b planted in corn and soybeans. 202b was put out of production and used in R5 Grassland Study 2001 – 2004. Put back to soybeans in 2006.
- **Field 203:** Switchgrass area currently reverting to brush.

- **Fields 204-208:** all fields cultivated in corn and soybeans until 2006.
- **Fields 210-212:** was grassland now reverting to brush/saplings with Phrag encroachment. Sprayed with herbicide and burned in 2007, partially mowed in 2008.
- **Field 213:** "Old corral" mowed in 1970s and 1980s and reverted to brush.

Current Vegetation

Total acreage of Unit II is 1,997.5 acres (808.3 ha) in size, of which 1,681.8 acres (680.6 ha) are natural communities and 315.7 acres (127.7 ha) are anthropogenic communities (Table 3 and HMP Map 4). The Generic Marsh cover type was identified as the largest vegetation community and the smallest is the Maritime Red Cedar Woodland. As of 2006, this Unit had been invaded (~100 acres) by the river seedbox (*Ludwigia leptocarpa*), a native plant of the south, but considered non-native in Delaware and apparently has invasive characteristics here at Prime Hook NWR. The presence of wetland vegetation identified in the 2005 vegetation mapping has been altered as a result of the introduction of tidal waters through breaches in the barrier dunes. Table 2-2 reflects the baseline vegetation community present prior to the formation of the breaches.

Table 3. Acreage of Natural and Anthropogenic Communities in Management Unit II

NVCS - Natural Community	UNIT II acreage (ha)
Atlantic Coast Interdune Swale	20.1 (8.1)
Beachgrass-Panicgrass Dune Grassland	22.6 (9.1)
Brackish Tidal Creek Shrubland	3.3 (1.3)
Coastal Plain Depression Swamp	47.2 (19.1)
Maritime Red Cedar Woodland	1.9 (0.8)
Generic Marsh	918.9 (371.8)
Mesic Coastal Plain Oak Forest	99.0 (40.0)
Mid-Atlantic Maritime Salt Shrub	7.2 (2.9)
Overwash Dune	4.2 (1.7)
Successional Maritime Forest	71.3 (28.8)
Successional Sweetgum Forest	9.4 (3.8)
Open Water	476.7 (192.9)
Natural Community Total	**1,681.8 (680.6)**
Anthropogenic Community	
Agricultural Field	221.8 (89.8)
Northeastern Successional Shrubland	82.2 (33.2)
Open Lawn	0.2 (0.1)
Road	11.5 (4.6)
Anthropogenic Community Total	**315.7 (127.7)**
UNIT II Total	**1,997.5 (808.3)**

UNIT III (HMP Maps 5 and 6)

Management Unit III is bounded by Prime Hook Beach Road on the north, Route 16 (Broadkill Beach Road) on the south, upland edge on the western boundary, and the Prime Hook and Broadkill Beach developments immediately adjacent to the refuge's eastern boundary.

Hydrology

Unit III consists of roughly 4,400 acres which includes upland forest, impounded emergent marsh, Red Maple-Seaside Alder Swamp, low lying farmed areas, brush, barrier beach on the east, and 140 acres of flowage easement (Tract Nos. 84R, 99F & 99i) on the southeastern boundary of Unit III. This flowage easement drains directly into Prime Hook Creek and flows south to the water control structure of this watercourse. A large portion of Unit III is managed as a freshwater impoundment, however culverts under Prime Hook Rd. bring brackish and saline water in from Unit II, where breaches have restored full tidal flow.

Over the last 2,000 years, sedimentation filled a lagoonal area producing the refuge's marsh (Hoyte 1980). Hoyte extracted nine stratigraphic cores on PHNWR along the Slaughter and Prime Hook Creeks (Units II and III) and has suggested that lagoons behind barrier beaches changed from fresh water over the past 500 years to more saline influences. About 150 years ago, Unit III was a tidal marsh system with several small creeks and abundant potholes where Prime Hook Creek and Deep Hole Creek drained directly into the Delaware Bay (1.5 miles north of current Prime Hook Creek water control structure) (USFWS 1982).

Soils and Topography

Most of the wetlands in Unit III are relatively flat and lie below the 4 foot contour with a few islands rising above 4 foot (between 5 and 9 foot contour). These islands include Tea Cup Island, east of the headquarters ditch, Hay Hummock, south of Prime Hook Road and Bleacher's Island just west of the Prime Hook Creek water control structure. Prime Hook Creek and Petersfield Ditch are the principal water courses in Unit III. The majority of Unit III falls above 2.2 feet {mean sea level (msl)}which is the normal tidal range for the area and is flooded only when the tide is above normal (Spring tides plus storm surges).

The predominant soil types in Unit III are Transquaking and Mispillion soils (TP) and Broadkill mucky peat (Br), both characterized by having large quantities of organic matter on 2,500 acres of impounded wetlands. Soft sediments reach to about 30 feet below the marsh surface. Adjacent upland soils are non-plastic to slightly plastic sandy soil derived from fluvial deposits of the Pleistocene (Matthews and Ireland 1974). The other major soil types found in the Unit III Prime Hook Creek drainage basin include Rosedale loamy sand, Lenape mucky peat, Pineyneck loam (PyA), Carmichael loam (CaA), Hurlock loamy sand (HuA), and Henlopen-Rosedale complex. Minor soil types found in Unit III include Askecksy loamy sand, Broadkiln-Appoquinimink complex, Downer loamy sand, Evesboro loamy sand, and Klej loamy sand.

Management History – Wetlands

A major storm in 1911 plugged and sealed the Deep Hole Creek and Prime Hook Creek outlets to the Delaware Bay. The closing of these 2 outlets drastically changed the daily tidal influence and hydrology of Unit III. Prime Hook Creek now flows through the Petersfield Ditch to ultimately empty into the Broadkill River, which drains into the Delaware Bay about 2 miles south of the present-day refuge. In the 1920s several attempts were made by landowners to create or block drainage within the Unit III area to provide water control. In the 1930s Unit III marshes were heavily grid ditched for mosquito control (USFWS 1982).

Historically, during the 1940s and 1950s, marsh management (e.g., hydrologic manipulation to maintain and/or alter vegetation) on Prime Hook's wetland habitats had been a controversial issue between those who wanted marshes for hunting and trapping and farmers who wanted to drain the upland edges surrounding these wetlands. In 1951, landowners and the UD Cooperative Extension Service unsuccessfully attempted to develop a plan for the management of Prime Hook marshes. Public Law 766 was enacted by Delaware in 1953 and prohibited the draining of Prime Hook Creek into the Delaware Bay between October 1 and March 10 of the succeeding year. This law was enacted for the benefit of the muskrat industry and permitted the blocking of any marsh draining. Several attempts were made afterwards to eliminate blockages including the use of dynamite by opposing landowners (USFWS 1982).

In the 1950s vegetation coverages in the area east of Petersfield Ditch at the lower end of Unit III consisted of salt hay (*Spartina patens)* and cordgrass *(S. alterniflora). Spartina* grasses were cut for hay and grazed by cattle through the late 1950s. The remainder of Unit III marsh, including much of the marsh west of the ditch was open water with cattail and pickerelweed as co-dominants. Brush was managed in drier areas by grazing and fire. Trees were mostly absent (USFWS 1982).

Phragmites was first observed along Prime Hook Road in Unit III also in the early 1950s and by 1965 it had spread south throughout the unit. Encouraged by drier conditions from mosquito ditching, draining, and excessive soil deposition, red maples began growing along Prime Hook creek, which was once a tidal emergent marsh. Just prior to Service acquisition, portions of the Unit III Prime Hook marshes were also managed by a system of water control structures and a pumping station in Unit III owned by Island Farm Corporation and King Cole, designed by the Soil Conservation Service to provide water for cattle (USFWS – 1982).

Between 1962 and 1968, all the outlets of Prime Hook Creek were permanently blocked either from severe storms or private landowner actions. These blockages severely hampered tidal flow, enhanced sediment deposition in Unit III marshes, and increased the elevation of these wetland habitats.

In 1963, the Service proposed a water management plan which outlined marsh management restoration needs for the entire refuge. It was designed to provide water for the Unit III marsh without backing up water against upland areas. As mentioned under Unit II, it was rejected, and a “No Management” policy was adopted by the Service. This management policy generated severe degradation of Unit III’s marshes, as environmental conditions proved detrimental to the quantity, quality, and productivity of Prime Hook’s wetland complex from the early 1960s to 1980 (USFWS 1982).

In 1968, a developer of Broadkill Beach had the Broadkill Sound excavated and ditched to drain 10.25 miles of marsh, one mile south of the current Prime Hook Creek water control structure. This action coupled with the retrogression of the blockages of Prime Hook Creek and Petersfield Ditch had continued to exacerbate cumulative negative impacts that contributed to a steady degradation of the Unit III marshes, hastening its drying out and causing considerable deterioration of wetland values. Severe droughts in 1977 and 1980 resulted in the complete desiccation of most potholes and water areas in the Unit III marsh. By 1984 much of Unit III became a *Phragmites* jungle. In addition to the loss of high quality marsh habitats, extreme fire hazards created by dense stands of *Phragmites,* threatened private property values adjacent to the refuge (USFWS 1982).

An Environmental Assessment for the Rehabilitation Management and maintenance of wetlands in Unit III was written in 1982 and by 1984 the water level management infrastructure to restore water level manipulation capability was in place. This infrastructure included a one mile dike east and west of the Petersfield water control structure, tying in the uplands areas to the structure and the construction of 2 large concrete structures, one spanning Petersfield Ditch (35 feet with 8 bays) and the second spanning Prime Hook Creek (20 feet long with 5 bays).

Although water level manipulation is still conducted, the vegetation, water levels, and salinity in Unit III have been influenced by the increased flow of brackish or saline water from Unit II through culverts under Prime Hook Rd., and over the road during storms and high tides.

Management History – Upland Fields 1978 – 2008 (HMP Maps 5 and 6):

- **Fields 301, 330, and 333:** tilled in corn/soybeans until 2006.
- **Field 334:** tilled until 1990; Maintained as early successional grassland w/some brush; mowed 2008.
- **Field 302: Pb-shot site:** cultivated for "goose browse" until 1987. Mowed until mid-1990s; Reverted to trees; Adjacent to private gun-club and current lead shot remediation area.
- **Fields 303-307:** cropped until 1986; Planted in 1987 to pasture mix and mowed annually until late 1990s, and currently reverting to shrubs/trees.
- **Fields 309-314:** cropped until 1987; crop yields poor, farmers gave up fields. Planted in crimson clover/barley mix and mowed annually until 2001, when planted to hardwoods.
- **Field 315:** Reverted to trees in 1970s; designated historic site.
- **Field 317:** Never tilled by USFWS; Used as grassland buffer but stopped mowing in 2000; currently reverting to dense sweetgums.
- **Field 318: c**ropped in corn and soybeans until 2006.
- **Field 319:** pasture only never cropped; a portion is designated historic site.
- **Fields 321 & 332: c**ropped until 2001-2004 part of R5 grassland study; Put back in corn and soybeans until 2006.
- **Fields 322 & 323:** cropped until 2006.
- **Fields 324 & 325:** cropped until 1982, dropped by farmer as too small in size; reverted to grasses and mowed annually until 2001 when it was planted to hardwoods.
- **Field 326:** cropped annually until 1998, too wet to till; planted in hardwoods in 2001.
- **Field 327:** "Cemetary field" tilled until 1983 then let revert to natural succession. Twice planted in trees with poor results.
- **Field 328:** tilled on and off until mid 1990s; planted in hardwoods in 2001.
- **Field 329:** never tilled, mowed as grassland until late 1990s; reverting to shrubs.
- **Fields 350-357:** newly acquired in 2001. Tilled in corn and soybeans until 2006.

Current Vegetation

Management Unit III is the largest of the Units and lies between Unit II and Unit IV. Like Unit II, it is a freshwater system and is non-tidal. It is 4,431.0 acres (1,793.1 ha) in size, of which 3,822.6 acres (1,546.9 ha) are natural communities and 608.4 (246.2 ha) are anthropogenic communities (Table 4 and HMP Maps 5 and 6). The Generic Marsh, which represents the refuge's impounded wetlands, is the largest cover type and an Overwash Dune at the north end of the Unit is the smallest.

Unit III is the most biologically and ecologically diverse of all the Units (Note: Generic marsh and open water roughly correspond to impounded wetland areas). Unit III supports three vegetation communities that are currently known in Delaware only from Prime Hook NWR. These include the Twig Rush Peat Mat, Pond Pine Woodland and Red Maple-Seaside Alder Woodland. Prime Hook Creek flowing east to west roughly divides this unit into a northern half and southern half. This unit contains the largest amount of anthropogenic communities at 608.4 acres (246.2 ha), which is more than the other three units combined.

Table 4. Acreage of Natural and Anthropogenic Communities in Management Unit III

NVCS - Natural Community	UNIT III acreage (ha)
Atlantic Coast Interdune Swale	15.8 (6.4)
Atlantic White Cedar-Seaside Alder Woodland	9.8 (4.0)
Brackish Tidal Creek Shrubland	1.3 (0.5)
Buttonbush Coastal Plain Pond	0.8 (0.3)
Coastal Loblolly Pine Forest	41.5 (16.8)
Coastal Loblolly Pine Wetland Forest	56.3 (22.8)
Coastal Plain Depression Swamp	248.7 (100.6)
Interdunal Switchgrass Brackish Depression	0.7 (0.3)
Loblolly Pine Plantation	10.6 (4.3)
Loblolly Pine-Sweetgum Semi-Natural Forest	39.0 (15.8)
Maritime Red Cedar Woodland	7.8 (3.2)
Marsh	1314.7 (532.0)
Mesic Coastal Plain Mixed Hardwood Forest	19.2 (7.8)
Mesic Coastal Plain Oak Forest	43.8 (17.7)
Mesic Rich Forest	24.5 (9.9)
Mid-Atlantic Maritime Salt Shrub	1.5 (0.6)
Overwash Dune	0.2 (0.1)
Peat Mat	9.0 (3.6)
Pond Pine Woodland	7.2 (2.9)
Red Maple-Seaside Alder Woodland	699.3 (283.0)
Reed Canarygrass Eastern Marsh	1.9 (0.7)
Southern Red Oak/Heath Forest	289.1 (117.0)
Successional Maritime Forest	90.6 (36.6)
Successional Sweetgum Forest	88.0 (35.6)
Swamp Cottonwood Coastal Plain Pond	1.5 (0.6)
Open Water	797.9 (322.7)
Water-willow Shrub Swamp	2.2 (0.9)
Natural Community Total	**3,822.6 (1,546.9)**
Anthropogenic Community	
Agricultural Field	507.1 (205.2)
Building	0.3 (0.1)
Northeastern Successional Shrubland	73.4 (29.7)
Open Lawn	5.0 (2.0)
Parking Lot	1.6 (0.6)
Road	21.0 (8.5)
Anthropogenic Community Total	**608.4 (246.2)**
UNIT III Total	**4,431.0 (1793.1)**

UNIT IV (HMP Map 7)

Management Unit IV is surrounded by Rt. 16 on the north, the Broadkill Beach community on the east, the Broadkill River on the south and west, and the upland edge on the west.

Hydrology

Tidal action occurs along the Broadkill River, whose salinity ranges from 10 to 30 ppt. The majority of the water for Unit IV is provided through the Broadkill River. Some tidal action and leakage of salt water into the Unit IV impoundment also occurs during peak tides from a ditch connected to the Broadkill Sound. Rainfall and excessive runoff from Unit III are other sources that provide fresh water. However, normal runoff and tidal action are not sufficient to recharge the impoundment above its perimeter elevation.

Soils and Topography

Unit IV topography is relatively flat with less than one percent slope. Much of the area lies below the three foot contour. Dominant soils found in this unit are Broadkill-Appoquinimink complex (Ba), Broadkill mucky peat (Br), Transquaking and Mispillion (TP), and Purnell mucky peat (Pu). The largest variation in Tidal marsh soil profiles is the depth to underlying material, which in most places is sandy. The depth ranges from 2 to 3 feet in some hummocks and near the boundaries with upland soils, to an undetermined depth in the interior of broad marsh areas. These areas where tidal fluctuations are great, the horizons are completely liquid. Other minor soil types found in upland habitats include Askecksy loamy sand (AsA), Fallsington sandy loam (FaA), Hammonton loamy sand (HmA) and sandy loam (HnA), Hurlock sandy loam (HvA), and Rosedale loamy sand (RoB).

Management History – Wetlands

Prior to Service ownership, this marsh had been excessively drained by man-made ditches. When the refuge was established, about 1,000 acres of tidal salt marsh surrounded about 150 acres of farm fields. Before 1963, private owners maintained pumping stations for ponds in Units III and IV for cattle and to manage waterfowl and muskrats. Much of the marsh was grid ditched for mosquito control.

The vegetation was predominantly salt marsh cordgrass (*Spartina alterniflora*) and salt hay (*S. patens*) with several patches of high-tide bush (*Iva frutescens*). Unit IV was continually grazed by cattle on the Island Farm which was operated as a large cattle feed-lot operation from the early 1950s up to refuge establishment. Cattle continued to graze in Unit IV until the early 1970s.

In 1980, an Environmental Assessment was written to rehabilitate 200 acres of Unit IV's brackish marsh with the construction of water control structures. Two concrete control structures with logs on the impoundment side and flap gates on the tidal side were installed in 1982 to impound this wetland (Vergie's Pond). By 2003 these structures were seriously deteriorated and were subsequently replaced in 2005 in order to maintain water level management capability in this unit.

Management History – Upland Fields 1978 – 2008 (HMP Map 7):

- **Field 401:** cropped until 1982; maintained as grassland (mowed annually) to 2008.
- **Fields 402-405 & 409:** cropped until 1999; ceased farming due to salt water encroachment; mowed every other year.
- **Field 406:** never cropped, only maintained as grassland.
- **Field 407:** maintained as grasslands until 1985; cropped in corn and soybeans until 1996; currently, has reverted to grassland with some brush encroachment.
- **Field 408:** never cropped only maintained in grassland/brush.

- **Field 410:** never cropped; last area used by Henslow's sparrow in 1970s; maintained as grassland in early 1960s and 1970s; brush encroachment treated with hydroaxe in 1990s to re-establish switchgrass community.
- **Field 411:** never cropped; maintained as grassland.

Current Vegetation

Management Unit IV is the southernmost management unit and is the smallest of all the units with a total area of 1,176.4 acres (476.0 ha), of which 1,111 acres (449.6 ha) are natural communities and 65.3 acres (26.4 ha) are anthropogenic communities (Table 5 and HMP Map 7). Unit IV receives tidal and brackish input from the Broadkill River and as a result, the largest natural community in Unit IV is the *Spartina* low salt marsh. The smallest natural community is an Interdunal Switchgrass Brackish Depression. A Coastal Bay Shore/Succulent Beach is located within the impounded portion of Unit IV and is covered under the general Marsh category. Unit IV is the only known location for this community in Delaware.

Table 5. Acreage of Natural and Anthropogenic Communities in Management Unit IV

NVCS - Natural Community	Unit IV acreage (ha)
Atlantic Coast Interdune Swale	30.5 (12.3)
Brackish Tidal Creek Shrubland	17.7 (7.1)
Coastal Loblolly Pine Forest	9.7 (3.9)
Interdunal Switchgrass Brackish Depression	5.7 (2.3)
Maritime Red Cedar Woodland	66.2 (26.8)
Marsh	4.1 (1.6)
Mid-Atlantic Maritime Salt Shrub	40.4 (16.3)
Spartina High Salt Marsh	7.8 (3.1)
Spartina Low Salt Marsh	774.8 (313.5)
Successional Maritime Forest	22.0 (8.9)
Water	132.2 (53.5)
Natural Community Total	**1,111.1 (449.6)**
Anthropogenic Community	
Building	0.2 (0.1)
Northeastern Successional Shrubland	58.7 (23.7)
Road	6.4 (2.6)
Anthropogenic Community Total	**65.3 (26.4)**
Unit IV Total	**1,176.4 (476.0)**

2.3 Physical and Geographic Setting

Climatic Influences

Delaware's climate is generally mild, continental weather moderated by the effects of the Atlantic Ocean in general, so periods of sustained hot or cold temperatures are typically brief. Extreme temperatures are moderated by the Delaware Bay, the Atlantic Ocean and the Chesapeake Bay. On refuge, weather conditions are mild year round with temperatures ranging from 32° F for an average low and 80° F for an average high. Normally summer ocean breezes keep the Refuge cooler than inland areas and most winter days are mildly attenuated by the same breezes.

Yearly and seasonal precipitation is highly variable. Average annual refuge rainfall is 41.98 inches. Snowfall is usually light, averaging 10 to 15 inches per year. Prevailing winds from March through October are from the northwest except during summer months when they become more southerly. Prevailing winds from November through February are northeast. Average annual wind speed is about 9 mph, but winds can reach 50 to 60 miles per hour or higher during summer thunderstorms, hurricanes or intense winter northeasters. These climatic conditions correspond to USDA Plant Hardiness Zone (7a). Native plant and ecological restoration biologists refer to the USDA zones for guidance in selecting appropriate species and planting times.

The entire refuge lies within Delaware's Coastal Zone and is subject to periodic flooding by coastal storms. Most of the Refuge lies within the 100 year floodplain. The March storm of 1962 inundated 90% of the current refuge lands. When PHNWR is subjected to intense winter storms with strong sustained winds and high tides, this leads to extreme flooding of impoundments with saline Delaware Bay waters and severe erosion of dunes and impoundment dikes, resulting in heavy salt water intrusion of freshwater wetlands and adjacent upland habitats. This occurred on the winter of 1998 from a severe Nor'easter, and again in 2006 from Hurricane Ernesto, and 2008 from another Nor'easter on May 11th.

