

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 (^{210}Pb and ^{137}Cs) 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		
<i>Forest Habitat Cover-types</i>	<i>Forested Acres with Projected Restored Acres</i>	<i>Silvicultural Management Expected over the Next 15 Years?</i>
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 depression 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 CO₂ 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 \pm 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.

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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 adaptation 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 depression 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.

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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 successional 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
<i>UBIQUITOUS SPECIES</i>	
Brown thrasher	Young Shrubland
Eastern towhee	Young Shrubland
Blue grosbeak	Young Shrubland
<i>MULTIPLE HABITAT SPECIES</i>	
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 (≥ 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 America 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.

Chapter 5. Habitat Management Strategies and Prescriptions

5.1 Development of Management Strategies and Prescriptions

This chapter identifies management strategies and prescriptions to address the habitat management goals and objectives discussed in Chapter 4. Management strategies identify the tools and techniques (e.g., burning, mowing, water-level manipulation, chemical application, etc.) utilized to achieve the habitat objectives. Prescriptions provide the details behind the specific means by which the strategies will be implemented (e.g., timing, frequency, and location). A review of available literature related to potential strategies and prescriptions was incorporated during their development. The identified treatments were selected in consultation with other Refuge biologists, managers, and experts, to ensure their effectiveness. Many environmental factors including wildlife populations, weather, seasonal variations, and habitat conditions affect the selected prescriptions and their ability to achieve objectives from year to year. As such, many of prescription details will be identified in the Annual Habitat Work Plan. Prescriptions outlined herein are discussed on a conceptual level. General management prescriptions are also depicted in HMP Maps 8 – 12.

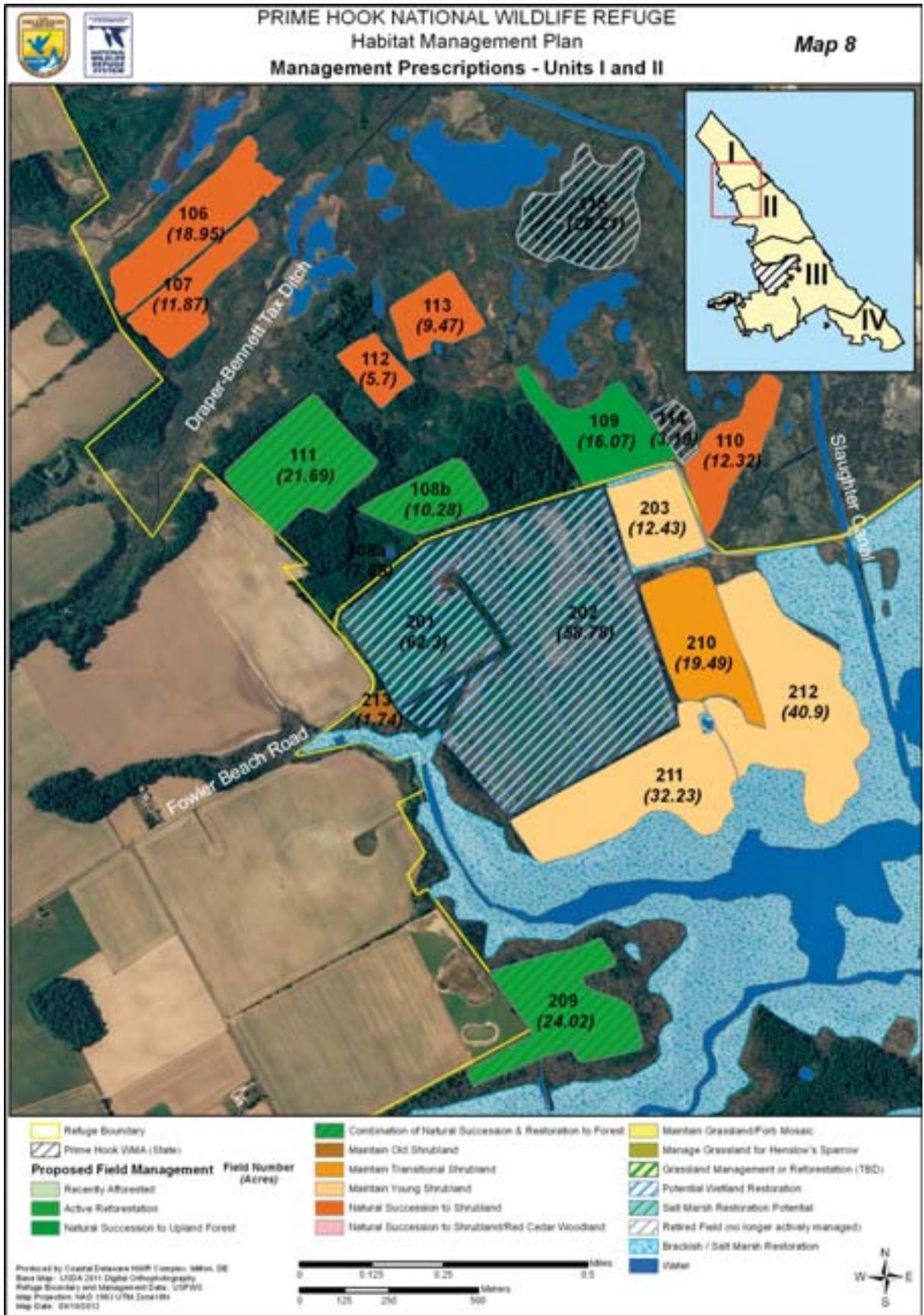
The natural world contains a myriad of extremely complex and dynamic systems. As land stewards and habitat managers, we can never completely understand every aspect of these continually changing systems, but must be ready to react to its ever-changing geophysical, ecological, social, and political factors that influence status of biodiversity and its conservation. Despite the extensive planning efforts undertaken within this Habitat Management Plan, there will undoubtedly be additional need to address changes to physical, ecological, social, political, and financial factors that influence biodiversity and its conservation. Specific details concerning implementation of the inventory and monitoring prescriptions will be identified in the Inventory and Monitoring Plan. The management prescriptions outlined here represents a comprehensive effort to guide management primarily over the next fifteen years. However, it is impossible to predict the full suite of management strategies and prescriptions required over this period.