Delaware's Landscape Ecology

The state of Delaware occupies approximately 1.3 million acres along the mid-Atlantic coast. Despite its small size, the state possesses a diversity of flora and fauna since it spans 2 physiographic provinces. More than 1,000 species of wildlife are known to presently occur or have occurred in the past with approximately 125 different types of vegetative communities recently mapped in the Delaware Wildlife Action Plan (2005).

The Delaware Natural Heritage Program, tracks rare species distribution and abundance using the methodologies of the international network of Natural Heritage Programs. This methodology allows for comparison of species status across all taxa, and for this reason was chosen by the State of Delaware as the foundation for determining Species of Greatest Conservation Need (SGCN) in Delaware's Wildlife Action Plan. The state plan identifies 457 species of greatest conservation need associated with 50 different habitats required to support rare flora and fauna (DNREC 2005).

Floristically, Delaware lies within the transition zone, in which species of southern and northern affinities intermingle. This creates a unique biological interface of falling on the southern end of the most northern ranges of species and also at the most northern end of the southern ranges of flora and fauna, a situation that serves to heighten its biological diversity. Avian diversity also derives from the state's location on the Delaware Bay, adjacent to the Atlantic Ocean and its strategic placement along a major migration route on the Atlantic Flyway.

Wetlands Past and Present

Coastal wetlands found on the refuge are comprised of three wetland classifications as defined by NWI, these are; estuarine emergent, estuarine scrub-shrub, and intertidal flats. Estuarine wetlands represent about one-third of Delaware's marsh habitats with palustrine wetlands encompassing the remaining marsh habitats. About 75% of Delaware's vegetated wetlands are emergent or forested types. Ninety-eight percent of the state's wetlands occur in the coastal plain (Tiner 2001). More than 45,000 acres of the state's tidal wetlands were grid-ditched for mosquito control by the Civilian Conservation Corps in the 1930s (Whitman & Cole 1986).

During the past 300 years, Delaware has lost about 55% of its original wetland acreage. Channelization and drainage still pose serious problems for palustrine wetlands; large-scale drainage ditches are still constructed, lowering water tables. Restoration efforts are needed to improve water quality and function of these damaged wetlands and to re-establish the functions of lost wetland areas (Tiner 2001).

Open water environments account for approximately 4% of Delaware's cover-types. The state contains about 843 miles of perennial streams and creeks forming several drainage sub-basins that are distinctly different according to geographic location. Piedmont streams are exclusively freshwater with steeper gradients and swifter flow than Coastal Plain waterways. However, in estuarine creeks powerful currents can be generated by tidal flow and salinity varies seasonally with distance from the ocean or Delaware Bay. More than 1,000 acres have been classified as deepwater habitats (water depths > 6.6 feet) in Delaware (Tiner-1985).

Many small coastal plain streams in Sussex County have been channelized for drainage through a state "tax-ditch" system. Delaware Code Title 7, Chapter 41, provides the basis for a uniform system for establishing, financing, administering, maintaining, and dissolving tax ditch organizations in Delaware, under the supervision of DNREC. Currently more than 2,000 miles of channels in Delaware are managed by 228 tax ditches and political state subdivisions that have maintenance taxing authority. Tax ditch channels range in size from 6 to 80 feet wide and 2 to 4 feet deep. The dimensions depend upon the acreage being drained and the local topography (State of Delaware-1998). It has been estimated that 13% of the state's palustrine forested wetlands (mostly in Kent and Sussex Counties), continue to be drained by these tax ditches (Tiner-1985). Two tax ditches occur on the Refuge, Draper-Bennett Tax Ditch in Unit I and Naylor-Wells Tax Ditch in Unit III.

Prior to European settlement virtually all of Delaware's upland areas were forested. Transitional habitats representing small blocks of early successional grassland openings and thickets were more prevalent than today likely due to Native American set fires to maintain open areas for hunting (Tetra Tech 2004).

Agricultural and urban development have eliminated much of the forests of Delaware. By 1950 agricultural lands accounted for 904,000 acres of the state's 1,251,000 total acres. This had dropped to 600,000 acres by 2000, lost to commercial and residential development. Today, forested cover types have dropped significantly with the greatest losses occurring in Sussex County, leaving less than 150,000 acres remaining throughout the state. Continuing forest losses, forest fragmentation and clear cutting throughout Delaware have resulted in a loss of over 85% of forested habitats (ELI-1999 & DE Office of Planning 2005).

Delaware Natural Heritage Program (DNHP) data lists over 2,200 plant species, varieties, and hybrids of native (1,590) and non-native (610) vascular plants known to occur in Delaware. The overall flora is represented by 173 families and 770 genera. A full synopsis of the flora of Delaware is provided in "*The Flora of Delaware: An Annotated Checklist*" (McAvoy & Bennett -2001).

Species rarity on a local, regional, and global level as assessed by the DNHP is primarily a function of habitat loss. Habitat losses within the Delaware landscape have been due to the conversion of natural habitats to agriculture, commercial and residential development, and from draining and filling wetlands. Over 40% of the known native flora (620 taxa) are classified as species of Conservation Concern and are in need of some level of proactive protection (DNREC 2005).

Seventy-seven plant species are known from only a single population in Delaware; 171 species have not been reported in the state for 15 years or more (historical), and 57 species are considered to be extirpated from the state. Fifteen percent of the known native flora of the state is either historical or extirpated. Seven species in Delaware are listed by USFWS as either threatened or endangered, and 36 species are considered globally threatened by The Nature Conservancy.

Of the 620 plant species of Conservation Concern, 585 native species of plants are restricted to the Coastal Plain physiographic province. Forty-five percent of all rare plants in Delaware are found in freshwater non-tidal wetland habitats (or 266 species). Non-tidal freshwater wetlands in Delaware are not protected by the state. By comparison, 55 native species of Conservation Concern are found in tidal (fresh and saline) wetlands or 8% of all rare plants in the state. Tidal wetlands are state protected. There are 297 species of plants that occur in upland habitats (forests, forest canopy gaps, early successional habitats and coastal dunes) that are of Conservation Concern in Delaware. Natural upland habitats have been identified as rare key wildlife habitats in Delaware's 2005 Wildlife Action Plan. These habitats in Delaware have no regulatory protection (DNREC 2005).

2.4 Current Refuge Condition

In this section we have identified individual plant and community types, vegetative composition, invasive species, contaminant problems and other current conditions that affect habitat management. We have also identified existing rare floral and faunal species, declining, or unique natural communities, and species within the Refuge's boundaries. These species along with the focal species identified in Chapter 2 of the CCP are important to the management of biological integrity, diversity, and environmental health of the Refuge habitats.

Plant Communities at Prime Hook NWR

Thirty four natural vegetation communities were mapped on PHNWR by the Delaware Natural Heritage Program (DNHP) in 2005 and 2006. It should be noted that, as a result of the recent shoreline changes in Unit II (overwashes, inlets), these vegetation communities have been changing in composition and in size. With many of these areas in transition, the exact nature and extent of these changes are not known. Thus, we recognize that the vegetation map information is already outdated for portions of our managed wetland impoundments that have been affected by recent coastline changes. However, the vegetation map is still useful for much of the refuge uplands, and serves as a baseline summary of vegetation conditions. At the time of the mapping, the Spartina low marsh (1,685 acres) was the largest association and the Button Bush Coastal Plain Pond was the smallest (1 acres). Four associations (*) were identified on the Refuge that are unique in Delaware and found nowhere else in the state. These include the Red Maple/Seaside Alder (799 acres), Pond Pine Woodland (8 acres), Coastal Bay Shore/Succulent Beach (150 acres) and Twig Rush Peat Mat (10 acres) associations (See Table 6 and HMP Map 2). As of the preparation of this HMP, the vegetation map for the refuge is being updated by DNHP to reflect the changes in recent years, which will serve as a new baseline to track vegetation community changes as a result of future management and restoration.

Table 6. Habitat Types by Acres and NVCS Common Names on PHNWR in 2005-2006

HABITAT TYPE	ACRES	NVCS Association Common Names
Overwash Dune	17	Salt Meadow Cordgrass, Common Threesquare, Seaside Goldenrod (G2G3) (Habitat of State Conservation Concern)
Beachgrass/Panicgrass Dune Grassland	35	American Beachgrass, Bitter Panicgrass (G2) (Habitat of State Conservation Concern)
Atlantic Coast Interdunal Swale & Depression	74	Wax-Myrtle, Salt Meadow Cordgrass, Panicgrass Shrubland (G3) (Habitat of State Conservation Concern)
Mid-Atlantic Maritime Salt Shrub	60	Groundsel, Maritime Marsh Elder, Salt Meadow Cordgrass (Habitat of State Conservation Concern)
Maritime Red Cedar Woodland	76	Eastern Red Cedar, Northern Bayberry Woodland (G2) (Habitat of State Conservation Concern)
Southern Red Oak/Heath Forest	289	White Oak, Southern Red Oak, Dangleberry
Mesic Coastal Plain Oak Forest	193	Southern Red Oak, Willow Oak, American Holly

HABITAT TYPE	ACRES	NVCS Association Common Names
Successional Sweetgum Forest	180	Sweetgum, Loblolly Pine, Red Maple
Coastal Loblolly Pine Forest	51	Loblolly Pine, Wax-myrtle, Royal Fern
Mesic Coastal Plain Rich Forest	19	Tuliptree, Red Oak, Green Ash, Bellwort (Habitat of State Conservation Concern)
Mesic Coastal Plain Mixed Hardwood Forest	19	American Beech, Red & White Oak, Tuliptree, Christmas Fern
Pond Pine Woodland*	8	Pond Pine, Sweetbay, Highbush Blueberry, Atlantic Sedge (Habitat of State Conservation Concern)
Red Maple-Seaside Alder Swamp*	799	Red Maple, Seaside Alder Saturated Woodland (S1) (Habitat of State Conservation Concern)
Waterwillow Shrub Swamp	2	
Coastal Plain Depression Swamp	335	Sweetgum, Red Maple, Willow Oak, Fetterbush Flooded Forest (Habitat of State Conservation Concern)
Buttonbush Coastal Plain Pond	1	Buttonbush/Swamp Smartweed/Warty Panicgrass Shrubland (Habitat of State Conservation Concern)
Coastal Loblolly Pine Wetland Forest	91	Loblolly pine, Southern Bayberry, Royal Fern Saturated Forest
Atlantic White Cedar swamp	10	Atlantic White Cedar, Seaside Alder Seasonally Flooded Woodland
Cottonwood Coastal Plain Pond	2	Swamp Cottonwood, Red Maple, Pin Oak, Sweetgum (Habitat of State Conservation Concern)
Coastal Bay Shore/Succulent Beach*	150	
Impounded Freshwater/Brackish Wetlands ➔ Generic Marsh = 2946 Water = 1554	4,500	(1/3 Perennial Vegetation) Wild Rice Marsh, Narrow-Leaf Cattail, Rosemallow Marsh, Fall Panicum, Olney Three-Square Marsh, Pond Lily Marsh, Cattail, Bulrush Marsh (2/3 Annual Moist Soil Veg) Sea Purslane, Spearscale Marsh (Habitat of State Conservation Concern)
Peat Bog Community*	10	Twig Rush, Ten-Angle Pipewort, Tawny Cotton Grass (S1) (Habitat of State Conservation Concern)
Salt Marsh	2,200	*Spartina* Low Salt Marsh, Salt Panne, *Spartina* High Salt Marsh, Bayberry-Salt Meadow Cordgrass (Habitat of State Conservation Concern)

Refuge plant surveys conducted in 2004 and 2005 by Delaware Natural Heritage Botanists provided data on habitat conditions and species composition at that time. The flora of PHNWR is represented by 100 families and 247 genera (See Appendix E of the CCP). The largest families are the sedge family (Cyperaceae) with 60 taxa and 11 genera, followed by the aster family (Asteraceae) with 57 taxa and 34 genera, and the grass family (Poaceae) with 45 taxa and 30 genera. The largest genera include: *Carex* (28 taxa), *Quercus* (9 taxa), *Eleocharis* (8 taxa), *Polygonum* (8 taxa), *Bidens* (7 taxa), *Eupatorium* (7 taxa), *Juncus* (7 taxa), *Asclepias* (6 taxa), *Cyperus* (6 taxa), and *Rhynchospora* (6 taxa).

The majority of Refuge plants are perennial broad-leaf herbs with 131 taxa, followed by annual broad-leaf herbs with 58 taxa. Graminoids (grasses, sedges, and rushes) are a large component of the Refuge's flora, equaling 112 taxa, (45 taxa of grasses, 60 taxa of sedges, and 7 taxa of rushes). Trees and shrubs are also very prominent in the flora, with 29 taxa of deciduous trees, 6 taxa of evergreen trees, 32 taxa of deciduous shrubs, and 5 taxa of evergreen shrubs.

True ferns [e.g., cinnamon fern (*Osmunda)*] and their relatives [e.g., tree club-moss (*Lycopodium*)] form a unique assemblage of the flora with 16 taxa. Most of the Refuge's flora is wetland plants (wetland indicator status of facultative-wet and obligate) represented by 236 taxa, compared to 189 that occur either occasionally in wetlands, or never occur in wetlands. The majority of the flora on the refuge has southern affinities with 104 taxa having a more southern natural geographic distribution. By comparison

47 taxa have a more northern natural geographic distribution. Documented rare plants included 42 species (7-S1, 20-S2, and 17-S3).

Rare Plants and Exemplary Communities

Exemplary natural communities are those that have been minimally impacted by humans and contain an exceptional diversity or unique rare plant species. The most significant community found on the Refuge was the Twig Rush Peat Mat. These sites (6 were mapped by McAvoy and Coxe 2007) support many state rare plant species and occur in open water within a shrub-dominated swamp matrix. This unique habitat develops on deep, mucky, peat that appears to float (true "quaking bog"). Of the six quaking bogs inventoried and mapped, the most exemplary was the **"**Prime Hook Bog**,"** described below.

The "Prime Hook Bog" is about 1.5 acres in size and is floristically diverse with 66 species and varieties documented. Twig rush sedge (*Cladium mariscoides)* is the dominant herb with many rare plants (See Table 7) including several insectivorous plants like purple pitcher-plants, round-leaf sundew, fibrous bladderwort, and southern bladderwort. In addition, a subspecies new to the flora of the State of Delaware and the Delmarva Peninsula was discovered here: the bushy bluestem (*Andropogon glomeratus* var. *hirsutior.*

Table 7. State-rare plants associated with the NVCS - Twig Rush Peat Mat Community on Prime Hook National Wildlife Refuge

SCIENTIFIC NAME	COMMON NAME	STATE RANK
Alnus maritima	Delmarva alder	S3
Andropogon glomeratus var. *hirsutior*	bushy bluestem	S1
Bartonia paniculata	twining bartonia	S2
Bidens coronata	tickseed sunflower	S3
Bidens mitis	small-fruit beggar-ticks	S2
Cyperus diandrus	Umbrella flatsedge	S1
Drosera rotundifolia	round-leaf sundew	S2
Eleocharis robbinsii	Robbins spike-rush	S3
Eriocaulon decangulare	ten-angle pipewort	S1
Eriophorum virginicum	tawny cotton-grass sedge	S1
Eriocaulon parkeri	Parker's pipewort	S2
Fuirena squarrosa	hairy umbrella-sedge	S2
Fuirena pumila	Dwarf umbrella sedge	S3
Juncus pelocarpus	brown-fruited rush	S2
Lycopus amplectens	sessile-leaved bugleweed	S2
Pogonia ophioglossoides	rose pogonia	S2
Rhynchospora alba	white beakrush	S2
Rhynchospora scirpoides	Long-beaked beakrush	S2
Sagittaria engelmanniana	Engelmann's arrowhead	S2
Sagittaria graminea	Grass-leaf arrowhead	S2
Sarracenia purpurea	purple pitcher-plant	S2
Spiranthes cernua	nodding ladies'-tresses	S3
Utricularia fibrosa	fibrous bladderwort	S2
Utricularia juncea	southern bladderwort	S2

In addition to rare vascular plant data, exceptionally large individual tree species (relative to PHNWR and the state of Delaware) were measured and recorded. One willow oak measured 53" diameter at breast height (dbh) with several other willow oaks in the 40" dbh range.

Nonvascular plants are the simplest of all land dwelling plants. Like their closest ancestors, the green algae, they lack an internal means of water transportation. They do not produce seeds or flowers. They generally only reach a height of one to two centimeters, because they lack the woody tissue (xylem and phloem) necessary for support on land. Because of their sensitivity to the environment around them, they can be useful indicators of environmental conditions as they are particularly susceptible to air and water pollution. They also serve as food for small animals and insects. Non-vascular plants grow from spores. Non-vascular plants include two distintly related groups Bryophytes and Algae Bryophytes include the Bryophyta (mosses), the Marchantiophyta (liverworts), and the Anthocerotophyta (hornworts). A number of mosses and liverworts were documented in various habitats on the refuge by DNHP (Table 8).

Table 8. Nonvascular plants documented on Prime Hook National Wildlife Refuge

HABITAT (Refuge Unit)	SCIENTIFIC NAME (substrate)	TYPE
Southern Red Oak Heath Forest (Unit III)	*Amblystegium serpens* (bark)	moss
	Capylium hispidulum (base of tree)	moss
	Coloejeunea biddlecomiae (bark)	liverwort
	Dicranum condensatum (soil)	moss
	Orthotrichum stellatum (bark)	moss
	Pylaisella selwynii (bark)	moss
	Tortella humilis (base of tree)	moss
Coastal Loblolly Pine Wetland Forest (Units I and II)	*Aulacomnium palustre*	moss
	Climacium americanum	moss
	Dicranum flagellare	moss
	Hypnum imponens	moss
	Isopterygium tenerum	moss
	Leucobryum albidum	moss
	Plagiothecium denticulatum	moss
	Thuidium delicatulum	moss
	Cephalozia connivens	liverwort
	C. lunilifolia	liverwort
	Cephaloziella rubella	liverwort
	Leucolejeunea clypeata	liverwort
	Lophocolea heterophylla	liverwort
	Nowellia curvifolia	liverwort
	Odontoschisma prostratum	liverwort
	Pallavacinia lyellii	liverwort
	Sphagnum cuspidatum	peat moss
	S. palustre	peat moss

HABITAT (Refuge Unit)	SCIENTIFIC NAME (substrate)	TYPE
Twig Rush Peat Mat (Unit III)	*Sphagnum fimbriatum*	peat moss
	S. recurvum	peat moss
	S. perichaetile	peat moss
Early Successional / Open Field Habitats	*Riccia hueberneriana* subsp. *Sullivanti*	liverwort
	R. hirta	liverwort
	Notothylus orbicularis	hornwort

Rare Fauna

Zoological surveys were undertaken for reptiles, amphibians, and state-rare insects in 2004-2005 as part of the Refuge's CCP pre-planning baseline data inventory efforts. For insects, inventories focused on species of conservation concern (DNHP ranks: S1, S2, & SH) for which information regarding status (local, regional, global) were available. This included dragonflies and damselflies (Odonata), fireflies (Coleoptera: Lampyridae), tiger beetles (Coleoptera: Carabidae), moths and butterflies (Lepidoptera), and wasp species (Hymenoptera). Other species reported included undescribed species, new county and state records. Rare fauna documented on the refuge are summarized in Table 9.

Table 9. Rare fauna documented on Prime Hook National Wildlife Refuge

SPECIES GROUP	COMMON NAME	SCIENTIFIC NAME	STATE RANK	ASSOCIATED HABITAT(S)
Amphibians	Carpenter Frog	*Rana virgatipes*	S1	Coastal Plain Depression Swamp; Coastal Loblolly Pine Wetland Forest; Red Maple-Seaside Alder Woodland; Atlantic White Cedar-Seaside Alder Woodland
	Cope's Gray Treefrog	*Hyla chrysoscelis*	S1	
Reptiles	Ribbon Snake	*Thamnophis sauritus*	S2	
	Rough Green Snake	*Opheodrys aestivus*	S2	
Odonata	Elfin Skimmer	*Nannothemis bella*	S1	Twig rush peat mat; Impounded Freshwater Marsh
	Sphagnum Sprite	*Nehalennia gracilis*	S1	
	Lilypad Forktail	*Ischnura kellicotti*	S1	
Hemiptera: Delphacidae (Planthoppers)	Unnamed –Species is new to science	*Megamelus sp*		Twig rush peat mat
Coleoptera: Carabidae	Beach Dune Tiger Beetle	*Cicindela hirticollis*	S1	Beachgrass-panicgrass dune grassland; Overwash dune grassland
Lampyridae (Fireflies)		*Photuris pensylvanica*	S2	Twig rush peat mat; Red maple-seaside alder woodland; Impounded marsh
		P. tremulans	S2	
		P. pyralomimus		
		P. frontalis	S1	
Cerambycidae: (Long-horned Beetles)		*Prionus laticollis*	County Record	Southern red oak heath forest

SPECIES GROUP	COMMON NAME	SCIENTIFIC NAME	STATE RANK	ASSOCIATED HABITAT(S)
Lepidoptera (Butterflies and Skippers)	Great Purple Hairstreak	*Altides halesus*	S1	Red Maple Seaside Alder Swamp
	Southern Broken Dash	*Wallengrenai otho*	S1	Maritime Red Cedar Woodland
	Little Glassy Wing	*Pompeius verna*	SU	
	Delaware Skipper	*Anatrytone logan*	SU	Coastal Plain Depressions; Coastal Loblolly Pine Wetland Forest; Maritime Red Cedar Woodland
Moths	Hydrangia sphinx	*Darapsa versicolor*	S1	Red maple-seaside alder woodland
	Graphic Moth	*Drasteria graphica*	S1	Maritime Red Cedar Woodland (host plant = *Hudsonia tomentosa)*
	Blueberry Dart	*Xestia youngii*	S1	Twig rush peat mat
	Pitcher Plant Borer Moth	*Exyra fax*	S1	
	Maritime Sunflower Borer Moth	*Papaipema maritima*	S1	Early successional grassland; Successional maritime forest
	Little Wife Underwing	*Catocala muliercula*	State Record	All communities with significant component of southern bayberry (*Morella cerifera)*
	Marbled Underwing	*Catocala amrmorata*	S1	Southern red oak-heath forest
	Tearful Underwing	*Catocala lacrymosa*	S1	
	Praeclara underwing	*Catocala praeclara*	S1	Coastal Plain depression swamp; Coastal loblolly pine wetland forest; Red maple/seaside alder woodland
	Noctuid Moths	*Zale metatoides & Z. metata*	S2	Coastal loblolly pine forest; Pond pine woodland

Invasive Plants

Of the 429 plant taxa listed in Appendix E of the CCP, 46 are non-native of which eleven are considered to be invasive. Some of these invasive include spotted knapweed (*Centaurea bieberstei)*, Canada thistle (*Cirsium arvense*), Japanese honeysuckle (*Lonicera japonica),* water-willow (*Ludwigia leptocarpa)*, Japanese stilt-grass *(Microstegium vimineum),* reed canary grass (*Phalaris arundinacea)*, alien common reed (*Phragmites australis* subsp. *Australis*), multi-flora rose (*Rosa multiflora*), porcelainberry (*Ampelopsis brevipeduncaulata)*, autumn olive (*Elaeagnus umbellate)*, and kudzu (*Pueraria Montana)*.

Spotted knapweed and Canada thistle are restricted to roadside areas, fallow agricultural fields, edges of hedgerows, and early successional fields throughout the Refuge. Japanese honeysuckle is ubiquitous throughout the Refuge mostly in wooded habitats. Water-willow, which is adventive in Delaware (native further south), may dominate about 100 to 150 acres of impounded marsh in Unit III, depending upon annual water regimes that may promote germination of this annual species. Japanese stilt grass (about

50 acres) is mostly found on Oak Island, where it dominates the herbaceous layer. All invasive plants are scattered throughout the refuge.

Reed canary grass, another invasive species in Delaware dominates an old field habitat in Unit III (corners of Field # 328). This is the same location where the state-rare plant lance-leaf orange milkweed (*Asclepis lanceolata)* grows. The lance-leaf orange milkweed is abundant here and is the largest known population in the state (100+ individuals), where current annual mowing late in the growing season appears to be favoring this milkweed species by suppressing woody vegetation. Multi-flora rose is widespread throughout the Refuge, growing in scattered areas within hedgerows, thickets, early successional fields, and woodland edges.

Pollutants and Contaminants

The Clean Water Act (CWA-33USC 251) is the cornerstone of surface water quality protection of aquatic habitats and has established WQS (Water Quality Standards) for individual states in the US. If water bodies are designated as “impaired” by not meeting WQS, the most common state strategy is the development of a Total Maximum Daily Load (TMDLs) for a non-compliant watershed. TMDLs determine what level of pollutant load would be consistent with meeting WQS by allocating acceptable loads among sources of relevant pollutants.

State-wide water quality assessments performed by DNREC has shown that more than 90% of Delaware’s waterways are “impaired.” Impaired waters are deemed polluted waters suffering from excess nutrients, low dissolved oxygen, toxins, bacteria, or any combination of these problems. Delaware has 41 designated watershed boundaries and most of Prime Hook NWR is located within the Broadkill River Watershed which is approximately 69,000 acres in size.

The Broadkill River and its tributaries and ponds adjacent to the Refuge are impaired by high levels of bacteria and elevated levels of nitrogen and phosphorus as determined by state monitoring efforts (Broadkill Watershed Assessment-DNREC 2000). There has been a significant decrease in wetlands and forests over time as these natural filters have been converted to other uses and the area develops into a more urban/suburban watershed. A pollution control plan (Jan 2008) has established TMDLs for the Broadkill River Watershed requiring a 40% reduction in non-point source nitrogen load, 40% reduction in non-point source phosphorus load, and 75% reduction in non-point source enterococcus bacteria, relative to 2002-2003 DNREC baseline data. The Refuge partnered in developing strategies to abate Broadkill River Watershed pollution and on-going watershed water quality sampling includes sampling points both on and near the Refuge.

Sussex County’s extensive poultry industry produces over 600 million chickens and 1.6 billion pounds of manure annually (USDA 1997). In addition to nitrate and phosphate overloads that create hyper-eutrophication of adjacent waterways, poultry litter contains feed additives such as trace metals, antibiotics, and hormones. Excessive land application of poultry litter has resulted in severe water quality problems in surface and groundwater contamination in the Delmarva area (McGee et al 2003). Greater quantities of animal feed additives used in the poultry industry include metals such as arsenic, selenium, zinc copper and antibiotics. The majority of these additives are excreted and found at elevated concentrations in manure. Studies have indicated that these environmental contaminants are migrating to nearby surface waters (Miller et al 2000).

Due to the high density and intensity of agricultural operations and documented water quality problems throughout the peninsula, it seemed highly likely that contaminants associated with AFOs would represent a threat to Refuge ecological resources. This was the incentive to conduct a two-year investigation on Prime Hook NWR in Delaware and Blackwater NWR in Maryland, conducted by contaminant biologists of the Chesapeake Bay Field Office (CBFO), "*Evaluating the Potential Water Quality Impacts of Animal Feeding Operations on National Wildlife Refuges on the Delmarva Peninsula.*" The purpose of the study was to assess water quality impacts on these two Refuges associated with AFOs by evaluating chemical and biological conditions impacted by animal feed additives and other "nontraditional" contaminants. Based on sampling results, PHNWR was the refuge with greater water quality problems associated with AFOs (McGee et al 2003).

Study results provided direct evidence of transport of tetracycline family of antibiotics and hormones from poultry litter applied to fields adjacent to refuge waterbodies on Prime Hook. Fish tissue data suggest that Refuge fish are being exposed to significant concentrations of estrogenic compounds from AFOs. Tissue data demonstrated that pesticides, hormones and high levels of antibiotics are significantly contaminating Refuge and Delmarva Peninsula waterbodies and that the negative impacts on fish and wildlife resources merits further investigation.

An unexpected result of the study was the finding that mercury contamination of piscivorous fish species from Refuge waterbodies of Slaughter Canal and Prime Hook Creek were at levels of human health concern. Refuge largemouth bass (LMB) exceeded EPA fish tissue residue criterion for mercury [Hg] in two waterways: Prime Hook Creek (0.54 ug/g) and Slaughter Creek (0.53-0.68 ug/g) {EPA Standard = 0.3ug/g}. Other contaminants of concern in Slaughter Creek included PCBs and Furan.

In 2006 the Refuge was included in the State of Delaware's "Toxics in Biota Monitoring Plan for FY 2006 and 2007. Further studies conducted by the state concluded that mercury is the primary risk driver for LMB in Prime Hook Creek and Waples Pond, and PCBs, Dioxin and Furans are the primary risk drivers in Slaughter Creek. In 2007 and 2008 these two waterbodies have been added to Delaware's Fish Consumption Advisories posted by DNREC annually in its State Fishing Guide.

For 37 years, The Broadkill Sportman's Club adjacent to the Refuge operated a trap-shooting range, located on the southwestern corner of the headwaters of Prime Hook Creek. Clay-target launchers were oriented so that expended lead shot dropped into a forested wetland and upland grassland area on Refuge lands. After many years of lead shot deposition, it was discovered that lead shot concentrations were as high as 57,868 pellets per square foot in some areas on Prime Hook National Wildlife Refuge.

The trap club was founded in 1962 on Pikes Neck, Sussex County. Service property boundaries surrounding the club were established in 1964. The club used five trap houses, each containing five shooting stations. Shotgun rounds were projected across a grassy field toward a wooded wetland intending to hit airborne clay targets above the field. Numerous lead shot pellets from misses and overshot trajectories often hit trees inside the Refuge boundary and falling to the ground, accumulating through the years.

The club was located in an upland area about 0.1 miles from the Refuge's Prime Hook Creek. The highest elevation of club lands is about 10 feet above sea level and most of the adjacent Refuge forested wetlands is 5 feet or less in elevation (Soeder & Miller 2003). The trap-shooting range was operated from 1962 to 1998, at which time a proposed land swap with the USFWS was initiated by the club.

Upon this request the Service initiated a Level One Contaminant Survey of Refuge lands. During August and October of 1998, CBFO Service personnel collected soil samples to determine the extent of lead concentrations in Refuge soils. Results showed significant lead contamination. The EPA and Service then ordered the club to discontinue depositing lead shot onto Refuge lands and in 2000 initiated a five-year clean-up project.

A preliminary assessment in 2000 determined that an affected area of 22 acres down-range of the club had accumulated most of the lead shotgun pellets with the highest densities concentrated in a designated “drop-zone” sized at 26,200 square feet. (Crowley & Richardson 2001). As part of an environmental risk assessment prepared by CBFO contaminant biologists, USGS investigated the potential for lead soaked soils to leach into the groundwater and minor tributaries feeding into Prime Hook Creek.

Study results verified that low pH ground water values probably from acid rain deposition helped to create exceedingly acidic environmental conditions responsible for dissolving lead carbonate off the pellets. Due to a lack of buffering capacity and adsorption sites in the silica-rich sediments of the area, the dissolved lead was then easily mobilized and moved into the groundwater on the Refuge.

The Service has physically excavated and removed part of the pellet-contaminated soils on Refuge property, which has since revegetated with native plants. The major source of groundwater contamination has been remediated on Refuge lands but not on club lands. The mitigation of high lead concentrations in Refuge ground water resources will require long-term monitoring to confirm the potential of natural attenuation of the system.

A Central Hazmat Fund Proposal submitted by CBFO contaminant biologists will provide long-term monitoring of the Refuge lead shot area, which included 5 wells sampled every three months for a two year period followed by every six months for an additional eight years. Using EPA and USGS methods for groundwater sampling, USFWS will obtain samples for analysis of total and dissolved arsenic, antimony and lead. Samples will be analyzed by Severn-Trent Laboratories (Edison, N.J.) and the results will be provided to Delaware Department of Natural Resources and Environmental Control (DNREC). This lab is certified by the State and data is provided with detection limits required by DNREC (8.68 ppb for SB, 4.70 ppb for As and 2.70 ppb for Pb).

The results will be reviewed by DNREC and statistical analyses will follow DNREC guidance for groundwater monitoring of the 5 wells each year. Depending on lead levels, groundwater monitoring could continue for up to 30 years. Groundwater monitoring is required under CERCLA (Comprehensive Environmental Response Compensation and Liability Act).

Additional threats to refuge communities, especially salt marshes and other wetlands, include oil spills and other petro-chemical contamination, as the Delaware Bay is the third largest shipping channel in the US, Refuge communities are also impacted by atmospheric mercury deposition.

2.5 Changing Climate and Sea Level Rise

Climate Change

Climate change is an immense and serious challenge that will affect fish and wildlife profoundly. A growing body of evidence indicates that accelerating climate change, associated with increasing global temperatures, is affecting water, land, and wildlife resources (Titus et al. 2009). While climate change has occurred throughout the history of our planet, current changes are occurring at a greatly accelerated rate, largely as a result of the accumulation of greenhouse gases from human activities. Climate change can affect the migration phenology and body condition of migratory songbirds (Buskirk et al. 2009). Along our coasts, rising sea levels have begun to affect fish and wildlife habitats, including those used by waterfowl, wading birds and shorebirds on our National Wildlife Refuges.

Successful conservation strategies will require an understanding of climate change and the ability to predict how those changes will affect fish and wildlife at multiple scales. We need to develop, test, and implement conservation strategies to cope with to the physical changes in the coastal environment resulting from climate change. Some of the current and predicted impacts of climate change in the coastal zone include:

- Shoreline erosion and shoreline displacement
- Displacement of wildlife (as critical habitats decline)
- Conversion of upland habitats to wetter habitats, freshwater habitats to saline
- Conversion of forested areas to emergent wetlands
- Conversion of tidal wetlands to mudflat or open water
- Decreased nearshore and/or freshwater recreational opportunities
- Damage to refuge facilities, roads, trails, towers, etc.
- Decreased water quality as a result of increased temperatures, and runoff associated with stronger, more frequent storm events
- Decreased groundwater availability due to changes in precipitation regimes

Refuge staff will need to increase cooperative efforts with science partners, such as DNREC, Ducks Unlimited, USGS, NOAA, and others to research and monitor the current and likely physical and biological impacts of climate change, and to assess species and habitat vulnerabilities. This information will be used to formulate guidelines or thresholds to mitigate habitat losses and/or assist ecosystem adaptation to the refuge's changing environment.

Sea Level Rise

Sea level rise (SLR), a manifestation of a warming climate, has been gradually occurring for thousands of years. Increasing ocean water volumes are caused by thermal expansion of water and the melting of polar ice caps. In addition to the volume of the ocean increasing, land in the Mid-Atlantic is actually sinking as a result of geologic changes near the surface and deep within the earth. This is known as shallow and deep zone subsidence. Thermal expansion, melting of the polar icecaps and subsidence all combine to contribute to relative sea level rise.

Sea level rise has been recognized as a key issue facing coastal communities for decades. The Federal Coastal Zone Management Act of 1972 directed local governments to anticipate and plan for the effects of sea level rise. At the International Level, a committee was formed to assess SLR on a global scale the Intergovernmental Panel for Climate Change (IPCC). In its Fourth Assessment Report (FAR), The IPCC estimated that global sea level could rise between 0.2 and 0.6 meters by the year 2100 based on projected greenhouse gas emissions scenarios. Some climatologists believe that far underestimates the potential rise in sea levels and suggest that SLR may exceed 1.0 meters (Rahmstorf 2007). At the national level, the U.S. Climate Change Science Program was formed to investigate climate change and sea level rise. This committee recently released a multi-year study entitled "Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region." This study discussed the potential impact from sea level rise using three scenarios for the year 2100: a rise of 1.3 feet (current rate), 1.6 feet; and 3.3 feet.

Potential impacts from SLR can vary significantly depending upon the scenario; therefore, different SLR scenarios should be evaluated to consider an entire range of potential effects. SLR has the potential to significantly impact the refuge, Delaware's coastal resources and communities, and Delaware's overall economy over the next several decades. As a result of higher sea levels, low lying coastal communities are becoming more frequently inundated during storm events. As storm events are predicted to become more frequent and more intense, coastal erosion and flooding events will likely be more severe than previously experienced. These impacts will have profound effects on the refuge. Structured decision making models are being developed to provide a framework that will allow the Service to proactively consider potential effects of SLR when making long-term infrastructure and habitat management decisions.

In 2008 and 2009 the Delaware Coastal Program (DCP) conducted a Sea Level Rise Affecting Marsh Model (SLAMM) exercise, using high resolution elevation data, at PHNWR. The model used estimated maximum and minimum sea-level predictions, assuming that the actual sea-level will probably fall somewhere within that range. However, certain conditions are predicted by both scenarios and we assume they are good predictors of the future environment at the refuge. By the year 2050, the model projects that at least half of the current upland area of the refuge will be lost (either converted to wetlands or open water), decreasing from 20% to, at most, 12% of the current land base. Open water and tidal mud flat areas may increase throughout the next 100 years.

If sea level rises at an accelerated rate to one meter in the next 100 years, the impact will be much greater on the refuge. By the year 2050 open water and mudflats comprise 26% of the refuge under high accretion rates, or possibly up to 58% of the refuge with low accretion rates. Under the worst case scenario, by the year 2100, up to 88% of the today's refuge could instead be open water or tidal mud flats and only 1% for the refuge would be uplands. The full report can be found in Appendix D of the Refuge CCP, or at *http://www.swc.dnrec.delaware.gov/coastal/Pages/SeaLevelRiseAdaptation.aspx*. Additional information regarding climate change and sea level rise can be found at the Service's website, *http://www.fws.gov/home/climatechange*.

Overwash

Overwash is a natural manifestation of rising sea levels, but also critical to maintaining healthy emergent wetlands in barrier island systems of estuaries like the Delaware and Chesapeake Bays. Emergent marshes must, in part, receive periodic influxes of sediment, to help build marsh elevation sufficiently to keep pace with rising sea levels. When humans impede natural overwash and marsh building processes (e.g. by constructing dunes, filling overwash areas) they impede back-bay marsh development.

Notable storm induced overwashes occurred on the refuge in 1982, 1988, and 1999. The dunes were artificially rebuilt in 1999. In 2006, Hurricane Ernesto caused a beach overwash just north of Fowler's Beach Road on Prime Hook NWR. On May 12, 2008, a Nor'easter brought flooding that overtopped or completely removed beach dunes extending from the Slaughter Beach Community to the Prime Hook Beach community. This includes the 2006 overwash area.

The overwash north of Fowler's Beach Road joins the Delaware Bay to a lagunal tidal salt marsh. Overwashes provide nutrients and sedimentation that is vital for tidal salt marshes, and provides critical habitat for priority coastal migratory birds. The area immediately south of Fowler's Beach Road has formed inlets during the past few years, as well. The impacted area covers approximately 4,000 linear feet of beach, with 95% of the breaches on private lands. During high tides this area floods a freshwater impoundment, Unit II, with saline bay water. In response to inlet formation, thousands of shorebirds are using the Unit II overwashes, during migration. In addition to the shorebird response, State endangered least terns and American oystercatchers have been confirmed nesting in the overwash.

There were numerous changes in the refuge freshwater habitats caused by the Mother's Day Storm of 2008. The salt intrusion plus the lack of rains to flush the salt from the system slowed the healing process in the freshwater marsh. The winter and spring rains allowed the staff to slowly flush the system, and it is gradually return to a managed freshwater emergent community. The salt water intrusion resulting from the storm greatly reduced invasive plants such as *Phragmites* and hydrilla, at least temporarily. Unit II has been one of the refuge's historic, premier waterfowl areas, managed as a moist soil unit via water control structures installed by DU. Accordingly, following the 2008 overwash event, the refuge re-established the dunes in this area through a relatively minor dune repair, to prevent high tides from entering the freshwater impoundment from the Bay. At that time, the refuge reasoned that allowing the overwashes to continue could result in a species and habitat composition shift in Unit II, and change in the quality of the PHNWR's hunt program.

However, storms in 2009 created two large breaches in Unit II, elevating the situation from that of minor dune repair to major management activity. Thus an Environmental Assessment was prepared to conduct dune repair one more time. The repeated overwash events in recent years necessitated a reconsideration of traditional impoundment management objectives and strategies, to be evaluated during the CCP. At this point, reasoning for dune repair shifted from a goal of perpetual maintenance, to a goal of maintaining the status quo while the wetland's response to the hydrological changes and potential for restoration, could be studied, and management alternatives evaluated through the CCP. Legal challenges delayed the dune repair until 2011. By the time the repair was conducted, Hurricane Irene (August 2011) had reduced the amount of on-site material available significantly. The repair was conducted by the Shoreline section of DNREC to the best of their ability, but the breaches reopened merely weeks later. Daily tidal flow of salt water through the breaches and into Unit II continues.

Throughout the planning process, refuge staff carefully examined the numerous factors influencing management of the freshwater impoundments, Unit II in particular. These include not only the natural processes of overwash and beach migration, but also the elevation and accretion of the marsh surface, elevation and subsidence of the management infrastructure (roads and water control structures), and increasing storm frequency and intensity. A detailed account of these factors is provided within the CCP (Under Objective 3.1, in Alternative B of the Draft CCP). The resulting impoundment management objectives are outlined within this Habitat Management Plan. We continue to meet with DELDOT and DNREC to comprehensively assess the roads (which also serve as dikes), sea level rise, transportation safety planning and wildlife resources as we draft a water management and restoration plan for the site.

Chapter 3. Resources of Concern

3.1 Resources of Concern (ROCS)

Resources of Concern are defined in the Habitat Management Planning Policy as *"all plant and or animal species, species groups, or communities specifically identified in Refuge purpose(s), System mission, or international, national, regional, state, or ecosystem conservation plans or acts"* {620 FW 14 (G)}. Each refuge has one or more purposes for which it was established that guide it's management objectives. For example, based on PHNWR's purpose legislation, migratory birds and endangered species are priority resources of concern (ROCs) for the Refuge.

Other Service "trust resources" that are also considered as resources of concern include inter-jurisdictional fishes, wetlands, marine mammals. Further, refuges support other elements of biodiversity, including invertebrates, rare plants, unique natural communities, and ecological processes that contribute to biological integrity and environmental health at refuge, ecosystem, and broader scales (USFWS 1999, 2003).

The Refuge supports other elements of biological diversity that include rare plant, amphibian and invertebrate species, unique natural communities for Delaware, and natural ecological processes that contribute and/or sustain biological integrity and environmental health at the Refuge, state, ecosystem, and broader scales, and many of these elements are also considered resources of concern (See Appendix E of the PHNWR CCP).

Given the multitude of purposes, mandates, policies, regional, national, international, and state plans that apply to PHNWR, there is a need to identify and prioritize all the potential ROCS that the Refuge would be best suited to focus its habitat management objectives and associated strategies. We used the process described in the Service's "*Handbook for identifying refuge resources of concern and establishing management priorities for the NWR System***"** (USFWS – March, 2007). The first step in this process yielded a comprehensive list of resrouces of concern (CCP Appendix E – Table A).

From this process, we selected priority habitats (CCP Appendix E – Table 5), and priority resources of concern (CCP Appendix E - Table 6) for PHNWR were identified. These ROCs served as the foundation for developing management goals and objectives. This process is described in more detail in Section 3.3.