5.2 Habitat Management Units

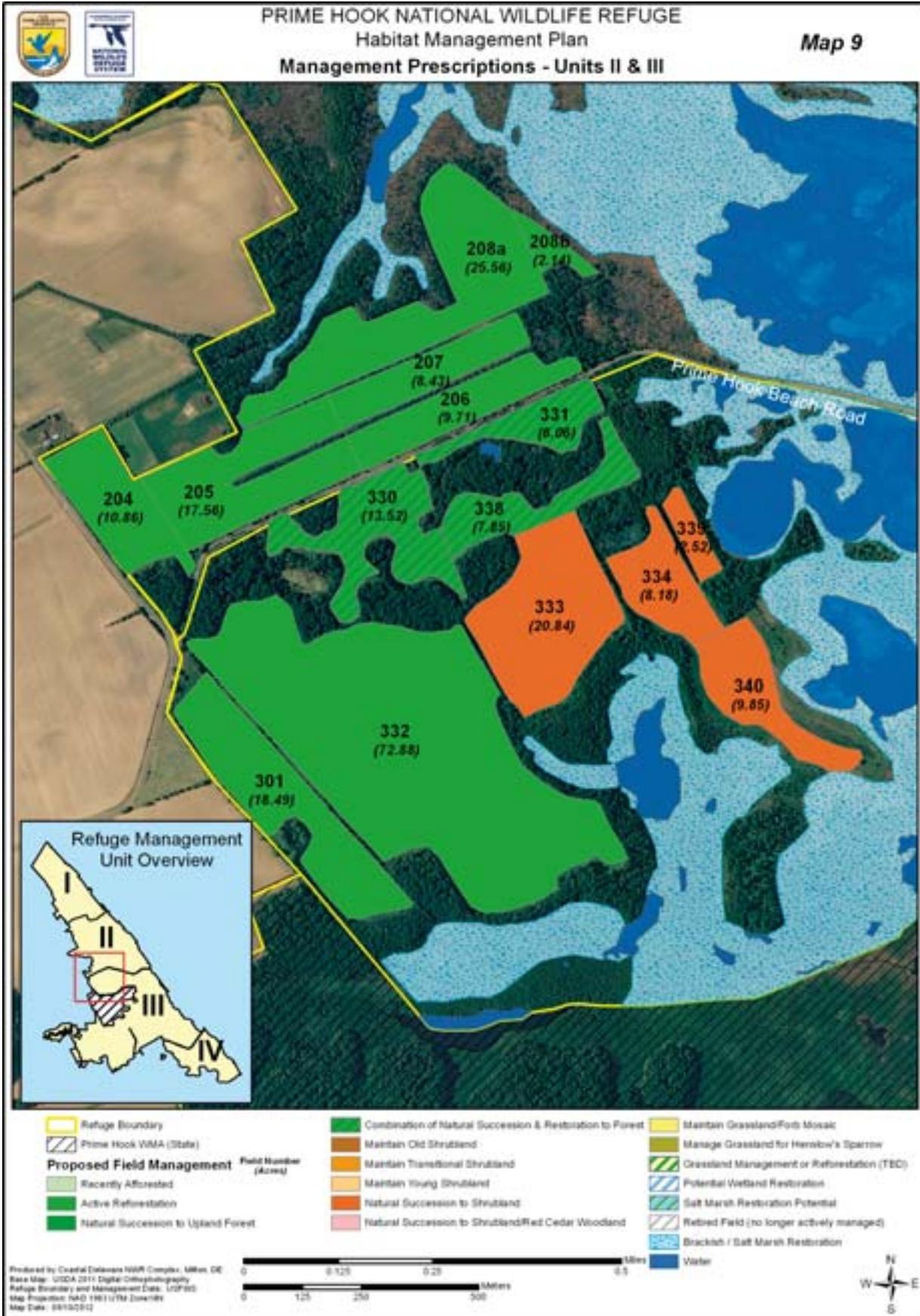
For the purpose of meeting habitat management objectives, Prime Hook NWR is divided into four main Refuge Management Units. These Management Unit boundaries were delineated based on physical features, such as a road or large waterway, as well as refuge boundaries. Within these units, individual fields have been delineated through past management actions, and are numbered to correspond with historical management references. See HMP Maps 3–7 for management unit boundaries and refuge field numbers.

See HMP Chapter 2 Section 2.2 for a description of NVCS Natural and Anthropogenic Vegetative Community Types represented within each Refuge Management Unit (HMP Maps 2–7). Where appropriate, Natural Plant Communities have been summarized by Refuge Management Unit for each Objective in Section 5.3 below. In the case that desired future condition differs from the current condition within a Refuge Management Unit, additional tables are provided to identify field and unit numbers and affected acres.