3.2 Biological Integrity, Diversity and Environmental Health (BIDEH)

The RIA in section 4(a)(4)(B) states that in administering the System the Service shall *"...ensure that the biological integrity, diversity and environmental health of the System are maintained for the benefit of present and future generations of Americans..."* The Service defines these terms in its policy (601 FW 3) for maintaining and restoring the biological integrity, diversity, and environmental health (BIDEH) of the National Wildlife Refuge System.

Wherever and whenever possible, Refuge habitat management will mimic and/or restore natural ecosystem processes and functions to maintain and enhance biological integrity, diversity, and environmental health. The policy states that *"We will, first and foremost, maintain existing levels of biological diversity, integrity, and environmental health at the refuge scale.* To help achieve this policy goal we have mapped the existing elements of BIDEH on the Refuge (CCP Appendix E - Tables 1-4) as our starting point in determining habitat goals and management objectives, strategies, and prescriptions, to first, maintain existing elements of ecological integrity and second, to restore lost elements of BIDEH when feasible.

Maintaining Biological Integrity and Scoring Biological Condition

Developing and using indicators that assess current habitat condition and measures the consequences of habitat management actions will improve Refuge management of BIDEH. James Karr's Index of Biological Integrity (1997) is useful in understanding biological integrity. Karr believes that biological condition is the primary indicator of ecosystem health.

Using the approach of Karr's multimetric index of biological integrity (IBI) for aquatic sites, the Service is currently developing a multimetric Salt Marsh Integrity Index to assess salt marsh condition and integrity on Refuges. Karr (2000) explains the idea of developing a multi-metric index as assessing the biological condition of a place along a continuum of human influence. He depicts this idea by plotting biological condition along the y-axis (representing a continuum from "pristine" to "nothing alive") versus along the x-axis (representing a continuum of human disturbance from "none" to "severe"). The slope of that graph defines a threshold range intercept on the y-axis where the site degrades from healthy to unhealthy.

Biological integrity is the condition of a place with its evolutionary legacy – parts (species) and processes (nutrient cycles, trophic structure, etc.) – still intact. Biological condition can degrade to a threshold beyond which the system is unsustainable. This threshold represents a biological tipping point beyond which neither the natural biota nor human activity can be sustained in a place (Karr 2000).

These are the principles the USFWS and scientists with the U.S. Geological Survey (USGS) are employing to develop a Salt Marsh Integrity Index, an ongoing project the refuge is participating in. It is envisioned that with the use of a structured decision making process we can apply multi-metric indices for other habitat types. Such indices will improve performance measures to monitor habitat management activities on other habitat types, like freshwater marshes, etc.

In planning habitat management activities we will focus on the establishment of native communities we believe can occur through natural succession and/or maintain native non-climax communities to best achieve Refuge purpose(s). We will favor techniques that set back succession such as water level management, prescribed fire, mowing and other techniques to maintain early successional communities for migratory birds and other priority resources of concern. But in the case of Delmarva fox squirrels, we wish to accelerate succession toward a more climax seral stage. When restoring habitats we attempt to re-establish native plant species and vegetative communities found under natural conditions and use native seed sources or rely on natural succession and native seed banks in ecological restoration projects.

Growing information that wildlife diversity can help buffer human populations from infectious disease point to the increasing evidence for the economically valuable ecological services provided by maintaining and increasing biodiversity. All refuge habitat management actions that increase biological integrity, diversity, and environmental health and avian diversity have the potential of providing a buffer against future disease outbreaks from refuge-produced mosquitoes.

Maintaining and increasing biodiversity has been recently shown to slow the spread of infectious disease to humans and wildlife. Recent infectious disease models illustrate a suite of mechanisms that can result in lower incidence of disease in areas of higher disease host-diversity (defined as the dilution effect). These models are particularly applicable to human zoonoses, i.e., infectious disease of wildlife or domestic animals that spill over into human populations (Keesing et al 2006; Krasnov et al 2007, Ostfeld and Kessing 2000). Examples of zoonoses include avian influenza, anthrax, Lyme's disease, and WNV, to name a few.

Research conducted in the eastern U.S., when the West Nile Virus (WNV) epidemic was in full swing in 2002, found fewer incidences of WNV in humans in areas with a diverse array of bird species (Swaddle and Calos 2008). This link between higher bird diversity and reduced human WNV infection is attributed to the fact that crows, jays, and other common West Nile viral hosts tend to increase in numbers when avian diversity is low. But when bird diversity is high, viral host populations remain in check, hindering their ability to spread disease. Similar studies showed how increased mammalian diversity decreased Lyme disease risk to humans (LoGiudice et al 2003).

3.3 Process for Determining Resources of Concern and Habitat Priorities

The refuge followed the process outlined in the Service's handbook (USFWS 2007) for prioritizing the key habitats and species upon which to focus habitat management actions in this HMP. First, a comprehensive list of potential resources of concern was developed from Refuge purpose and Service trust species that were found on the Refuge (CCP Appendix E – Table A), using the following list of regional and state wildlife and habitat data sources:

- BCR 30 Bird Species List
- PIF – Area 44 Bird Species List
- National and Regional Bird Conservation Plans for waterfowl, landbirds, shorebirds, and waterbirds
- USFWS Birds of Conservation Concern
- Federally Threatened and Endangered Species Listings
- State Threatened and Endangered Species Listings
- Anadromous Fish Resources Using Refuge Habitats
- Refuge Purpose/Service Trust Resources
- Delaware Natural Heritage Program Data
- Delaware Wildlife Action Plan (DWAP)
- Botanical and Zoological survey data plus NVCS habitat data to map existing elements of biological integrity, diversity and environmental health on PHNWR

Second, we cataloged existing elements of biological integrity, diversity and environmental health for each habitat type on PHNWR in tabular form (CCP-Appendix E, Tables 1 – 4). These tables also identified and listed specific habitat attributes and characteristics, described the natural processes responsible for these habitat conditions, and their respective limiting factors.

Consultation and coordination with state and other conservation professionals played an important role in the prioritization process. In collaboration with Bombay Hook NWR, Service Region 5 Biologists and Managers, cross-programmatic expertise from the Delaware Bay Estuary Program Office, State wildlife biologists, State of Delaware botanical and zoological experts, and a state community ecologist, were all participants in several collaborative meetings to narrow down the potential ROCS list and prioritize Refuge habitats, using all of the researched and compiled information described in ROCS handbook plus information from the DWAP.

To guide us in prioritizing this list, we considered the following concepts:

- Achieving Refuge purposes, and managing for trust resources as well as biological diversity, integrity, and environmental health can be addressed through the habitat requirements of "focal species" or species that may represent guilds that are highly associated with important attributes or conditions within habitat types. The use of focal species is particularly valuable when addressing USFWS trust resources such as migratory birds.

- The Bird Conservation Region (BCR) plans are increasing their effectiveness at ranking and prioritizing those migratory birds most in need of management or conservation focus. Although all species that make it to a ranked BCR priority list are in need of conservation attention, we selected focal species that were ranked High or Moderate in Continental concern with a High to Moderate BCR Responsibility. If there were too many or too few birds with these rankings for a given habitat type then species with the highest then high then medium final BCR ranking were chosen. (See www.abcbirds.org/nabci for BCR rules used to rank birds.)
- Habitat conditions on or surrounding the Refuge may limit the Refuge's capability to support or manage for a potential species of concern. The following site-specific factors were evaluated:
  - Patch size requirements
  - Habitat connectivity
  - Compatibility of surrounding land uses
  - Environmental conditions: soils, hydrology, disturbance patterns, contaminants, predation, invasive species
  - Specific life history needs
- The likelihood that a potential species of concern would have a positive reaction to management strategies.

The next step required linking selected priority ROCS to habitats and then prioritizing mapped NVCS habitat types for habitat management. We did this by linking priority species to their habitat structural requirement needs. The refuge focused immediate management attention to the most important umbrella species that will also benefit a larger number of priority resources of concern species. Lower priority habitats were designated, which benefit fewer species or require less active management. Simplistically, this led to defining two habitat categories as either Priority I Habitats or Priority II Habitat (See CCP Appendix E – Table 5).

The Refuge's Priority I habitats: 1) can be managed to provide the greatest conservation benefit to priority ROCS; 2) offer the greatest contribution to maintenance and restoration of BIDEH; 3) represents important ecological and ecosystem processes not well represented within state and regional landscapes; and, 4) in their current condition or as a result of other environmental factors suggests an urgent need for active management.

Priority II habitats are still important, providing value to a wide range of migratory birds and resident wildlife and contributing to the overall biodiversity at the Refuge scale. However they require less active management or are too limited in extent to make a meaningful difference on a larger landscape level. A summary of Refuge priority species and associated habitat types is in Table 10 below:

Table 10. Priority Habitats for Prime Hook NWR and Associated Priority Focal Species

Priority I Habitats	Associated Priority Focal Species
Barriers Beach Island Habitats • Overwash Areas • Beach/Panicgrass Dune Grassland • Atlantic Coast Interdune Swale • Maritime Red Cedar Woodland	American Oystercatcher, Sanderling, Whimbrel, Migratory Shorebirds, Beach Dune Tiger Beetle, Little Wife Underwing;
Salt Marsh Habitats • Spartina High Salt Marsh • Spartina Low Salt Marsh • Salt Panne	Black Rail, Clapper Rail, Least Tern, Gull-billed Tern, Black Skimmer, Willet, Saltmarsh Sharp-tailed Sparrow, Seaside Sparrow, Coastal Plain Swamp Sparrow, Henslow Sparrow, American Black Duck.

Priority I Habitats	Associated Priority Focal Species
Impounded Wetland Habitats • Emergent Freshwater & Brackish Marsh • Coastal Plain Depressional Ponds • Twig-Rush Peat Mat Bog • Button-Bush Coastal Plain Pond	American Black Duck, Northern Pintail, migrating Dabbing ducks, Snow goose, Canada goose, Virginia Rail, Forster's Tern, Least Bittern, American Bittern, Short-billed Dowitcher, American Avocet, Greater/ Lesser Yellowlegs, Alewife, Blue-backed Herring, American Eel, Hickory and American Shad, Striped Bass, American Eel, Rare Peat Bog Plants, Rare Obligate Amphibians;
Upland Forested Habitats • Southern Red Oak/Heath Forest • Mesic Coastal Plain Oak Forest • Coastal Plain Loblolly Pine Forest • Mesic Coastal Plain Mixed Hardwood Forest • Pond Pine Woodland • Mesic Coastal Plain Rich Forest	Delmarva Fox Squirrel, Bald Eagle, Black and White Warbler, Wood Thrush, Scarlet Tanager, Yellow-Throated Vireo, Kentucky Warbler, Great-crested Flycatcher, Northern Flicker, Whip-poor-will, Bay-breasted Warbler, and other breeding and migrating landbirds;
Forested Wetland Habitats • Red Maple/Seaside Alder Swamp • Atlantic White Cedar/Seaside Alder Saturated Forest • Swamp Cottonwood Coastal Plain Pond	Acadian Flycatcher, Prothonotary Warbler, Yellow-throated Vireo, Delmarva Fox Squirrel, Migratory landbirds.
Early Successional Upland Habitats • Early Successional Forested areas • Scrub/Shrub Habitats • Herbaceous, Farmed Areas	Prairie Warbler, Brown Thrasher, Whip-poor-will, Willow Flycatcher, Western Towhee, Field Sparrow, Northern Bobwhite, Henslow's Sparrow, Coastal Plain Swamp Sparrow, Maritime Sunflower Borer Moth, Migratory landbirds and waterfowl.

3.4 Habitat Requirements for Priority Resources of Concern

Species-habitat relationships of priority resources of concern were researched, listed, and described in Table 6 of CCP Appendix E. These relationships are central to understanding the precise habitat structure and habitat management strategies that are required to conserve target ROCS. Species-specific structural habitat requirements provided the framework to develop habitat objectives to conserve and support all of the focal priority wildlife species on the refuge for the next 15 years. Improved wildlife population monitoring conducted to implement the refuge's new Inventory and Monitoring Plan (IMP) will provide subsequent evaluation of various planned habitat management strategies and prescriptions to meet focal species life history requirements.

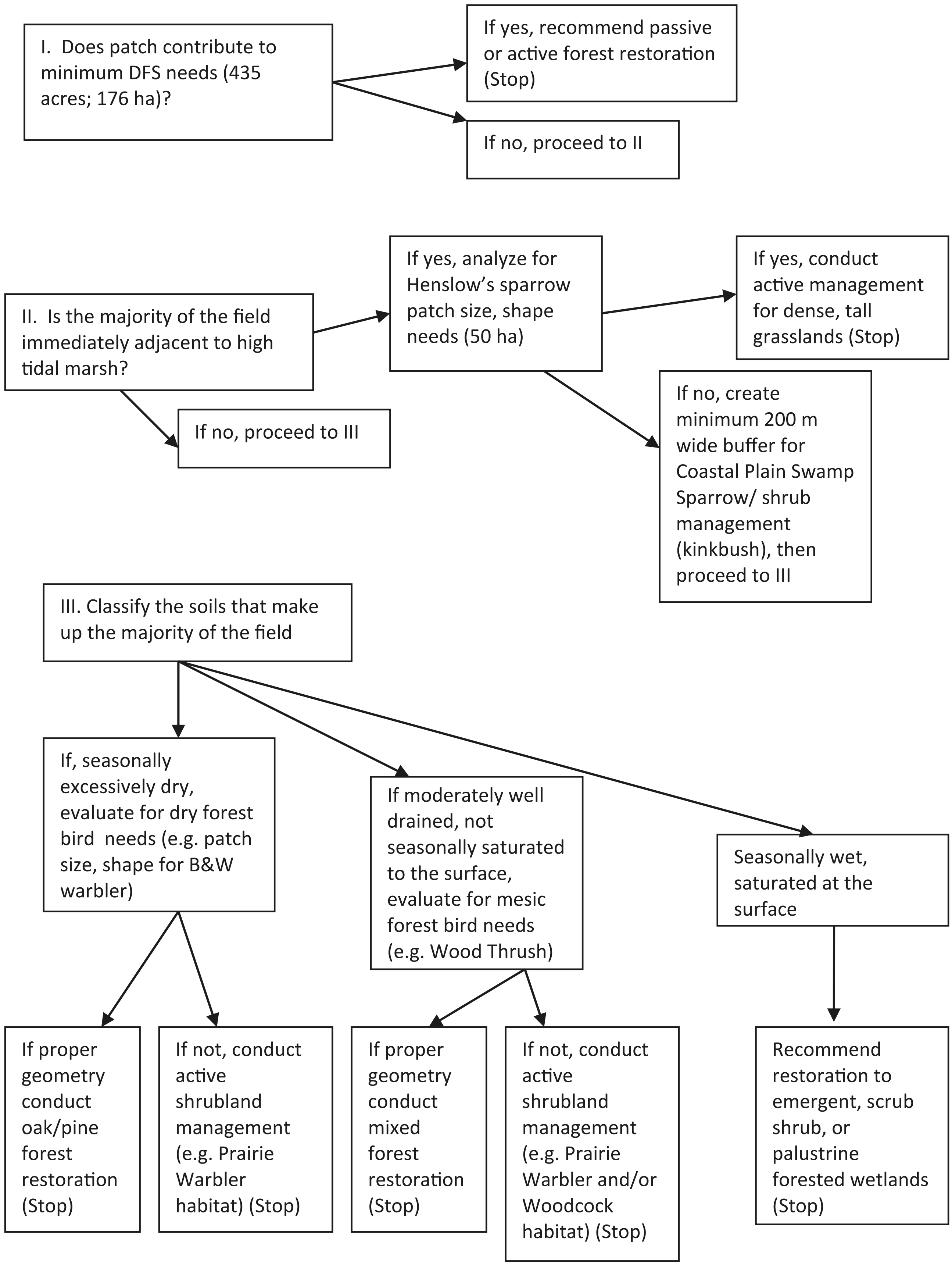
3.5 Conflicting Habitat Needs

Given the diversity of goals, purposes, and mandates for the NWRS, it is not uncommon to have conflicts over management priorities on a Refuge. Balancing the types and proportions of habitat conditions on the Refuge requires a thoughtful and documented process for determining the best course of action. Prime Hook NWR is taking a deliberate, transparent approach to resolving at habitat management conflicts associated with the HMP:

Open Fields versus Upland Forest Restoration

We utilized a habitat management decision process to guide where on the refuge we could best meet certain upland (primarily) objectives outlined in the HMP (Figure 1). This process incorporated the best available landscape and vegetation map data, soil type data, and literature on habitat requirements of identified priority species. Open fields were evaluated on the basis of the site capability (e.g., soil drainage) and potential contribution to the existing landscape context. This process is documented in greater detail in Appendix B [Not Yet Developed] of this HMP. The following flowchart summarizes how habitat management decisions were generally made. Deviations from the flowchart recommendations could occur at the discretion of refuge management.

Figure 1. Open Field Habitat Management Decision Flowchart



Mosquito Management in Salt Marshes

The Delaware Mosquito Control Section, under Service permits, has controlled mosquitoes on the refuge since its establishment in 1963. We have been working with our State partners to reduce the quantity of insecticides used on Refuge lands and ensure activities are consistent with the Service's policies. Mosquito management is a complicated issue for the Refuge. PHNWR is adjacent to residential beach communities where nuisance issues are amplified. A conflict of interests arises between nuisance complaints, managing refuge habitats for migratory birds, and maintaining and enhancing biological integrity, diversity, and environmental health within the refuge.

Although the refuge does not regard mosquito control, in and of itself, to be a salt marsh habitat management objective, the control of mosquitoes is a State priority and a reality of management of salt marshes in the State of Delaware. There have been three techniques employed to control mosquito populations on the Refuge within salt marsh habitats: use of the chemical adulticide, naled, source reduction using the chemical larvicides, Bti and Methoprene, and a biological control facilitated by open marsh water management (OMWM). These control methods are described in more detail in both the CCP, under Objective 1.3, and in HMP Appendix A.

Impoundment Management and Salt Marsh Restoration

As described briefly in Section 2.5 on Climate Change and Sea Level Rise, and in more detail in the Draft CCP (Under Objective 3.1 in Alternative B), the refuge faces considerable challenges and uncertainties regarding impoundment management. A Structured Decision Making (SDM) process is in development, cooperatively with other coastal refuges facing similar challenges. However, in the case of Unit II at Prime Hook NWR, changes are occurring presently and without an easy remedy. In the short-term, the refuge will likely have little choice but to restore Unit II to salt marsh, and this is outlined in Objective 3.1 below. Indeed, such restoration will have many biological benefits. However, there will also be trade-offs, as the freshwater impoundments do serve as valuable concentrated food sources for migrating and wintering waterfowl. The management fate for Unit III, in the long term, will be evaluated through the SDM process. Although both managed freshwater impoundments and salt marsh wetlands are valuable to wildlife, and even many species can and will utilize both habitat types, they cannot exist in the same place. Thus, this presents a conflicting habitat needs challenge that is actively being explored, even as the planning process proceeds.

3.6 Adaptive Management

The priority resources of concern and their respective habitat attributes were used to develop specific achievable habitat objectives. Many factors, such as the lack of resources, existing habitat conditions, species response to habitat manipulations, climatic changes, contaminants or invasive species, may reduce or eliminate the ability of the Refuge to achieve objectives. Although these limiting factors were considered during the development of management objectives, conditions are likely to change over the next 15 years and beyond. The Refuge will use adaptive management to respond to changing conditions that impair our ability to measure and achieve the habitat objectives. That will require the Refuge to establish and maintain a monitoring program to ensure that changing conditions can be detected and responded to adequately and efficiently. The monitoring program will be developed in accordance with 701 FW 2 as a step down plan.

Chapter 4. Habitat Management Vision, Goals, Objectives and Habitat Management Strategies and Prescriptions

This chapter outlines the Habitat Management Vision, as well as Goals and Objectives which are also associated with the refuge CCP. Strategies for each objective are provided as well. A detailed summary of all potential management strategies is provided in Appendix A of this Habitat Management Plan. Management prescriptions for open upland fields are summarized at the end of this chapter, because they span multiple management units and fulfill multiple management objectives.

Habitat Management Vision Statement: *We will conserve, restore, and enhance the biological diversity and ecological integrity of the Refuge's native plants and wildlife in wetland and upland habitats found within the Delmarva Coastal Plain Ecosystem.*

4.1 GOAL 1. (Barrier Beach Island and Coastal Salt Marsh Communities)

Manage, enhance and protect the dynamic barrier beach island ecosystem for migratory birds, breeding shorebirds and other marine fauna and flora. Perpetuate the biological integrity, diversity and environmental health of North Atlantic high and low salt marsh communities.

Objective 1.1 (Barrier Beach Communities: Overwash, Sandy Beach and Mudflat)

Maintain and monitor the dynamic nature and natural functioning of 1.5 miles of sandy beach, overwash dune-grassland and mudflat in Unit I parallel to the salt marsh management unit. Over time, permit the development of an additional approximately 1.5 miles of these features and communities along the shore of Unit II, as salt marsh restoration is pursued. These areas provide spawning habitat for horseshoe crabs, and nesting, foraging, and staging habitats for breeding (e.g., American oystercatcher, piping plover, least and common tern) and migrating shorebirds (e.g., red knot, sanderling, whimbrel) and other species of greatest conservation concern during critical periods (mid-March through mid-November). Barrier beach communities are characterized by the following attributes:

- Plant species typical of overwash grasslands include a mixture of Cakile eduntula, Spartina patens, Schoenoplectus pungens, Cenchrus tribuloides, Triplasis purpurea, and scattered Baccharis halimifolia seedlings.
- Diagnostic dune grassland species consist of a mixture of Ammophila breviligulata, Solidago sempervirens, Panicum amarum, and Opuntia humifusa.