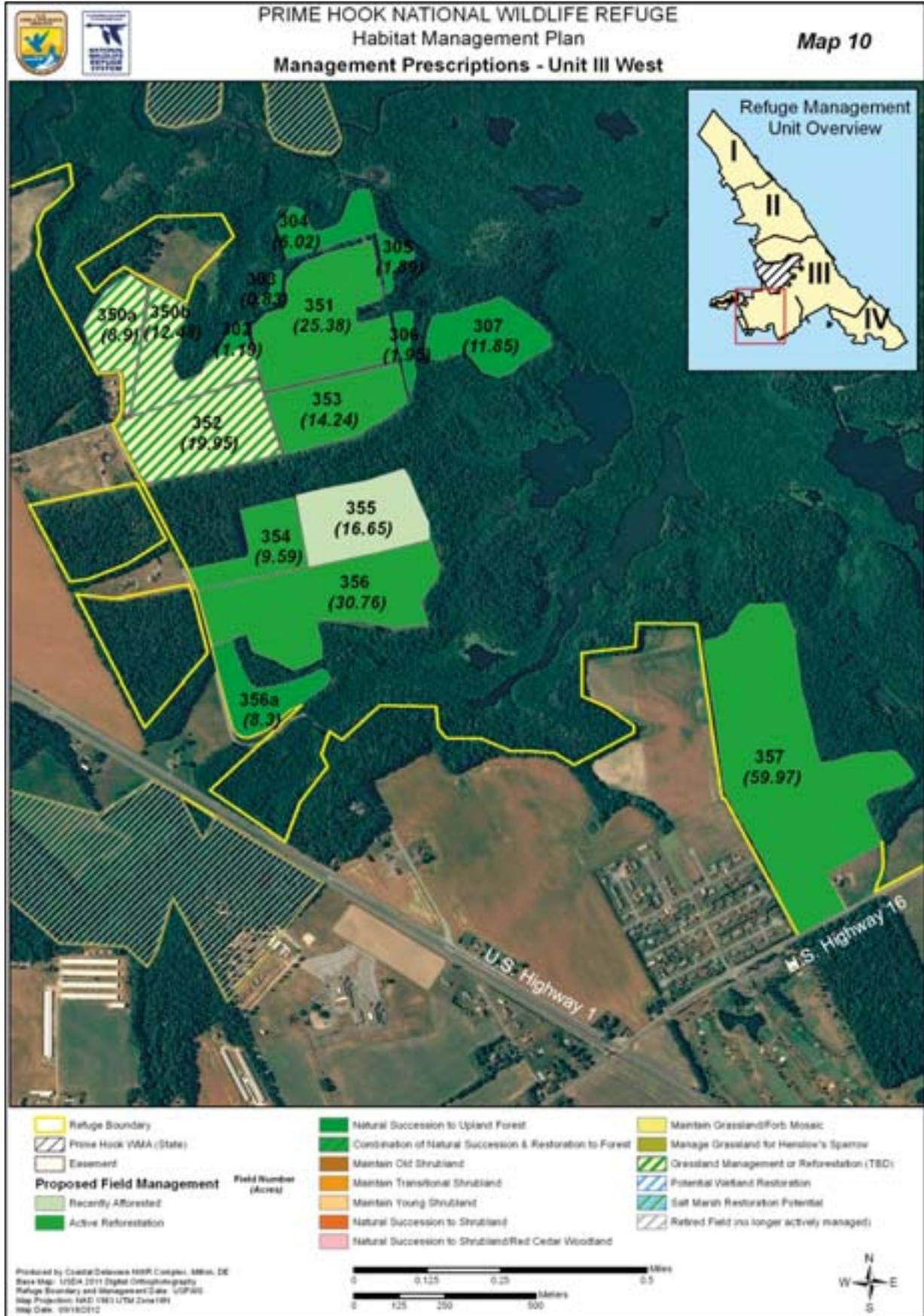
Map 8. Management Prescriptions - Units I & II