In years when piping plovers, American oystercatchers, and/or least and common terns do nest, maintain suitable nesting habitat through beach closures, predator management, and public education to achieve minimum productivity rates, as defined within current recovery or management plans. Proposed productivity targets are as follows:

- 1.5 piping plover chicks per nesting pair on average over a five year period
- 0.35 American oystercatcher chicks per nesting pair
- 1 least/common tern chick per nesting pair

Rationale

Barrier beach island and coastal salt marsh habitats are priority conservation habitat-types within the Delaware Bay and the mid-Atlantic coastal region. Remaining undeveloped coastal saltwater wetlands in Delaware support the greatest diversity of species of conservation concern, while beach overwash and dunes provide habitats for some of the state's and region's most critically rare and threatened species. Saltwater marsh and sandy overwash beach habitats also support a shorebird migration that has worldwide ecological significance.

Despite the heavy loss of habitat, Delaware Bay remains one of the country's most important migratory "stopovers" for hundreds of bird species (USFWS-Shore Technical Committee 2003).All remaining beach dune and overwash habitat patches are considered critical habitats regardless of size. These habitats are the most representative of the region, and should receive priority conservation protection on the Refuge, especially during the critical breeding and migration periods for highest priority shorebird species identified in BCR 30, BCC 2008, and bird and insect species identified in the DWAP (DNREC 2005).

On the Refuge, Barrier Beach Island habitats are comprised of five natural community types:

- Overwash Dunes
- Beachgrass/Panicgrass Dune Grassland
- Atlantic Coastal Interdune Swale
- Maritime Red Cedar Woodland
- Successional Maritime Forest

These highly dynamic habitats are closely related to the natural ecological processes of estuarine tidal creek shrubland, Spartina low and high salt marsh communities. Processes creating all of these habitat-types include tidal salt water flows and eolian actions that contribute to active sand deposition and/or erosion. Natural ecological processes responsible for shifting mosaics of sandy beach, mudflats and inland salt marsh habitat migrations have been impeded and/or altered by human activities within the state landscape.

Overwash dune communities of the mid-Atlantic are globally ranked as rare, and restricted to bayshore areas of Delaware, Maryland, Virginia, and some coastal areas of North Carolina. Dune-grassland communities are also rare, extending from Long Island to North Carolina. Less than 3,000 acres are currently undeveloped, and little of this acreage is protected (PHNWR NatureServe Report 2006). Comparing extent of Habitat Gap Class of Sparsely Vegetated and Unconsolidated shoreline on Refuge to State Habitat Gap Analysis Maps, it can be seen that although this coverage accounted for less than 0.4% of Refuge habitat-types, it accounts for 40% of the total coverage that is still left remaining in today's Delaware landscape.

Natural dynamic forces (e.g., tides, wind, and storms) are responsible for structuring overwash communities and creating shifting dune mosaics and contribute to these increasingly rare and threatened communities on the state landscape. These beach, dune grassland, and overwash communities are considered to be ephemeral components of a highly dynamic ecosystem, being buried over time by sand deposition and formed anew as other areas are subjected to overwash.

Importance to Priority Species and Species of Greatest Conservation Concern

Storm-maintained ecosystems are critical for the highest priority shorebird species identified in BCR 30 during breeding and migration periods, USFWS-Birds of Conservation Concern (2008) plus pollinator species, birds and rare insect species of greatest conservation need identified in Delaware's Wildlife Action Plan (2005). Maintaining natural coastal formation processes provides high quality breeding habitats critical for American oystercatchers, least terns, common terns, piping plovers, black skimmers, beach dune tiger beetles, and seabeach amaranth, which are all dependent on habitats maintained by coastal storms.

A dune system with overwash and ephemeral inlets, identified as a Key Wildlife Habitat of special conservation concern in the DEWAP and BCR 30 plan, is found from the northernmost private residence on Prime Hook Beach, north to Slaughter Beach. Beach heather (Hudsonia tomentosa), beach plum (Prunus maritima) and dune panicgrass (Panicum amarum) are interspersed with several overwash habitats along Unit I and Unit II. In 2006, Hurricane Ernesto plus several other Nor'easter storms of 2007 and 2008 expanded the overwash habitats, flattened most dune areas, and increased tidal flows in the salt marsh. This has increased habitat availability for shorebirds by providing greater amounts of invertebrate and fish food resources flowing in daily from the Delaware Bay for easier exploitation by nesting and migrating birds. Refuge sandy beach and overwash dune grassland habitats have recorded greater use by spring and fall migrating shorebirds since 2006. There has been an increase in nesting attempts by American oystercatcher, least terns, and common terns. Furthermore, observations of piping plovers staging on the Refuge, and spilling over from State -protected breeding piping plover beaches, suggest that refuge barrier beach island habitats could potentially host State and Federally endangered nesting shorebird species in the near future.

Immediately parallel to the Delaware Bay, Unit I habitats have increasingly become more important for both migrating and breeding shorebirds in the face of beach development along bay shore areas. The highest quality dunes remaining along the Delaware Bay shore occur from Big Stone Beach south to Beach Plum Island (Clancy et al. 1997) and have been identified as a Key Wildlife Habitat of special conservation concern in the DEWAP and the BCR 30 plan. Strand beach habitats along Unit I are migrating landward as a result of storm surges and sea level rise. Storms and high tides deposit wrack composed of algae, vascular plant fragments, and assorted mollusk shells, abundant casings of whelks and remnants of clams, crab, and fish. This rich, organic debris provides important feeding and breeding sites for a variety of invertebrates. Coupled with spawning sites for horseshoe crabs, wrack lines provide nutritious and plentiful natural food resources for migrating birds all year long and for nesting birds in the spring and summer.

Natural barrier beach island habitats and associated species are also threatened by a number of human activities such as the development of homes and cottages, artificial dune stabilization and replenishment, pedestrian activity, dogs running at large, and other public uses (Harrington and Drilling 1996; Pfister et al. 1992, 2008). According to Harrington (2003), human disturbance at non-breeding areas affect shorebirds by leading to reduced forage time, increased daily energy expenditure from increased numbers of flush flights (take-offs), loss of time for preening and resting, and decreased habitat availability due to chronic human disturbance. In addition, disturbance has been found to significantly lower body weights of shorebirds returning to Arctic breeding grounds (Harrington 2003, Pfister et al. 2008). This reduces the likelihood that birds will successfully complete their long-distance migrations and increases the possibility that they will arrive in poor condition on their breeding grounds. Pfister et al (2008) found reduced survivorship of sandpipers that do not achieve threshold weights at migration stopover sites. Shorebird research data strongly support the assertion that proactive management of public use and control of human-related trespass on critical habitats for both migrating and breeding shorebirds are the most effective management actions to benefit shorebirds, especially along coastal migration routes. .

The Importance of Detecting Changes in Shorelines

A major issue for the conservation, management, and vulnerability assessment of all refuge coastal wetland habitats in the face of climate change and sea level rise is the magnitude and rate of shoreline change in coming years. Coastal geomorphological changes and shoreline condition will be a direct consequence of sea-level rise inundation (CCSP-2009). Elements of monitoring coastal shoreline position provide coastal managers more detailed knowledge of the hydrodynamic forcing of sediment mobilization, transport, deposition, and measurements of morphologic change and ecosystem response. Compared to other geomorphological processes and responses, shoreline position is a highly valued metric with high data value as it can be measured effectively (Psuty et al 2010) and used to address refuge shoreline management issues.

In an effort to address seasonal and long-term changes in shoreline position, the National Park Service (NPS), in collaboration with geomorphologists, coastal and climate scientists, and other partners, has developed a Vital Signs Coastal Monitoring Program - Shoreline Position Monitoring Protocol. Prime Hook NWR, in coordination with NPS and other USFWS Region 5 coastal refuges, will begin recording changes in shoreline position in Spring 2011.

Collecting a record of the changes on the shoreline position in Units I and II over time, will chronicle variation in sediment supply, distribution, and will also function as a surrogate for sediment budget. Seasonal and annual shoreline monitoring will provide knowledge of the spatial and temporal variation in sediment transfers and sediment budget influences and will create a fundamental database for use in refuge sandy beach and marsh habitat management decisions. Decisions will derive from annual shoreline change metrics and marsh surface elevation data to assess wetland habitat vulnerability and resiliency to climate change and sea-level rise on an annual basis. Sediment and marsh surface elevation data will provide critical information to gauge and adjust annual habitat management decisions to changing climatic conditions and accelerating sea-level rise rates in annual habitat work plans.

Climate Change and Sea Level Rise Adaptation

The shoreline on the western side of the Delaware Bay, which include coastal areas within the refuge boundary, are characterized as a lagoon-barrier-marsh shoreline (Kraft 1976c). These shoreline areas occupy a low-lying coastal plain and are part of a larger geological structure known as the Atlantic coastal plain continental geosyncline. Delaware shorelines of both the Atlantic Ocean and Delaware Bay are migrating rapidly in geologic time in a landward direction (Kraft 1976b). This is caused by several geological processes:

- The continental shelf and coastal plain are known to be experiencing deep subsidence
- Local, apparent sea level rise
- Erosion and redistribution of sediments as shorelines shift in a landward and upward direction

Inlet formation acts as a safety valve mechanism by adjusting and shifting in size and location in response to each storm event or higher than normal tide cycles. The dynamic nature of inlets means that a stable, deep channel is rarely maintained naturally and inlets are filled after they are formed. Barrier island shorelines are dependent upon storm overwash formations to build shoreline elevation and width, and both inlet and overwash developments are critical processes, allowing these sandy beach ecosystems to keep pace with sea level rise. Overwash events also provide sediment inputs, helping coastal wetlands accumulate material reserves – or "elevation capital" – which increase the marsh elevation and may buffer these systems from rising sea levels (Cahoon and Guntenspergen 2010, Kraft 1976a; Drew 1981; Riggs and Amers 2007; Defeo et al. 2009).

Even non-storm, tidal surges can produce waves that overtop beach berms on the Delaware Bay shoreline and result in overwash fans on the marsh side of the shoreline. Through time, overwash events bury the marshes and associated peat deposits and/or fill in old inlet channels or create new ones. For example, during the last 47 years, numerous mini-inlets, various depositional overwash fans and shoreline recessions have occurred on the refuge. These natural processes are driven by hurricanes and Nor'easters and are all crucial and integral elements for both short-term and long-term evolution of healthy shoreline habitats (Kraft et al. 1975; Kraft 1976a; Drew 1981; Defeo et al. 2009; Pilkey and Young 2009). Shoreline transgression assists wetlands behind shorelines to accrete sediments and keep up with sea level rise and restores tidal flows that enhance salt marsh habitat and water quality (Cahoon et al.

2010). The ability of salt marshes to build upward and migrate landward with their associated shorelines has been a natural response to sea level rise for thousands of years.

The geological, ecological, and biological significance of overwash and natural sandy beach communities has been described by various scientists and summarized by Maurmeyer (1978) and others (Defeo et al. 2009; McLachland and Brown 2006). There are several benefits of these natural systems. The net effect of overwash processes is the maintenance of a fairly constant shoreline width. Barrier beach island habitats are raised naturally over time, providing resilience to sea level rise. Healthy salt marsh plant communities develop quickly on recently developed overwash fans. Rapid growth of salt marsh grasses act to dissipate wave energy, hold sand in place, and trap more sand to eventually develop a natural sand berm. Natural overwash, intertidal areas, and shorelines support diverse and rich biological resources that are exchanged between open water, the intertidal zone, and the back-barrier marshes, such as unique bacteria, protozoans, microalgae, meiofauna, and macroinvertebrates. These resources, in turn, form food webs that support birds and other wildlife species (McLachlan and Brown 2006, Defeo et al. 2009).

A major issue for the conservation, management, and vulnerability assessment of all refuge coastal wetland habitats in the face of climate change and sea level rise, is the magnitude and rate of shoreline change in coming years. Coastal geomorphological changes and shoreline condition will be a direct consequence of sea-level rise inundation (CCSP-2009). Monitoring coastal shoreline position provides coastal managers with more detailed knowledge of sediment mobilization, transport, deposition, and measurements of morphologic changes and ecosystem response. Compared to other geomorphological processes, shoreline position is highly valued information with high data value as it can be used to address refuge shoreline management issues (Psuty et al. 2010).

From a scientific perspective, shoreline position represents the morphological response of wave, current, tide, and other physical processes acting on sediment supply (Short 1999). Understanding the dynamics of changes in shoreline position over time, in a systematic manner and through standardized data collection, will provide a scientific basis for informed sediment resource management. The assemblage of reliable and consistent data enables robust statistical analysis, and yielding a better grasp of local sediment budget cycles, trends, and storm episode influences (Psuty et al. 2010). Collecting a record of the changes on the shoreline position over time, will monitor variation in sediment supply and distribution, and can also function as a surrogate for sediment budget. The determination of shoreline position twice a year, in the early spring (fully developed winter beach), and in the early fall (fully developed summer beach) will lead to the acquisition of a time series of seasonal shoreline positions that represent the annual maximum and minimum configurations of the beach. Each annual pair of shoreline position data, will document the variation caused by changes in the seasonal wave patterns on the beach sediment supply (Psuty et al. 2010).

Refuge shoreline habitats include areas of wide coastal marshes separated from Delaware Bay by a continuous, relatively narrow, sandy coastal barrier. This zone starts at Bowers Beach and continues southward to the Great Marsh in Lewes, and is one in which the longshore transport (parallel to the shoreline) of sand and mud sediments is fairly continuous. In this zone, a broad wave fetch which results in wave action and longshore drift systems help maintain continuous barrier-beach habitats between broad coastal marshes and the Delaware Bay. Within a tidal regime and frequent storm setting, sand is normally washed across barrier beach island habitats into marsh areas. However, these barrier beach island segments of Delaware Bay have a relatively limited supply of sand, resulting in narrow and shallow shorelines (sand sediment is rarely any deeper than 5 feet and no more than several hundred feet wide), dominated by inlet and overwash processes (Kraft 1976c).

Objective 1.2 Maritime Shrub and Maritime Forested Habitats

Over the next 15 years, maintain and protect unique and uncommon maritime shrub and forested habitats which include 67 acres of Atlantic Coast Interdune Swale, 76 acres of Maritime Red Cedar, and 184 acres of Successional Maritime Forest communities for migrating passerines and other maritime shrub and forest-dependent species.

Manage these habitats especially for short and long distance migrating songbirds, breeding birds, and rare flora and fauna dependent on maritime shrub-forest ecosystems. Conserve insect species (butterflies, skippers, moths, etc.) associated with these habitats include the following state ranked (S-1) species found on the refuge:

- Little Wife Underwing Moth – *Catocala muliercula*
- Southern Broken Dash – *Wallengrenia otho*
- Delaware Skipper – *Anatrytone logan*
- Little Glasswing – *Pompeius verna*
- Graphic Moth – *Drasteria graphica*

Rationale

Atlantic Coast Interdune Swale, mid-Atlantic Maritime Red Cedar and Successional Maritime Forested habitats are underrepresented within Delaware's landscape of natural communities and regionally at the mid-Atlantic coastal plain level. These habitat types found on the Refuge range from unvegetated pools and interdune swales to grass or forb-dominated and/or shrub dominated communities to red cedar woodlands and maritime shrub-forested areas.

Interdune swales are low depressions that form behind primary and secondary dunes where the water table intersects the soil surface for part or all of the growing season. This community may also receive salt spray from the Delaware Bay and is characterized by moderately open to dense stands of southern bayberry *(Morella cerifera)* and interspersed with wild black cherry *(Prunus serotina)* and sweetgum *(Liquidambar styraciflua)* (NatureServe-2006).

The herbaceous layer consists of switch grass *(Panicum virgatum)*, salt grass *(Distichlis spicata)* and smooth rush *(Juncus effusus)*. The community is found scattered on high points around marsh habitats in Units II, III, and IV. Maritime Red Cedar Woodland habitats are found in some Unit III sandy substrate areas, in Unit II on "Negro Island," where a 49 inch diameter willow oak *(Quercus phellos)* was measured, and Unit IV, which has the largest area.

Shrub layers include northern bayberry *(Morella pensylvanica)*, southern bayberry *(M. cerifera)*, salt shrub *(Baccharis halimifolia)*, marsh elder *(Iva frutescens)*, and highbush blue berry *(Vaccinium corymbosum)*. The Unit IV Red Cedar community is found adjacent to the dunes along the Delaware Bay and according to the Delaware Natural Heritage Program (DNHP) is the "best remaining examples in Delaware and maybe the East Coast" (McAvoy et al 2007).

The Little Wife Underwing Moth *(Catocala muliercula)* was not an expected resident at the Refuge and is a State Record species. The individual collected on July 29, 2004 represents the first specimen collected in the state of Delaware. Furthermore, this species has not turned up in other large collections of the *Catocala* of the Delmarva Peninsula. The DNHP considers this species as warranting special conservation attention by the Refuge. This moth's host plant is southern bayberry which is somewhat common on the Refuge but is very uncommon state-wide (McAvoy et al 2007).

The rare graphic moth *(Drasteria graphica)* feeds on beach heather *(Hudsonia tomentosa)*. Several adults were secured in the Maritime Red Cedar Woodland habitats of Unit IV, where beach heather was found. But since beach heather is patchily distributed, the DNHP suggests the graphic moth warrants consideration as a conservation target to protect its core population (McAvoy et al 2007).

Generally, the plant diversity is low due to stressful conditions, where the soils are hot, sandy and nutrient poor but this community does support the Delaware rare plant, golden heather (*H. ericoides)*, ranked S-1, as state botanists claim the Refuge's population represents only one of two known in Delaware (McAvoy et al 2007). Prior to its discovery in 2005, golden-heather was known on the Delmarva Peninsula only from Cape Henlopen State Park. This plant grows at the edge of openings bordered by red cedars, where it prefers sun with just enough shade supplied by the cedars.

Other species found in the Maritime Red Cedar community of Unit IV included several rare (S-1) butterfly species which included the Southern Broken Dash (*Wallengrenia otho)*, whose larval host plants consist of *Panicum* grasses and *Paspalum* species*;* Little Glassy Wing *(Pompeius verna),* whose larval host plants also include various grasses, especially "purpletop" *(Tridens flavus)*; and the Delaware Skipper *(Anatrytone logan).* The Skipper's host plants include big bluestem *(Andropogon sp.)*, wooly beard grass *(Eriantus divaricatus)*, and switchgrass *(Panicum virgatum & P. amarum).* The presence of any of these individual invertebrate species or collectively as a focal group can be used as indicators of environmental health of a mature and unique Maritime Red Cedar ecosystem.

The Refuge Maritime Red Cedar community is recognized status as an exemplary natural community of biological diversity in the state (McAvoy et al 2007). In addition, NatureServe has ranked it as globally rare (G2), in its habitat analysis report of Prime Hook's NVCS alliance and association descriptions. This conservation ranking was based on the following reasons: *"This maritime woodland community is naturally restricted to major coastal dune systems. An estimated maximum of 30 occurrences exist, ranging in size from less than an acre up to a maximum of 100, with an average size of 10 acres. The habitat is threatened by many of the same threats common to coastal dune systems: dune stabilization, commercial and residential development."* (PHNWR NatureServe Report 2006)

Widespread population decline in many migratory songbird species is one of the most critical issues in avian conservation. Studies have shown the critical role that barrier beach island shrub and maritime forested communities play for migratory passerines during the fall migration, which is second in importance only to the spring shorebird migration (McCann-1993; Clancy et al 1997).

The McCann study demonstrated that often these habitats support over twice as many migratory landbirds than adjacent mainland forested habitats. This is attributed to the fact that birds migrating long distances first reach landfall on barrier beach island habitats. These areas are also the last stop-over place where migratory passerines congregate to forage in dense mid-Atlantic shrub and maritime forested habitats. The value of these habitats during migration is attributed to significant populations of invertebrates and the production of fruits and berries, which provide the energy the birds require before moving on to their wintering grounds.

Radar data collected from migrants departing from stopover coastal habitat sites on PHNWR and along the Delaware Bay also support the importance of maintaining and managing Maritime shrub and forested habitats in a healthy condition. High densities of migratory songbirds during fall migration events along the Atlantic Coast and Delmarva Peninsula have been attributed to two factors: 1) a higher proportion of hatching year birds, and 2) maritime shrub and forested habitats containing a significant abundance of energy rich food resources in the form of fruits, berries, and high densities of insects (Mizarhi 2006).

Objective 1.3 (North Atlantic Low and High Salt Marsh Habitats)

By 2020, enhance and restore the quality and natural function of 2,200 acres of salt marsh by 10%, as measured by Region 5's Salt Marsh Index of Ecological Integrity and consistent with local reference sites by maintaining a mix of North Atlantic high and low salt marsh vegetation comprised of less than 5% invasive species cover, and pool, panne, and irregularly flooded tidal salt shrub communities to provide breeding, migrating and wintering habitats for key species (e.g., seaside sparrow, salt marsh sharp-tailed sparrow, clapper rail, shorebirds, and waterfowl), and passage and rearing habitats for diadromous and prey fish species and marine invertebrates.

- Increase cover of native vegetation to greater than 95% by controlling the presence of invasive plant species. Native plant species found high salt marsh communities include: *Spartina patens*, *Distichlis spicata*, and *Juncus gerardii* with lower densities of *Aster tenuifolius*, *A. subulatus*, *Atriplex patula*, *Solidago sempervirens*, and *Panicum virgatum*. In low marsh communities, native plant species include *Spartina alterniflora* with lower densities or *Distichlis spicata*, *Salicornia maritime*, *Juncus gerardii*, and *Juncus roemerianus*.
- Special emphasis will be given to conserving and protecting small patches of remnant high salt marsh areas on the Refuge that are less common than low marsh communities.
- For breeding obligate passerines, maintain extensive stands of salt-meadow hay with scattered shrubs or clumps of black needle rush and salt grass.
- Develop up to 4,000 acres of additional salt marsh within the refuge impounded wetland complex through active wetland restoration efforts; these efforts will be guided by a restoration plan developed with assistance from state and federal coastal scientists and other subject matter experts (see Objective 3.1).

Rationale

Salt marshes in North America are among the most degraded of all habitats (Amezaga et al 2002). Within the mid-Atlantic region, a substantial number of salt marshes have been lost over the past 200 years. From 1950 to 1970 loss rates were extremely high due to urban and industrial development (Tiner 1984). Protective legislation helped to slow down the loss with the passage of the Wetlands Act in 1972, when Delaware was losing nearly 450 acres of salt marsh annually. After protective legislation, losses declined to just 20 acres per year (Hadisky & Klemas 1983). Other states in the region experienced similar trends.

Habitat analysis mapping for Delaware shows less than 7% of herbaceous wetland habitats remain on the landscape (Appendix A of the CCP) while salt marsh communities are listed as habitats of conservation concern in the DWAP (DNREC 2005). Tidal salt marshes are one of the most productive ecosystems and provide significant invertebrate and small fish trophic levels that support many bird communities throughout the year. Patches of low marsh are abundant in the state and Refuge landscapes, but high marsh is very uncommon and spatially restricted on the Refuge (less than 85 acres of high marsh compared to 1,756 acres of low marsh (McAvoy et al 2007).

BCR 30 and PIF 44 plans listed eight species with high conservation concern scores dependent on salt marsh habitats. Priority species using the low marsh include Seaside Sparrow and Clapper Rail, and priority species using the high marsh include salt marsh sharp-tailed Sparrow, Black Rail, Prairie Warbler, Henslow's Sparrow, American Black Duck, Willet and Sedge Wren. Species that require high-marsh habitats are the most threatened marsh-nesting species within the region, state, and locally on the Refuge. Within the mid-Atlantic Coastal Plain, all the high marsh species listed breed within extensive stands of salt-meadow hay with scattered shrubs or clumps of black needle rush and salt grass.

Mosquito Management in Salt Marshes

The Delaware Mosquito Control Section, under Service permits, has controlled mosquitoes on the refuge since its establishment in 1963. We have been working with our State partners to reduce the quantity of insecticides used on Refuge lands and ensure activities are consistent with the Service's policies. Mosquito management is a complicated issue for the Refuge. PHNWR is adjacent to residential beach communities where nuisance issues are amplified. A conflict of interests arises between nuisance complaints, managing refuge habitats for migratory birds, and maintaining and enhancing biological integrity, diversity, and environmental health within the refuge.

Although the refuge does not regard mosquito control, in and of itself, to be a salt marsh habitat management objective, the control of mosquitoes is a State priority and a reality of management of salt marshes in the State of Delaware. There have been three techniques employed to control mosquito populations on the Refuge within salt marsh habitats: use of the chemical adulticide, naled, source reduction using the chemical larvicides, Bti and Methoprene, and a biological control facilitated by open marsh water management (OMWM). These techniques are described in more detail in Appendix A, and discussed under Section 3.5 on Conflicting Habitat Needs.

Climate Change and Sea Level Rise Adaptation

Delaware Bay-wide average salt marsh accretion rates have been estimated to range from 3.0-5.0 mm/yr (Kraft et al. 1989 in Fletcher et al. 1990). The dominant accretionary processes vary according to geomorphic settings. Peat accumulation is important to all wetlands in the Delaware Bay. Vertical accretion driven by peat accumulation is expected to increase in the future in response to sea level rise (Reed et al. 2008). However, salt marshes may only accrete up to a certain threshold rate set by natural processes. The rate of SLR may ultimately exceed and overwhelm the rate of marsh accretion, resulting in stress and potential loss of existing marshes. .

DNREC's Coastal Program is conducting a coastal impoundment accretion rate study. The State has collected baseline data on the sedimentation rates over the last 50 and 100 years in impounded and natural wetlands, by analyzing the presence of radioisotopes (210Pb and 137Cs) in sediment cores. This data can be utilized to evaluate a wetland's ability to achieve optimal habitat benefit under different management strategies and sea level rise scenarios. Correlating long-term wetland sedimentation rates to current wetland elevation will enable a detailed analysis of the potential sedimentation deficits that exist within the impoundments, as compared to the reference wetlands. The elevation and sedimentation gradients between the reference and impounded wetlands can be used to calculate potential future elevation trajectories under different sea-level rise and management scenarios.

For this accretion rate study, monitoring sites were chosen within impounded and reference (natural marsh) sites throughout the State based upon a wetland area change analysis (using a time-series of available imagery), and basins that have been identified as needing detailed study to aid in their management to optimize the future available habitat. Sites studied include: marshes along the Delaware River near New Castle; Ted Harvey Wildlife Area; St. Augustine Wildlife Area; and Prime Hook National Wildlife Refuge.

The early results show that the refuge's salt marshes are keeping pace with sea level rise. Results ranged from 3.1 mm/year to 6.9/mm/year. So, it is imperative that the processes discussed in Objective 1.1 be allowed to proceed naturally.

For further discussion refer to the rationale under objective 1.1.

4.2 GOAL 2. (Forested Habitats)

Manage the biological diversity, integrity and environmental health of Refuge upland and wetland forested cover-types to sustain high quality habitats for migratory birds, increase quality habitat for the endangered Delmarva fox squirrel (DFS), forest interior breeding and wintering landbirds, reptiles, amphibians and other resident wildlife.

Forested Habitats Summary

We envision a composite long term forest management goal, which combines objectives 2.1, 2.2, and 2.3 and their associated strategies that reflect the desired future conditions of a refuge forest matrix complex. This forest matrix complex incorporates the existing upland and wetland forested acreage plus projected restored upland forest acreage, and management actions will be conducted on approximately 1679 acres in the next 15 years. Mechanical silviculture management will generally not occur in hydric soils with the exception of some coastal plain depression swamp areas. A summary of anticipated future forested habitats and management is outlined in Table 11.

Table 11. Future Refuge Forest Habitats

Future Refuge Forest Habitats envisioned in next 100 years and silvicultural management expected over the next 15 years on wetland and upland forest habitats		
Forest Habitat Cover-types	***Forested Acres with Projected Restored Acres***	***Silvicultural Management Expected over the Next 15 Years?***
Southern red oak/heath	295	Yes
Mesic coastal plain oak	193	Yes
Northern coastal plain basic mesic hardwood	35	Yes
Successional sweetgum	181	Yes
Mid-Atlantic mesic mixed hardwood	20	Yes
Red maple/seaside alder swamp	799	No
Atlantic white cedar/seaside alder swamp	10	Yes
Coastal plain depression swamp	355	A Portion (75 acres)
Coastal loblolly pine wetland	91	No
Buttonbush coastal plain swamp cottonwood	3	No
Restored mixed-hardwood-oak dominated areas	870	Yes
TOTAL ACRES	2,903	1,679

These desired future forest conditions include approximately 2,900 acres and minimally taking 100 years to develop, will encompass two core areas of restored mature, upland, mid-Atlantic coastal plain mixed hardwood forest with a high oak component; one core area surrounding red maple-seaside alder and Atlantic white cedar swamp with the second core area restored to upland forest surrounding depressional swamp habitats (See CCP Map 2-10).

Restoring additional upland forested habitats is essential to increase the refuge population size of Delmarva fox squirrels and provide larger forest tracts for breeding, area sensitive FIDS. Conserving forested wetland habitats will provide critical supplemental late winter and early spring feeding habitats for fox squirrels and provide important foraging and stopover habitats for migrating landbirds (Mizrahi et al 2006).

Objective 2.1 (Mixed Hardwood Forest Communities)

During the next 15 years, conserve and enhance existing forest cover-types to conserve forest interior dwelling birds (e.g., bald eagle, black-and-white warbler, wood thrush, scarlet tanager, whip-poor-will, yellow-throated vireo, and Kentucky warbler) and the Delmarva fox squirrel (DFS) using silvicultural prescriptions as needed. These cover types include southern red oak/heath, mesic coastal plain oak, Mid-Atlantic coastal loblolly pine, Northern coastal plain basic mesic hardwood, Mid-Atlantic mesic mixed hardwood, and successional sweetgum forest communities. Mixed Hardwood forest communities are characterized by the following attributes:

- Sustain and enhance mast producing trees (e.g., white and red oaks, hickories, walnuts) greater than 12 inch dbh to comprise at least 40% of the total canopy cover and with shrub canopy closure of less than 30%, providing suitable habitat structure for DFS;
- Mature canopy closure 80% or greater, with a multi-layered tree species profile and with canopy gaps to maximize annual mast production and ensure regeneration of shade tolerant tree species (e.g., oaks); and,
- Oak dominated mixed hardwood patch sizes of greater than 250 acres. Use the presence of long-horned beetle (*Pronius laticollis*) as in indicator species for patch size and environmental health of oak dominated mature forest stands.

Rationale

Ecosystem function of forested habitats in Delaware has steadily declined in the past four decades. The Delaware Nature Society determined that less than 3.5% of the state remained in “anything resembling its natural conditions”. During the developmental boom of 1984-1992, most of Delaware’s residual upland and wetland forested ecosystems became highly fragmented due to increasing development pressures for agriculture and urbanization (ELI-1999). Between 1984 and 1992, Delaware’s human population grew by 14% but the percentage of developed land for urban and agricultural uses increased by 50%, incurring significant forested habitat fragmentation and/or losses (OSP-1998). Today, developmental pressures, especially urbanization, continue to accelerate and outpace state and local comprehensive planning efforts to protect natural areas in Sussex County (Broadkill River Watershed Assessment Report-2007).

A common consequence of the pattern and intensity of urban and agricultural development in Delaware has been the severe fragmentation of an originally connected forested landscape into an unhealthy and dysfunctional patchwork of isolated habitat patches (State-Wide Habitat Gap Analysis Map, CCP Appendix A). Extensive forest habitat loss and fragmentation provided the impetus for the state to designate upland forested blocks greater than 250 acres in size as Key Wildlife Habitats in its Wildlife Action Plan**.** Exotic species are also a concern. Of the 115 tree species found in Delaware, only 60 are native species. At the same time an estimated 273 of Delaware’s wildlife species are characterized as forest-dependent species. While the Delaware Department of Agriculture’s Forest Service owns and manages 9,000 acres, 81% of the state’s remaining forested cover-type is in private ownership (ELI 1991; DNREC 2005).

It has been estimated that there are currently over 1600 vascular plant taxa native to Delaware. Despite this fact, Delaware has lost “the highest percentage of its native species than any other state within the United States”. Key sources of loss of biological integrity, diversity, and environmental health in Delaware are the loss and fragmentation of upland forested and wetland habitats, habitat degradation, proliferation of exotic and invasive species, and serious water quality impairment (ELI-1999; DNREC-2005; Broadkill River Pollution Control Management Plan-2008).

The loss of upland habitats has taken a huge toll on migratory songbirds and forest interior breeding birds that require large contiguous blocks of forested habitat. These include black-and-white warbler, whip-poor-will, cerulean warbler, hooded warbler, and American redstart. Also the severe habitat fragmentation and loss has caused the extirpation of the Delmarva fox squirrel from Delaware (ELI 1999). Many of the songbirds that have experienced regional and state declines are those bird species that are area sensitive to forest fragmentation. The Delaware Natural Heritage Program estimated that 41% of Delaware's historically common forest-dependent birds have been extirpated or today are extremely rare. Declines are attributed to increased nest parasitism by edge species, increased rates of predation, and loss of quality nesting and wintering forested habitats (Heckscher 1997).

Creating and conserving larger patches of contiguous forested habitats are the best strategies to conserve and manage for area-sensitive vertebrate species, especially breeding and migrating songbirds, and the Delmarva fox squirrel. The state plan has targeted many landbird species of greatest conservation need (e.g., summer tanager, black-and-white warbler, yellow-throated vireo, Kentucky warbler, worm-eating warbler, hooded warbler, and veery), as requiring more restored upland habitats and more intensive forest management to increase the size and provide higher quality forest patches (DNREC 2005).

The federally endangered Delmarva fox squirrel (DFS) is a top priority resource. Its short-term viability and conservation recovery on the Refuge will depend on actively managing and improving the current available oak dominated mixed-hardwood habitats. Improving and restoring forested habitats will provide potential to expand the current population size for the squirrel's long-term viability on the refuge, while simultaneously providing for and improving the conservation of forest interior dwelling birds.

Our wildlife and habitat analysis described in the CCP identified the DFS, forest interior dwelling birds (FIDS), and other forest-dependent species as high priority management species, and identified forest habitats as a priority refuge habitat to manage for and restore within the next 15 year horizon. Once high priority forest focal species were identified, their life history requirements served as determinants of future forest conditions on the refuge. This habitat analysis determined that sustaining and enhancing a mature mid-Atlantic coastal plain mixed hardwood forest matrix with a high oak component, juxtaposition around a red maple-seaside alder-Atlantic-white cedar/coastal plain depression swamp matrix is the most important ecological contribution the refuge can make to recover the endangered DFS and conserve forest interior bird species in the region.

The 15 year scope of our CCP falls short of the decades we expect it will take to create and enhance this forest matrix and future desired forest conditions with the expectation that it will take at least 100 years to fully implement some of our forest management goals and objectives. This time frame is based on our prediction of how long it will take to achieve the desired forest matrix composition and structure of existing stands. Reducing forest fragmentation through reforestation projects would ensure the long-term viability of the DFS for the next 100 years. Within this 100 year horizon, our long-term objective is to improve refuge forest habitats by developing a structurally diverse forest in terms of size, class, and growth forms (trees, shrubs, vines, and forbs) within a heterogeneous forest canopy. These forest stands will have canopy gaps, based on habitat suitability models for the Delmarva fox squirrel, that maximizes annual hard mast production of existing oaks and hickories, supports natural regeneration of shade tolerant tree species (oaks), and encourages two to six super canopy trees.

Silviculture management can also be used to reduce the potential impact of gypsy moth and southern pine beetle threats to DFS habitat. The gypsy moth *Lymantria dispar* (L.) and southern pine beetle, *Dendroctonus frontalis* are the two most significant potential disease threats of the forests at PHNWR. Although annual surveys since 1990 for gypsy moth have revealed that insect presence or densities have never reached defoliating levels, oaks are still highly susceptible to gypsy moth infestations. Monotypic stand representing greater than 80% of pines offer the highest risk for pine beetle infestation.

Encouraging the development of mixed hardwood stands and reducing monocultures of pines through silviculture management can decrease the likelihood of spot pine beetle infestation originating from monotypic stands. Assessing disease hazards (high, moderate, and low) in specific areas when cruising timber stands will provide improved information to plan prescribed forest management actions to protect DFS habitats.

Upland forest management enhancement will also benefit nesting and migrating bald eagles on the refuge. The bald eagle (*Haliaeetus leucocephalus)* was removed from the list of endangered and threatened wildlife in July of 2007 by the Service. However, other protections remain in place under the Bald and Golden Eagle Protection Act and Migratory Bird Treaty Act. To provide further clarity in the management of bald eagles after delisting, the Service published a regulatory definition of "Disturb" as it relates to bald eagle management (50 CFR Part 17) plus National Bald Eagle Management Guidelines to ensure that eagle populations will continue to be sustained in the future.

The bald eagle due to its rarity and high level of threats in Delaware remains listed as a state endangered species. The refuge currently has two active bald eagle nests. Some birds disperse off refuge but many birds remain where summer roosts average between 5 to 10 birds and winter Refuge roosts may contain 15 – 25 birds. We will follow the State and National management guidelines when establishing nest and landscape buffer zones for bald eagle protection and actively manage and protect current bald eagle nesting and roosting sites on the refuge which vary in numbers and locations each year.

Climate Change and Sea Level Rise Adaptation

Forest communities are expected to change in the face of climate change, as many tree species shift their ranges northward over time in response to changing conditions. Forest birds, as a group, are generally predicted to adapt well to climate change, with the exception of certain species. The State of the Birds 2010 Report on Climate Change, prepared by the USFWS in conjunction with numerous partners, addresses climate change impacts to various bird groups and attempts to quantify vulnerability on the basis of the following five factors of sensitivity: migration status, habitat specificity, dispersal ability, niche specificity, and reproductive potential (NABCI 2010). Only 2% of forest bird species show high vulnerability to climate change. However, more than half of the species with medium or high vulnerability were not previously considered to be species of conservation concern (NABCI 2010). In other words, climate change effects could pose new challenges for species that are not at high risk today.

Expected shifts in eastern forest community distribution could lead to changes in the avian species communities on the refuge in the long term. The U.S. Forest Service provides predictions on these shifts in their Climate Change Atlas. They incorporated both climate variables and tree-species distributions (to quantify habitat availability) to model the current distribution patterns of 147 common bird species in the Eastern United States (Matthews et al. 2007). The Forest Service used two climate model scenarios to forecast the shift in forest and bird distributions: the Canadian Climate Center model (CCC) and the Hadley Center for Climate Prediction and Research model (Hadley). The two models span the spectrum of predicted climate change using projected atmospheric CO_2 concentrations. Some forest species identified by NABCI (2010) to be especially vulnerable to climate change are predicted by the Forest Service Climate Change Atlas (Matthews et al. 2007) to increase in Delaware, perhaps presenting future conservation opportunities, even if they are not currently priority resources of concern. Examples include Chuck-will's-widow and hooded warbler. Species which are common in the area of the refuge, but predicted to incur a clear shift northward and decline in Delaware, such as the house wren, may serve as indicators that predicted change is occurring.

It is not possible to predict exactly how forest communities or associated wildlife species will respond to climate change, and some of these changes are likely to manifest beyond the timeframe of this plan. However it is imperative to begin managing the refuge now with this challenge in mind. In order to meet the long-term needs of forest-dwelling species as describe above, we will manage refuge forests in a way that minimizes the factors associated with sensitivity to climate change, to the extent possible. This will maximize the likelihood of species persistence or adaptation, as appropriate.

Noss (2001) suggests a number of management guidelines that will promote the resilience of forest ecosystems in the face of climate change. Our forest management strategies for climate change adaptation capture those recommendations which are applicable to a local scale. For example, the refuge seeks to protect its largest patches of forest, which are most buffered by change. The refuge will also utilize prescribed fire and thinning to avoid high-intensity fires. Programs that reduce outbreaks of invasive species, damaging insects, and diseases, also enhance forest health and long-term sustainability. The State of the Birds Report (NABCI 2010) recommends that forest management focus on processes (such as fire regime and hydrology) rather than structure and composition, which will increase the resilience of forests to accommodate gradual changes. The emphasis is on healthy and diverse forests. Indeed, as Noss (2001) notes, good forest management principles are largely the same in the face of a changing climate as they are during more static conditions.

Sustainable forest management is the practice of managing forest resources to meet long-term forest goals while maintaining the biodiversity of the forested landscape. The primary goal is to restore, enhance and sustain a full range of forest values. One of those values is the forest's ability to sequester carbon. Carbon sequestration is one mitigation strategy used to offset effects of climate change. The U. S. Forest Service provides widely-accepted calculations of carbon stored in various forest types (Smith et al. 2004). Opinions in the literature regarding the effect of active forest management on carbon sequestration capability of forests are not consistent among scientists (Nunery and Keeton 2010, Hennigar et al. 2008). Management of refuge forests will be focused on providing wildlife habitat, and as such would not generally involve intensive or widespread harvest of trees. Practices may include supplemental planting of poorly stocked lands, age (rotation) extension of managed stands, thinning and/or fire management and risk reduction. These practices are consistent with refuge objectives to promote healthy native forests, and also support the ability of refuge forests to sequester carbon effectively. These strategies also support the carbon sequestration activities within the Service's proposed climate change objectives, as outlined in the draft strategic plan for responding to accelerating climate change (USFWS 2009b).

Objective 2.2 (Mixed Hardwood Forest Restoration)

In the next 15 years reduce forested habitat fragmentation and promote habitat connectivity between upland forest patches to improve quality habitat for the Delmarva fox squirrel (DFS) and conserve focal forest interior dwelling birds. Restore appropriate "old field" and cropland areas to forest to reflect the historic range of variability for mature upland forest vegetation to sustain the long-term viability of the DFS. Create approximately 870 additional acres of forested habitats to maintain at least two core habitat patches (~435 acres/patch) with connecting corridors. Expand forested habitat acreage will provide greater opportunities to increase the Refuge's DFS population size and benefit migratory landbirds.

Rationale

Population numbers and refuge acreage to improve DFS management on the Refuge are based on the latest scientific information from population analysis modeling data for the Delmarva fox squirrel. Managing for conditions that benefit DFS will simultaneously conserve and protect migratory birds of greatest conservation concern.

Contemporary human activities and land use changes have extirpated DFS from Delaware's landscape, while habitat fragmentation of the Refuge's upland habitats has been one of the primary factors in limiting the expansion of DFS numbers. Although Refuge populations have been stable since the re-introduction of squirrels in 1986 and 1987 (25 squirrels ± 15), this small population size has little probability of being sustained for the long term with current Refuge habitat acreage.

The most recent population viability analysis (PVA) data has been incorporated into reforestation objectives. From PVA data, a minimum viable population (MVP) on the Refuge of 130 individuals would be the smallest number of individuals required to maintain a population with a 95% probability of persisting for 100 years. This provides a quantitative measure for sustaining DFS on the Refuge for the long term. Reforesting 700 to 800 acres and creating new habitat would take 50 to 100 years for areas to mature with the potential of providing habitat for at least 250 individuals.

Reducing habitat fragmentation by reforesting the Refuge's landscape also increases carbon sequestration at our location, addresses long term habitat needs and requirements to sustain a healthy DFS population and simultaneously provides conservation benefits for focal breeding forest interior dwelling birds (FIDS) and other migratory landbirds.