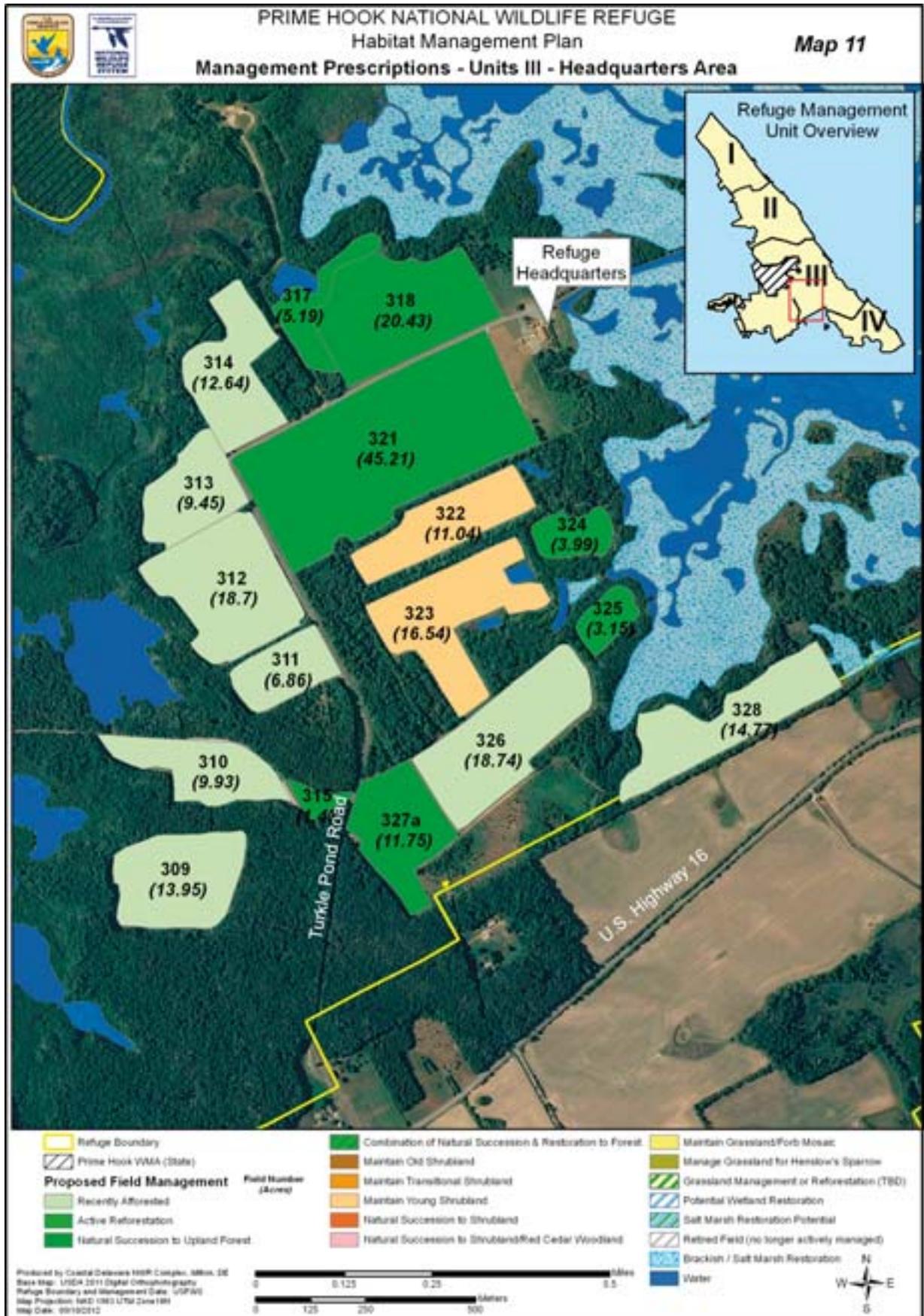
Map 9. Management Prescriptions - Units II & III