The loss of upland forests has taken a huge toll on migratory songbirds and forest interior breeding birds that require large contiguous blocks of forested habitat. These include black-and-white warbler, whip-poor-will, cerulean warbler, hooded warbler, and American redstart. The severe forest habitat fragmentation and loss has caused the extirpation of the Delmarva fox squirrel from Delaware (ELI 1999). Many of the songbirds that have experienced regional and state declines are those bird species that are area sensitive to forest fragmentation. The Delaware Natural Heritage Program estimated that 41% of Delaware's historically common forest-dependent birds have been extirpated or today are extremely rare. Declines are attributed to increased nest parasitism by edge species, increased rates of predation, and loss of quality nesting and wintering forested habitats (Heckscher-1997).

Forest interior dwelling species (FIDS) require large forest areas to breed successfully and maintain viable populations in the future. This diverse group includes songbirds (tanagers, warblers, and vireos) that breed in North America and winter in Central and South America, as well as residents and short-distance migrants, like woodpeckers, owls, hawks, and eagles. According to Breeding Bird Survey (BBS) data since 1966 there has been a 60% decline in occurrence of individual birds of neotropical migrant species in Maryland and an 83% decline in Delaware from 1980 to 2007 (Sauer et al 2008). Many factors are contributing to these declines but the loss and fragmentation of forests in breeding grounds in North America and the Delmarva Peninsula is today playing the most critical role in these declines (USDA 1996: Jones et al 2001).

The conservation of FIDS requires the inclusion of their nesting requirements including minimal area as well as structural characteristics of their habitat. As continental or regional populations of various forest bird species decline, there is more concern over the number of breeding pairs necessary to conserve appropriate gene pools. Increasing available contiguous forest patches helps to provide more breeding areas to retain more species of the forest-breeding avifauna in the Middle Atlantic State (Chandler et al 1989). Increasing the size of refuge forest tracts supports more pairs of focal bird species (Blake et al 1984) and provides greater food resources for migrating and wintering landbirds.

The DFS acts as an "umbrella species" not only by encompassing the structural nesting characteristics of FIDS but also providing for a wide variety of other forest-dependent species. Expanding forest acreage and baseline habitat to meet DFS life history requirements also provides a wide variety of ecological forest benefits. These forests provide a more complete ecosystem of plants and animals that sustain greater numbers of target wildlife species, protect and restore seed dispersal and nutrient recycling processes, and buffer Refuge wetland and aquatic ecosystems from pollution.

Many of the refuge's upland fields proposed to be reforested in accordance with objectives 2.1 and 2.2 have been part of the refuge's cooperative farming program. In the past, the primary objective of the farming program was to provide food for certain waterfowl species (mallard, American black duck, northern pintail, and Canada geese during the fall, winter, and spring. A secondary objective of the farming program was duck production where croplands in grass/clover stages of rotations were designed to provide nesting habitats for ducks. In recent years, duck species seldom or never used cropland field habitats due to plentiful wetland and aquatic habitats available on Refuge marsh habitats. Sufficient natural foods are also produced to satisfy the needs of Canada geese in these habitats, especially if measures are taken to reduce snow goose numbers. Also, waterfowl production is no longer a management objective for Prime Hook NWR. In addition, the elimination of farming on the refuge is consistent with recommendations in the Service's Final Environmental Impact Statement on the Management of Light Geese (USFWS 2007), which encourages refuges to reduce areas planted to agricultural crops that serve as a supplemental food source for overabundant greater snow geese. Reforestation of a portion of these previously-farmed acres better serves numerous refuge objectives.

Climate Change and Sea Level Rise Adaptation
Further discussion can also be reviewed under Objective 2.1.

Corridors provide connectivity and improve habitat viability in the face of conventional challenges such as deforestation, urbanization, fragmentation from roads, and invasive species. Because dispersal and migration become critical for species of all taxa, as vegetation shifts and conditions change in response to climate changes, corridors also offer a key climate change adaption tool. Management of connectivity between protected habitats is an important conservation strategy (Hannah et al. 2002). Reforestation provides an opportunity to increase connectivity of forested habitats. In many areas, forested riparian corridors provide connectivity among conservation units.

Reforestation, rather than relying on local seed sources and natural succession, can proactively incorporate individuals from a wide range of localities, and perhaps should emphasize sources from lower elevations or latitudes (Noss 2001). This has the potential to increase genetic diversity in the forest which may promote genetic adaptation to climate change as local conditions evolve over time. Choosing planting sources from lower elevations or latitudes anticipates the expected species range shift northward expected by most scientists for eastern tree species (Iverson and Prasad 1998). In addition, this objective promotes the implementation of practices, such as soil preparation, erosion control, and supplemental planting to ensure conditions that support forest growth following establishment.

Increasing forest and tree cover provides additional benefits for mitigation of greenhouse gases through carbon sequestration. Regenerating or establishing healthy, functional forests through afforestation (on lands that have not been forested in recent history, including agricultural lands) and reforestation (on lands with little or no present forest cover) contributes to carbon sequestration on the refuge. Forest patches should be sufficient in size to function as a community of trees and related species. Forests planted on land not currently in forest cover will likely accumulate carbon at a rate consistent with accumulation rates of average forest cover in the region (Matthews et al. 2007). Therefore, carbon sequestered by afforestation activities can be assumed to occur at the same rate as carbon sequestration in average Delaware forests. These strategies also support the carbon sequestration activities within the Service's proposed climate change objectives, as outlined in the draft strategic plan for responding to accelerating climate change (USFWS 2009b).

Objective 2.3 (Wetland Forest Communities)

Protect and manage 1,238 acres of forested wetland cover-types with less than 10% invasive species for breeding and migrating birds of greatest conservation need identified in DWAP, BCR30, and PIF 44 plans and provide critical late winter and early spring feeding habitats for Delmarva fox squirrel. Improve habitat quality and manage appropriate patch sizes (>250 acres) for breeding Acadian flycatcher, prothonotary warbler, yellow-throated vireo, migrating and wintering landbirds, and other species of conservation concern (e.g., carpenter frog, hydrangea sphinx).

- Wetland refuge cover-types targeted for conservation and protection include red maple/seaside alder swamp, Atlantic white cedar/seaside alder saturated forest, Coastal Plain depressional swamp, Coastal loblolly pine wetland, buttonbush coastal plain pond, and cottonwood swamp.

Rationale

Breeding and wintering birds

In the BCR 30 and PIF 44 plans, Swainson's warbler, Cerulean warbler, Kentucky warbler, Acadian flycatcher, Yellow-throated vireo, and Prothonotary warbler are all species associated with forested wetlands and have high conservation concern scores within the mid-Atlantic Coastal Plain Region, as well as in Delaware (DNREC 2005). The following are brief descriptions of focal species habitat requirements:

> *Yellow-throated vireos* utilize a diversity of forest types from mixed upland forests to mature deciduous they appear to reach their highest densities in forested wetlands. However, it has been suggested that they require a high percentage of landscape in forest cover to breed successfully. They generally do not breed in forest interiors but prefer edges and openings (Rodewald & James 1996).
>
> *Prothonotary warblers* select mature deciduous swamp forests during the breeding season. Habitat characteristics include a relatively low, open canopy with a high density of small stems and a variety of natural cavities 2 to 35 feet high over water. As cavity nesters, cavity availability may serve as a limiting factor to habitat selection and use. Flooded breeding areas usually have higher occupancies due to greater numbers of nest sites and greater prey species densities (Petit and Petit 1996).
>
> *Acadian flycatchers* typically occupy moist deciduous forests along creeks and streams and wetland forested habitats. It is generally associated with closed canopy forests with an open understory. Nests are also placed near or over water. Acadians have been shown to be area-sensitive with populations only reaching 44% of maximum breeding densities in patches below 70 ha (168 acres) (Whitcomb 1981).

Rare Forested Wetland Flora and Fauna

The mid-Atlantic Coastal Plain forested wetlands include a highly diversified gradient of forest types (Cowardin et al 1979). On the Refuge this diversity is typified by some of the rarest communities remaining in the Delaware landscape. These include Red Maple/Seaside Alder Swamp, unique in Delaware and found nowhere else in the state, Coastal Plain Depression Swamp, Atlantic White Cedar/Seaside Alder Saturated Forested, Coastal Loblolly Pine Wetland, Swamp Cottonwood Coastal Plain Swamp, and Buttonbush Coastal Plain Pond (McAvoy et al 2007). These habitats are dominated by woody species that are adapted to tolerate saturation of the root zone for varying duration and frequency throughout the growing season. Nationally and locally, forested wetlands have also experienced dramatic fragmentation and losses. Much of this loss has been due to the harvest, filling or draining of forested wetlands for conversion to agriculture or urban development (Cowardin et al 1979; ELI 1999). As with upland forests, occupation of these habitats by forested wetland-dependent birds is influenced by a number of factors including patch size, vegetation structure, and hydrology.

Several studies and inventories have been conducted by the DNHP in 2004 and 2005 of Refuge forested wetland communities contracted by the Service (McAvoy 2007). These inventories and studies were part of the Refuge's CCP preplanning efforts to assess the current status of its natural resources. Botanical and zoological surveys focused on identifying the presence/absence of rare flora and fauna and assessed the current condition of the Refuge's biological diversity. Survey data identified a diverse assemblage of rare flora and fauna in the following refuge forest community types: Red Cedar Maritime Forest, Coastal Plain Depression Swamp, Atlantic White Cedar/Seaside Alder Saturated Forest, Swamp Cottonwood Coastal Plain Seasonal Pond, and Coastal Loblolly Pine. A description of rare flora and fauna found within these habitats is located in *Chapter 2, Section 2.4 Current Refuge Condition Tables 2-7 and 2-8.*

Notable Flora: Within the Coastal Plain Depression Swamp community type about 25 individuals of the state-rare cattail-sedge *(Carex typhina*, S3) in Unit III along with scattered colonies of slender blue-flag iris (*Iris prismatica*, S2) were recorded by DNHP. Both species are growing in closed canopy and would prefer more sun to expand populations. This could be achieved by selective thinning or girdling some adjacent trees in the areas (McAvoy & Coxe 2007). Several rare plants were inventoried in Atlantic White Cedar/Seaside Alder Saturated Forest growing in association with Atlantic White Cedar. These species included: seaside alder, S3, G1), coast sedge *(Carex exilis, S1)* bayonet rush *(Juncus militaris, S2)* and flattened pipewort (*Eriocaulon compressum, S2)* (McAvoy 2007). Within Coastal Loblolly Pine Wetlands, the southern twayblade orchids (*Listeria australis, S3)* distribution and abundance is significant. Two locales have been documented with 500 to 1,000 plants occurring between both locations. This species can easily be overlooked due to its small size (15 cm/6 inches) and ephemeral nature (blooms in early spring and persists for only a few weeks). Also growing here is Walter's Greenbriar (*Smilax walteri, S3)*. This species is an uncommon woody vine in Delaware that is an obligate wetland species and prefers swampy habitats. The fruit of Walter's greenbriar is red in color, as opposed to other greenbriar species with black fruit.

Notable Fauna: Most (S1) species were directly associated with large tracts of shrub swamps bordering Prime Hook Creek in Unit III either as residents of open water along the creek, as associates of host plants occurring within the shrub swamp, or as residents of the peat wetlands and bogs embedded within forested wetland habitats. The State Zoologist emphasized the need for future inventories as there is a high probability that many additional rare or uncommon species of Delaware will continue to be discovered on the Refuge. The refuge report (2007) states, "it is possible that nowhere else on the Delaware Coastal Plain maintains such a high concentration of rare invertebrate animal species."

The carpenter frog was found in freshwater wetland forest and emergent wetland ecosystems around the Prime Hook creek drainage. It is a very rare amphibian species in Delaware and the Refuge's populations is only one of two that are left in the state (Heckscher 2007). The great purple hairstreak is another insect species of very high concern in Delaware (DNREC 2005). This butterfly's host plant is mistletoe *(Phoradendron flavescens)* and a large concentration of this parasitic plant occurs on the refuge. Adjacent fallow fields and open wetland areas where adult nectar plants occur, such as milkweed, several species of goldenrods, and buttonbush, provide important food resources for this and other lepidopteran species (McAvoy & Heckscher 2007).

Hydrangea sphinx was found in several locations throughout the Refuge's freshwater shrub and swamp communities. However, it is very rare across the Delaware landscape. The last confirmed state record prior to the Refuge discovery in 2004/2005, was in 1886 (Heckscher 2007, Jones 1928). Host plants for this species are buttonbush *(Cephalanthus occidentalis)* and waterwillow *(Decodon verticillatus).*

Praeclara underwing *(C. praeclara)* populations were found in Red Maple/Seaside Alder along Prime Hook creek Coastal Plain Depression Swamp, and Coastal Loblolly Pine Wetland Forest. The host plant for this species is red chokeberry *(Aronia arbutifolia).* Due to its rarity in the state landscape DNHP suggested making this species and its host plant a conservation target on the Refuge. Red chokeberry is also a known host plant for *Catocala pretiosa*. Although not found during 2004/2005 surveys on the Refuge, if it is found in coming years, its discovery would warrant consideration as an extremely high conservation target as only a few secure populations are known worldwide (Heckscher 2007).

Although no rare plants were found in the Swamp Cottonwood Coastal Plain Pond community, the presence of the rare marbled underwing *(Catocala marmorata*) was recorded and considered highly notable by the DNHP. It is state, regionally, and globally rare and an uncommon species in Delaware (S1, Tier 1, G3). The species was found with its suspected host plant swamp cottonwood *(Populus heterophylla)*. This species is the largest underwing moth in eastern North America and is confirmed from only one other location in the state of Delaware. From a global perspective, the marbled underwing in the rarest animal species recorded by the DNHP with the possible exception of state record firefly species *(Photuris pyralomimus)* and new Delphacid species to science, a plant hopper secured from the Refuge's peat bog community currently being studied for taxonomic classification.

Climate Change and Sea Level Rise Adaptation
Wetlands with long periods of inundation or surface saturation during the growing season are especially effective at storing carbon in the form of peat, though there are uncertainties associated with carbon storage in wetlands. Riparian wetlands can also capture carbon washed downstream in litter, branches, and sediment. Because they accumulate sediment and bury organic matter, floodplain and tidal wetlands, including forested wetlands, are especially effective as carbon sinks. These lands also reduce nutrient, sediment, and other pollution into the Delaware Bay and other bodies of water.

4.3 GOAL 3. (Refuge Impounded Marsh Complex)

Maintain the quality of the wetland habitats within and surrounding the refuge's wetland impoundment complex for migrating shorebirds, breeding rails, wading birds, American black ducks, and migrating and wintering waterfowl consistent with the BIDEH policy. Support other native wetland dependent species and provide fish passage and nursery habitats for anadromous fish species.

Objective 3.1 (Wetland-dependent breeding and migrating birds)

Provide up to 4,200 acres of healthy impounded/semi-impounded brackish wetlands and salt marsh to meet the needs of a wide variety of wetland-dependent migratory birds, including rails, bitterns, terns, migrating shorebirds, and migrating and wintering waterfowl, by restoring salt marsh vegetation communities and natural wetland processes in the impounded wetlands in Unit II and Unit III. Successful restoration will include the following elements:

- Restoration of the natural tidal range and salinity with a physical connection with the marine environment for exchange of nutrients, organic matter, and biota
- Restoration of the natural sediment budget to counter wetland subsidence
- Improvement of water quality realized by restored salinity and pH
- Control of invasive plants to less than 5% cover, once salt marsh vegetation is established
- Re-establishment of native salt marsh vegetation communities, with a moderate (20-25%) component of open water/mudflats
- Return of native salt marsh wildlife species, including salt marsh obligate birds
- Improvement of estuarine fish and shellfish habitat

Rationale

The refuge's impounded marshes represent large wetland patches greater than 1,000 acres or more, which are attractive to wetland-dependent breeding and migrating bird and significantly contribute to wetland biological diversity and integrity at both the refuge and state landscape levels. Even as these wetlands undergo changes as a result of storm activity and coastal processes, the refuge remains committed to providing high quality wetland habitat for a diverse assemblage of migratory birds, in a manner that is effective and sustainable. The emphasis under this objective is on active restoration of healthy salt marsh and brackish wetland conditions within wetlands formerly managed as freshwater impoundments. This shift in habitat management serves as an immediate response to manifestations of sea level rise and climate change, and a proactive adaptation in anticipation of further future changes. However, given the road infrastructure in place, these wetlands will remain at least partially impounded for the foreseeable future, and thus require active management and restoration. Active management of water levels will continue to play a role in influencing habitat conditions, and potentially as a tool for salt marsh restoration. Management strategies in sensitive freshwater wetlands and restoration in inland wetland areas will still be pursued, to the extent feasible.

The SLAMM model (Scarborough 2009) and the State's Inundation maps (DNREC, unpublished) predict accelerated rates in sea level rise in the next 50 to 100 years. Portions of the refuge's marshes and/or impoundments may have already reached a tipping point. It is important to note that the timeframe of impoundment management has been relatively short on the refuge, in relation to the timeframe of natural coastline processes. Relatively speaking, freshwater impoundment management is not a long-standing management regime on the refuge. It was conceived to meet valid wildlife management objectives. However, it was established in part using existing roads as dike infrastructure, which had not been formally engineered for long-term water level management. In the development of a Memorandum of Agreement with DNREC, during the time the impoundment infrastructure was established, it was acknowledged that the lifespan of the facilities would be 20 years, a time span which has now passed. Evidence from numerous sources, as described in Chapter 3, clearly indicate that the wetlands on the refuge were historically salt marsh, although there had always been areas of freshwater marsh due to natural freshwater inputs and/or altered hydrology resulting from human activity.

As information in Chapter 3 of the CCP outlines, portions of the managed impoundments are losing ground to sea level rise. While the visible vegetation and wildlife response was favorable during the decades of impoundment management, significant problems were developing beneath the surface. For example, Unit II is accreting new sediment at a pace that is half the documented rate of local sea level rise. It is not reasonable to expect that such a large deficit in "elevation-capital" can be recovered within Unit II utilizing freshwater impoundment management strategies. Freshwater marshes dominated by annual vegetation differ from salt marshes in that predominantly annual wetland plant vegetation contributes to high above ground biomass, whereas the persistent below-ground organic matter of perennial vegetation, such as that found in tidal salt marshes, make greater contributions to vertical accretion (Cahoon et al. 2009). Impounded freshwater wetlands would be difficult and costly to re-establish, and more importantly are not sustainable in a dynamic coastal setting for the long term.

Our refuge goals and objectives strive for successful management of a variety of wetland habitat types, including both salt marsh and freshwater wetlands. But, it is our responsibility to manage for these community types where conditions are appropriate. As our evaluation of the available data illustrates, a shift in management is necessary to ensure healthy wetlands, rather than permit artificially created freshwater wetlands to convert to open water because they are not keeping pace with rising water levels. Although open water environments are not without ecological value, such an outcome would not directly support the wetland objectives outlined in this HMP. It is neither responsible nor sustainable to maintain freshwater impoundments along a coastal environment indefinitely.

Management action will be necessary to stabilize the health of the degraded impounded wetland system. If no active restoration is undertaken, it is unclear how quickly or effectively the wetlands, in

Unit II in particular, would revert to salt marsh vegetation on their own, given the existing elevations and degraded state of the sediments (Williams and Orr 2002). It is also possible that large areas of open water will form instead (Pearsall and Poulter 2005; Williams and Orr 2002; Portnoy and Giblin 1997; DeLuane et al. 1994). The most practical and economical management alternative to re-stabilize the impounded wetlands is carefully executed restoration. Furthermore, an established salt marsh will be able to migrate landward into adjacent uplands, as sea levels rise, in a process that represents the natural adaptation of the coastal ecosystem.

Ultimately, restoration of the refuge impoundments to health brackish and salt marsh will encourage the conditions most resilient to sea level rise, while still providing valuable habitat for waterfowl, salt marsh obligate passerines and waterbirds, shorebirds, and other wildlife. Furthermore, additional healthy salt marsh in the refuge's wetland complex would provide benefits to neighboring human communities that the freshwater impoundments could not provide, or certainly could not provide in a self-sustaining manner. The presence of salt marsh vegetation in coastal marshes can reduce shoreline erosion by dissipating wave energy completely within 100 feet of the shoreline, which in turn increases the potential for sediment deposition (Morgan et al. 2009; Broome et al. 1992). Because they are perennials, salt marsh plants develop extensive root systems that improve soil stability through deposition of belowground biomass, thus over time salt marshes will accrete vertically to better keep up with sea level rise (Cahoon et al. 2009; Reed et al 2008; Knutson 1988), providing a buffer to adjacent uplands. Through greater stability and resilience, a healthy salt marsh will provide neighboring communities with more flood protection than an artificially sustained freshwater wetland or open water. Restoration of salt marsh vegetation within impounded wetlands is a key climate change adaptation approach.

Active restoration is more effective than passive restoration in wetlands with degraded conditions (NOAA 2010). The preferred means of restoration will be the incremental increase in the exchange of tidal floodwaters between the Delaware Bay and at the water control structure in Slaughter Canal. Ideally, tidal restoration will occur gradually over an extended period and will entail concurrent monitoring of environmental response to assess the achievement of project objectives, including assessment of public and stakeholder concerns (Smith et al. 2009). This method is advantageous because the rapid reintroduction of salt water to a system which has been primarily fresh can cause rapid and extensive death of salt-sensitive plants, which can impose further problems with sediment loss, erosion, and subsidence through peat collapse (Smith et al. 2009; Pearsall and Poulter 2005; Weinstein et al. 2000; Portnoy and Giblin 1997; DeLuane et al. 1994). It is difficult to successfully monitor such a rapid change and, regardless of our monitoring and management efforts, the response will be difficult to accurately predict. A critical factor in the restoration design process is to achieve tidal flooding up to the spring high tide elevation in order to restore ecologically sustainable estuarine communities, by restoring sufficient tidal exchange to flood as well as drain the wetland effectively (Williams and Orr 2002).

The refuge must also evaluate and address the elevation of the wetlands to be restored, in relationship to the growth range of desired species (e.g., *Spartina alterniflora*), because elevation is a critical factor in establishment of salt marsh vegetation (Weinstein et al. 2002; McKee et al 1989; Baca and Kana 1986). The sand-starved system may require decades or more to naturally recoup the elevation already lost in portions of the wetland complex, due to peat collapse in the manipulated freshwater sediments. In the absence of sufficient elevation, portions of the wetlands will convert to open water (this has already occurred in some areas). Ideally, open water should comprise only 20% of restored Delaware Bay salt marsh wetlands (Weinstein et al. 1996). Although open water environments are not without value to wildlife, they can contribute to erosion and inhibit the return of salt marsh vegetation, especially in large sites such as Unit II and Unit III (Williams and Orr 2002). Salt marsh vegetation will establish more readily if there is sufficient elevation in place, which in turn will facilitate further accretion and salt marsh development (Boumans et al. 2002). This prompts the consideration of "assisted accretion" through the addition of supplemental sediment by some means (e.g., thin layer deposition of dredge material or modified beach nourishment) and/or through engineering techniques that reduce wind and wave fetch across expanses of open water and encourage the natural capture and deposition of sediment throughout the wetland complex (Weinstein et al 2000). In addition, the refuge will limit the control of *Phragmites* to only areas identified in the Fire Management Plan as a "zero tolerance" zone for the purposes fuels control. Although not a preferred wetland species for habitat value, the presence of *Phragmites* can help to trap sediment, preserve wetland elevation, and reduce peat collapse.

While a carefully monitored, gradual reintroduction of salt water into the impoundment complex is a preferred management option (Smith et al. 2009), the feasibility of such an approach is dependent on some factors beyond the refuge's immediate control. The shoreline, for example, is extremely vulnerable to overwash, but cannot readily be engineered to prevent breaches, and thus the refuge may have little control of water levels and salinity within the impounded wetland without substantial intervention. In addition, it can be difficult and costly to find large amounts of supplemental sediment for restoration of elevation, but the refuge will work with partners to seek such opportunities. The restoration plan for the wetland will include an iterative and adaptive approach to manage incremental restoration in response to observed and measured conditions (Teal and Weinstein 2002). Although the conditions at the refuge are somewhat unique, given the management history, there are examples of successful salt marsh restoration projects throughout the eastern U.S., including in the Delaware Bay, which provide valuable guidance (NOAA 2010; Smith et al. 2009; Herring River Technical Committee 2007; Teal and Weinstein 2002; Warren et al. 2002; Weinstein et al. 2000, 1996; ACOE 1996; Roman et al. 1995; Baca and Kana 1986).

For Unit III, the future of management is less certain, although management capabilities are still somewhat intact, and management infrastructure is not as compromised. The natural freshwater inputs within Unit III dictate that under any management or restoration scenario, it would likely retain more brackish marsh characteristics and vegetation than Unit II would. However, it may also be at risk for new Phragmites invasion. Although the objective for Unit III is also to develop a healthy self-sustaining wetland (rather than continue to manage strictly as a freshwater impoundment), the specific fate of Unit III may depend on the actions taken and outcomes realized in Unit II restoration efforts. It is anticipated that this will be a salt marsh dominated system in the areas dominated by salt water inputs and brackish to freshwater in areas with greater freshwater source. Factors such as the pace of Unit II restoration, how natural storms events may affect the wetland complex, modifications of Prime Hook Rd by DelDOT, when and whether sediment from outside sources are added, etc. may all affect the pace of restoration actions, but not the long-term goal, which is to end up with a habitat that is consistent with BIDEH. The refuge will need to adapt future management direction and actions in Unit III, depending on the progress of management and restoration in Unit II, which directly influences Unit III. Coastal refuges in Region 5 are currently developing a structured decision tool that can be used to weigh the costs and benefits of maintaining an impoundment, and reach a decision about whether to restore or maintain it. Since this model will be science-based, developed through a structured decision-making process, have technical expert review, and consistency with other refuges, Prime Hook NWR plans to use the Coastal Impoundment SDM model to evaluate future management direction for the Unit III impoundment. Currently the refuge is collecting the data necessary to populate the decision model in order to further evaluate management options.

While the active restoration of salt marsh within the refuge's impounded wetlands is the underpinning of this objective, the development of a detailed and site-specific wetland restoration plan is outside the scope of this HMP process. However, a number of potential restoration strategies have been identified in consultation with a wetland management and restoration advisory team. During the latter stages of preparing this the refuge CCP and this HMP, the refuge convened a group of world-renowned wetland management and restoration experts from outside Delaware for a meeting with refuge staff and a number of DNREC scientists and managers. The invited group of scientists included Dr. Donald Cahoon (U.S. Geological Survey, Patuxent Wildlife Research Center), Dr. Norbert Psuty (Rutgers University), Dr. Charles Roman (National Park Service, Cooperative Ecosystem Studies Unit, University of Rhode Island), and Patricia Rafferty (National Park Service, Jamaica Bay Wildlife Refuge, New York). These scientists represent a wealth of experience in studying, managing, and restoring degraded wetlands throughout the U.S.

During a meeting in May 2011, these state, federal, and invited scientists and managers reviewed preliminary monitoring data and toured the refuge's shoreline and wetlands firsthand, and provided feedback and recommendations both at the end of the meeting and during follow-up discussions. The resulting suggestions have been incorporated into the CCP and this HMP (in Chapter 5) as potential restoration strategies. The refuge proposes to continue working with this advisory team as restoration plans are developed and introduced to the public. Potential restoration strategies to be considered are derived from the salt marsh restoration scientific literature, as well as from consultation with this advisory team. The public will be given opportunities to learn about restoration plans as they are developed, and provide feedback to the refuge staff and restoration team. Public involvement is recognized as a critical element for successful restoration projects (NOAA 2010). Some or all of the restoration strategies may be implemented in some combination, as determined to be appropriate, feasible, and fundable, during the later development of a detailed restoration plan.

Objective 3.2 (Manage water quality for trust fishery resources, migratory birds, and resident wildlife)

Over the next 15 years protect and improve the water quality of 6,000 acres of impounded marsh and waterways, aquatic habitats and delineated buffer zones to provide clean water to safeguard and enhance the quality of breeding and nursery habitats for river herring (alewife, blue-back herring), American and hickory shad, striped bass, American eel, and other fishery resources, to conserve healthy populations of fish, breeding and migrating birds and resident wildlife.

Rationale

Many of the refuge's natural resources are water-dependent, and adequate quantities and quality of freshwater are of paramount importance to conserve and manage trust wildlife resources. Protecting healthy aquatic habitats and conserving fish and other aquatic organisms and managing targeted migratory and breeding birds identified in this CCP will require clean water and good water flow and circulation within the refuge impounded wetland habitats. Cyclic ditch cleaning is the only way to preserve good water circulation within the impoundments.

In addition to perpetuating healthy migratory bird populations, the Service is committed to restoring and conserving America's fisheries resources (National Fish Habitat Action Plan 2006). Over one third of the Nation's freshwater and anadromous fish species are threatened. It is increasingly urgent to identify and implement actions that will reverse declining trends in fish health and populations before it is too late. Protecting the health of aquatic habitats and restoring fish and other aquatic resources is a very high Service priority.

The Atlantic States Marine Fisheries Commission data and management plans targeting declining species was used to identify and prioritize refuge aquatic and fisheries resources for this CCP. River herring, striped bass, and elvers are top resources of concern for the refuge. The conservation of river herring (alewife and blue-back herring), striped bass, and other anadromous fish plus the American eel depend on freshwater habitats that are used by spawning adults and required by fry and early juveniles of these species.

4.4 GOAL 4. (Early Successional Upland Habitats)

Maintain, enhance and restore the native vegetation, biological diversity and ecological integrity of early successional upland habitats to create an assorted mosaic of early successional habitats mixed with transitional forested areas to conserve migratory birds, breeding landbirds, endangered species, and to maximize benefits for other priority resources of concern.

Objective 4.1 (Transitional habitats: Grasslands, Shrublands and Young trees)

Within the next 15 years restore and maintain early successional areas to represent the historic range of variability for upland transitional habitats. These habitats will be dominated by native vegetation reflecting several seral-stages that mimic natural conditions. Transitional habitats will usually be small in size and imbedded within a matrix of wetlands and upland forested habitats. Create a continuum of natural habitats to include a mosaic of grassland, transitional, young, and old shrublands, and young forest habitats on 2,000 acres undergoing restoration to native vegetation (including those areas planted in trees or transitioning through natural succession for DFS management purposes).

Maintain at least 20% of the above acreage in an early successional condition (shrubland and/or grassland mix) to meet the needs of priority resources of concern. These habitats will support high priority breeding and migrating birds identified in BRC 30, PIF 44, DWAP and Birds of Conservation Concern (USFWS 2008) lists and include the following: prairie warbler, blue-winged warbler, Northern bobwhite, brown thrasher, whip-poor-will, willow flycatcher, eastern towhee, field sparrow, and Henslow's sparrow.

Rationale

Our habitat vision statement supports the notion that in the next 15 years we will strive to restore Refuge habitats to natural communities and manage for wildlife species dependent upon the native plants representative of the Delmarva Coastal Plain Ecosystem. This includes restoration of several early successional upland habitats consisting of agricultural and fallow "open fields" to natural, native conditions. By managing native plant succession from early pioneering stages through climax communities through seral stages, we will simultaneously accommodate multiple priority focal species that will be able to use a wide diversity of ecological niches that develop with this habitat management scheme. These lands will be managed in a transitional and ever-changing state.

Early successional grassland and shrub-dominated habitats were historically widely distributed throughout the Northeast, including the mid-Atlantic, but are rare today. Historically, coastal areas were susceptible to large disturbance patterns like wild fires and hurricanes, so patches of early successional forests, barrens, and grasslands represented at least 20% of land area cover-types of the coastal state of New England, Long Island, New Jersey, Maryland, and Delaware (Litvaitis 2006). Shrub-dominated habitats are the most altered and most rapidly declining habitat types in the Northeast (Litvaitis et al. 1999; Litvaitis 2006). National breeding bird survey data indicate that populations of thicket specialists (thickets defined as sites dominated by persistent shrubs or seedling to sapling sized trees) continue to also decline in the Northeast (Askins 1998). Bird species that rely on open grasslands and shrublands for breeding are among the highest priority management targets due to the greatest rates in population declines both in the BCR 30 and PIF 44 regions.

The reduction in areas and diversity of shrub-land dominated communities has also taken a toll on obligate invertebrates of this habitat type. Tiger beetle conservation status throughout the northeast also exemplify the rarity of shrublands on the landscape. Two are federally listed and 19 are ranked as S1 by several Heritage Programs throughout the region. Likewise more than two thirds of Lepidoptera listed as S1 and S2 throughout the Northeast are obligates of non-forested early successional communities. The native forbs that grow interspersed in a thicket matrix also support substantial invertebrate richness and abundance (Litvaitis et al. 1999).

Ecological Model for Managing Shrubland Birds: Most early successional communities are temporary and dynamic in nature, constantly changing as more shade-tolerant trees replace sun-loving shrub species. Since old-fields and shrubland habitats are relatively short lived (20-25 years), recurring active management must be conducted to maintain desired habitat structure. Shrubland communities are disturbance dependent, but no single prescription effectively manages every successional community. Given the highly ephemeral nature of these successional communities, maintaining specific stages will require strategic periodic disturbance activities to sustain them and constant monitoring to cue the management actions.

Peterjohn (2006) suggests that it is more practical to direct management towards maintaining generalized categories of shrubland seral stages rather than targeting specific plant community composition. To manage shrubland seral stages on the Refuge, we will use his ecological model for managing breeding shrubland birds in the mid-Atlantic region. These managed successional stages include transitional shrublands, young shrublands, and older shrublands.

Shrubland Bird Ecological Requirements: All the priority shrubland species listed in objective 4.1 utilize old-fields with different levels of woody intrusion. Prairie warblers, field sparrows, and willow flycatcher prefer relatively young "old fields" with scattered shrubs and trees with moderate shrub cover. Neither of these species likes later successional stages where shrubs and/or saplings form dense continuous tangles. By comparison, brown thrasher, Eastern towhee and blue-winged warbler prefer later stage old-fields with moderate to dense shrub cover and white-eyed vireo and yellow-breasted chat also benefit (See CCP-Appendix E Table 6 of focal species life history requirements for early sucessional habitats).

Review of the life history requirements of targeted birds show that none of the shrubland-dependent species has very specialized habitat requirements, so they can be readily placed into the three distinct shrubland bird guilds (Field specialists, ubiquitous species, or multiple habitat species) described by Peterjohn (2006) for shrubland birds in the mid-Atlantic. (See Table 12)

- Field Specialists: Restricted larger (2-20 ha / 5-50 acres) patches of shrubland habitats.
- Ubiquitous Species: Occurring along linear edge habitats and fields, such as bushy woodland edges, roadsides, hedgerows, and other corridors less than 10 meters (33 ft) wide.
- Multiple Habitat Species: Requiring other habitats in addition to shrublands for breeding.

Table 12. Shrubland Bird Ecological Requirements

Shrubland Bird Ecological Requirements	
FIELD SPECIALISTS	***HABITAT REQUIREMENTS***
Field sparrow	Transitional Shrubland
Common yellow throat	Transitional Shrubland
Prairie warbler	Young Shrubland
Willow flycatcher	Young Shrubland
Yellow-breasted chat	Young Shrubland

Shrubland Bird Ecological Requirements	
White-eyed vireo	Young Shrubland
Blue-winged warbler	Young Shrubland
Yellow warbler	Young Shrubland
UBIQUITOUS SPECIES	
Brown thrasher	Young Shrubland
Eastern towhee	Young Shrubland
Blue grosbeak	Young Shrubland
MULTIPLE HABITAT SPECIES	
Northern bobwhite	Transitional Shrubland
Black-billed/Yellow-billed cuckoos	Older Shrubland
Whip-poor-will	Older Shrubland

Restoring, improving, and maintaining shrubland areas interspersed with grassland and forested areas is conducive to creating a continuum of shifting mosaics of various sized patches and configurations that will benefit a large suite of priority breeding and migrating songbirds. For example, many birds of mature forests heavily use shrubland habitats during the postbreeding period. Dense vegetation and abundant fruit resources found in early successional forest and shrubland habitats have been shown to be very important for survival of mature forest birds during the postbreeding period (Vitz and Rodewald 2007).

Abundant fruit resources produced in shrubland habitats provide an easily captured food source but also attract insects, further enhancing foraging opportunities for both adult (AHY) and juvenile (HY) mature-forest dependent birds during migrational periods. Dense shrub cover also decreases the need to move widely in search of food, reduces energy loss and exposure to predators. Fruits have high sugar content that aids in accumulating fat reserves to facilitate migration (Parrish 2000).

The Vitz and Rodewald study (2007) results have shown that during the postbreeding period birds (especially red-eyed vireo, worm-eating warbler, ovenbird, hooded warbler, and scarlet tanager) seek out structurally complex and low vegetation structure ($\geq$ 4.5 m) that shrub and sapling habitats provide. These habitat factors showed the highest capture rates during migration, demonstrating their importance for seasonal frugivores. It was concluded that early successional stands have legitimate conservation value to mature-forest breeding birds as well as early-successional breeding birds, as shrubland habitats promote their survival and improve postbreeding season condition for migrants.

Objective 4.2 (Grassland Bird Habitat Management)

Manage for an interspersion of habitat structures for breeding, migrating and wintering? bird species that utilize grasslands, during breeding as well as non-breeding seasons, by maintaining a mixture of short, medium, and tall native grassland vegetation in areas of the refuge not well-suited to reforestation. This may be accomplished in varying amounts in rotation with shrubland and forest management. This will provide breeding habitats for Northern bobwhite, Northern Harrier, and other obligate grassland nesting birds, and also provide migrating and wintering habitats for Canada geese, shorebird, and songbird species.

Specifically, manage 50 hectares or more of grasslands adjacent to salt marsh habitat to meet the needs of breeding Henslow's sparrows and wintering northern harriers.

- Habitat characteristics include patch sizes of no less than 30 ha (75 acres) in moderately tall grassy vegetation (> 30 cm) with well-developed litter layer, woody species accounting for less than 10% habitat coverage, a forb component of about 25%, and less than 10% of non-native grasses and/or invasive plant species.

Rationale

Grassland birds are those birds that rely on grassland habitats for nesting and include various species of waterfowl, raptors, shorebirds, upland gamebirds, and songbirds that require native grasslands for nesting and other habitat functions. We will use habitat generalizations to create a mosaic of grassland habitat conditions to provide quality food and cover resources for a wide spectrum of grassland nesting and wintering birds.

Grassland bird use will vary with the physical habitat structure, disturbance patterns, and other factors (Table 13). For each bird species, these grassland habitats can provide protective cover for nesting and broodrearing activities in the spring and summer. They provide a diversity of native plants that produce important food items – mostly insects and other invertebrates that include grasshoppers, crickets, beetles, caterpillars, ants, katydids, dragonflies, cutworms, wasps, flies, spiders, snails, sow bugs, etc. for nesting female birds and young. These habitats provide important raptor prey items like mice, voles, shrews, rabbits, groundhogs, snakes, lizards, songbirds and other wildlife species and provide food and cover resources for migrating and wintering Canada geese, Northern bobwhite, black-bellied plover, sparrows, and other grassland-dependent bird species

Table 13. Habitat Preferences of Some Birds using Grasslands

Species	Preferred Grassland Growth			Avoid Woody Vegetation
	Short	Medium	Tall	
Northern Harrier			X	X
Barn Owl	X	X	X	X
Short-eared Owl		X		X
Northern Bobwhite			X	
Willet	X	X		X
Canada Goose	X	X		X
Horned Lark	X			X
Sedge Wren			X	
Black-bellied plover	X	X		X
Bobolink		X		X
Eastern meadowlark		X		
Vesper sparrow	X			
Savannah sparrow	X	X		
Grasshopper sparrow	X			
Dickcissel		X	X	
Henslow’s sparrow		X	X	X

Henslow's Sparrow is one of the fastest declining songbirds in North American and is in danger of extinction within its historic range in the northeast. This decline is due to loss of suitable grassland nesting habitat and hence is a Service and a state species of management concern (USFWS 2008; Steinkamp 2008; DNREC 2005) as well as a high priority species in PIF 44 plan due to drastic population declines of the past 30 years. Henslow's sparrows have been extirpated from the state landscape (last reported May 1982 – Hess et al. 2000) and they previously bred on the Refuge in Unit IV where cattle grazing operations maintained early successional grassland habitats near salt marsh areas up until the late 1970s (pers comm. O'Shea). Along the Atlantic coast, the species bred on the edges of salt marshes before the arrival of settlers (Schneider et al. 1992; Smith et al. 1992). Prior to European settlement, small open grassland habitats within the mid-Atlantic Coastal Plain were maintained by Native Americans within a forested landscape (Pyne 1982).

Although perpetual grassland maintenance is not a focal component of our habitat management program, we have the opportunity to meet the needs of several species of conservation concern. By focusing some grassland management in areas adjacent to high salt marsh, our efforts can target Henslow's sparrow as a priority species while also serving to "umbrella" habitat requirements for other grassland species, such as Northern bobwhite, and for various species of waterfowl, raptors, shorebirds, upland gamebirds, and songbirds that need grassland habitats for nesting and other habitat functions. The Henslow's Sparrow nests in the highest portion of high marsh zones within the marsh/upland ecotone. This habitat is often linear and is characterized by stands of salt meadow hay interspersed with shrubs that grade into patches of switch grass. Availability of switch grass seems to be important to the distribution of these sparrows (Zimmerman 1988 & Smith 1992). Maintaining grassland habitats near high salt marsh areas would also benefit Coastal Plain swamp sparrow, short-eared owl, eastern meadowlarks, migrating savannah sparrow, vesper sparrow, grasshopper sparrow, willet, sedge wren, horned lark, Northern harrier, black-bellied plover and Canada geese. In addition to birds, species such as migrating and resident butterflies, Frosted elfin, American burying beetle, Eastern box turtle, milk snake, least shrew, and rare native plant species would benefit.

As with shrubland management, maintenance of grassland communities will require periodic disturbance, resulting in a range of seral stages over time and/or space. The result of this is a diversity of grassland structure (short, medium, tall) at any one time and/or in any particular place, each potentially serving the habitat needs of different suites of species.

Many of the refuge's upland fields proposed to be managed in accordance with objectives 4.1 and 4.2 have been part of the refuge's cooperative farming program. In the past, the primary objective of the farming program was to provide food for certain duck species (mallard, American black duck, northern pintail, and wood duck) and Canada geese during the fall, winter, and spring. A secondary objective of the farming program was duck production, where croplands in grass/clover stages of rotations were designed to provide nesting habitats for ducks. In recent years, duck species seldom or never used cropland field habitats due to plentiful wetland and aquatic habitats available on Refuge marsh habitats. Sufficient natural foods are also produced to satisfy the needs of Canada geese in these habitats, especially if measures are taken to reduce snow goose numbers. Also, waterfowl production is no longer a management objective for Prime Hook NWR. Finally, the elimination of farming on the refuge is consistent with recommendations in the Service's Final Environmental Impact Statement on the Management of Light Geese (USFWS 2007a), which encourages refuges to reduce areas planted to agricultural crops that serve as a supplemental food source for overabundant greater snow geese. Management of a portion of these previously-farmed acres as grassland and other transitional habitats better serves numerous refuge objectives.