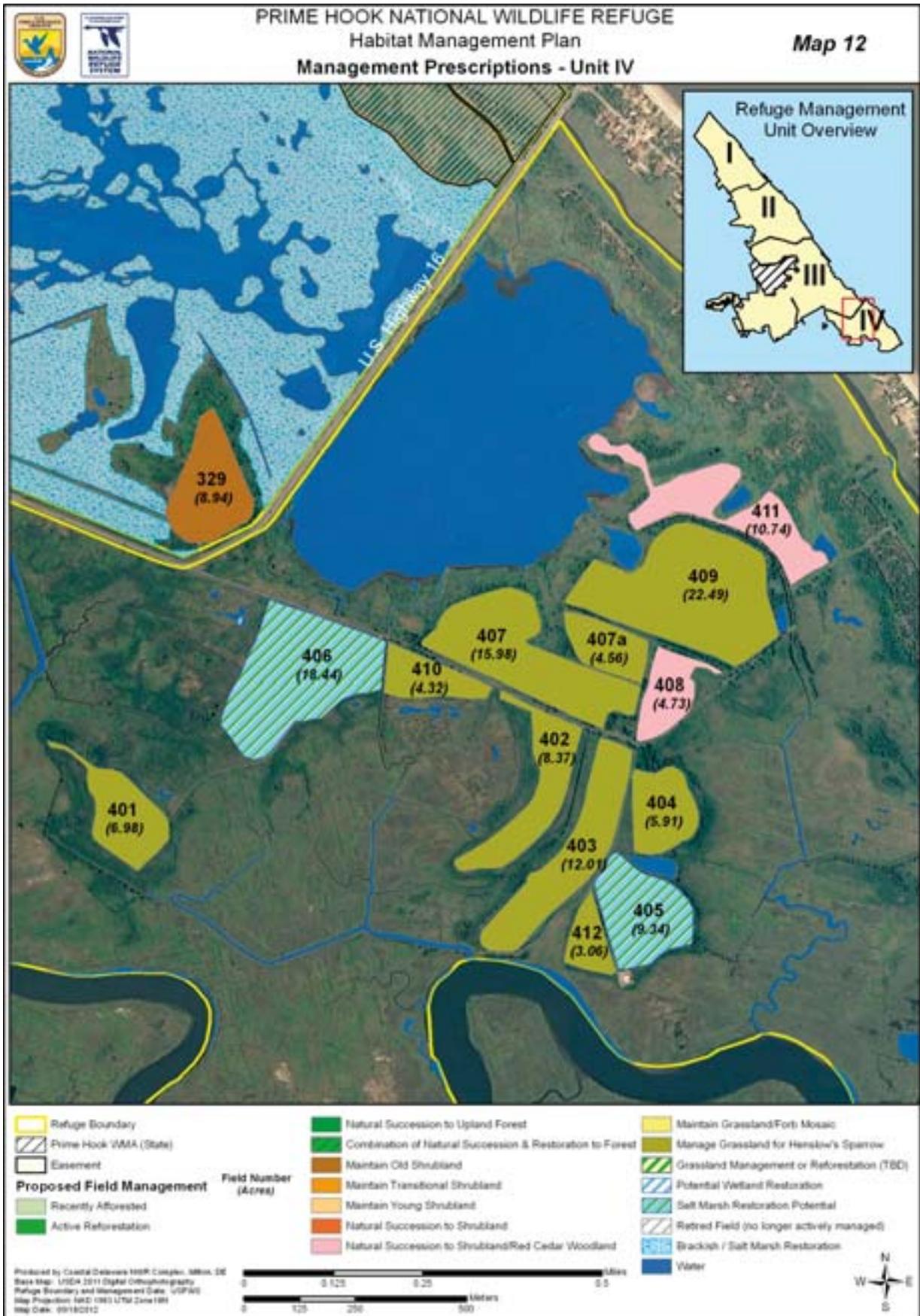
Map 10. Management Prescriptions - Unit III (West)



Map 11. Management Prescriptions - Unit III (HQ Area)



Map 12. Management Prescriptions - Unit IV



5.3 Management Strategies and Prescriptions by Habitat Objective

Objective 1.1 (Overwash, Sandy Beach and Mudflat Habitats)

Table 14. Objective 1.1 Natural Community Types and Acres by Refuge Management Unit

NVCS - Natural Community	Unit #	Acres
Beachgrass/Panicgrass Dune Grassland	I	12.5
	II	22.6
	III	0.0
	IV	0.0
Overwash Dune	I	5.1
	II	4.2
	III	0.2
	IV	0.0
Total Acres:		44.6

Management Strategies and Prescriptions

- Allow the natural processes of inlet formation, sand migration, and/or overwash development;
- Avoid artificial dune stabilization to occur where tidal flow from the Delaware Bay is naturally restoring salt marsh habitats;
- Develop a site-specific restoration plan for Unit II, with the input of an advisory team of subject matter experts, which will include recommendations for short-term and long-term shoreline management which will maximize the success of salt marsh restoration efforts (See Objective 3.1);
- Control invasive plant species (mostly *Phragmites australis* and *Salsola kali*);
- Seasonally protect beach berm, wrack-line, and associated dune edge, and overwash from human disturbance and predators to protect listed breeding and migrating shorebirds, establishing and enforcing nesting area closures from March 1st to September 1st;
- Develop a Refuge-specific piping-plover contingency management plan should piping plovers establish nesting sites on Refuge over-wash areas;
- Consider the use of enclosures to protect state and federally listed shorebird species that establish nest sites on barrier beach island habitats; and,
- Determine the potential number of nesting pairs of American oystercatcher, piping plover and other focal species that could be supported by available overwash, sandy beach, and dune grassland habitats by 2012, to fine-tune protection prescriptions.

Monitoring Elements

Conduct appropriate monitoring and survey programs as funding and staffing permits to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or a reevaluation or a refinement of our objectives. Examples of monitoring or surveys that we may implement include:

- To determine number of nesting pairs of American oystercatcher, least and common terns, and piping plover and estimate productivity, conduct annual surveys during the breeding and nesting season;

- Prevent new invasive species from becoming established by utilizing Early Detection Rapid Response Techniques that detect newly established invasive species and immediately addresses those populations through the appropriate control measure. This approach will incorporate a combination of plant identification and inventories, maintaining updates of new invasive species present in the region, as well as having knowledge of the appropriate management techniques prior to conducting control efforts; and,
- Establish annual habitat assessment protocols of overwash areas and mini-inlet openings and closures along Unit I and Unit II strand beach habitats to monitor expansion and contraction of overwash acreages, creation and plugging of mini-inlets, and tidal flow changes feeding Unit I salt marshes and Unit II impounded wetlands using GPS/GIS tools;
- Conduct shoreline position and topography monitoring along the full length of refuge coastline, consistent with National Park Service (NPS) protocols and in coordination with other Northeast refuges.
- Conduct surveys to determine presence/absence of Northeastern beach tiger beetles to assess the health of overwash, dune grassland, and sandy beach habitat;
- Develop and implement weekly bird use censusing protocols. Utilize data to document the on-going effectiveness of water level management activities and adjust management protocols as necessary;
- Monitor habitat impacts from public use and impacts to resources of concern during the spring and summer periods;
- To maintain suitable nesting habitat for beach nesting shorebirds, monitor presence of red fox, raccoon, feral cats, and other predators and implement predator removal measures in collaboration with USDA Wildlife Services;
- Work collaboratively with DNREC Coastal Programs to set up physical markers on the ground to establish baseline of overwash formations, sea level rise changes, and changes in tidal flow patterns;
- Re-survey and calibrate all refuge water control structures to reflect the true local mean sea level of refuge marshes and water inflows and outlets;
- Reset all gauges to one common vertical datum; and,
- Establish several tides gauges, starting with locations in Slaughter canal in Unit I and Broadkill River in Unit IV.

Climate Change and Sea Level Rise Adaptation Strategies and Monitoring:

- Train USFWS staff to conduct shoreline survey data as per National Park Service (NPS) protocols for Northeast Coastal and Barrier Network (NCBN)-Geomorphological Monitoring Protocol for shoreline position (Natural Resource Report (NPS-NCBN-NRR-2010/185). Protocols include a number of highly detailed SOPs that are intended to ensure scientific consistency and repeatability; Conduct these surveys in early spring (mid-March to late April) and early fall (mid-September to late October) – a period that coincides with the peak expression of seasonal beach variability.
- Co-ordinate Refuge shoreline monitoring efforts with other R5 Coastal refuges to integrate NCBN database to foster DOI-wide sharing of standardized monitoring data. NPS Vital Signs Program-“Shoreline Position Monitoring Protocol” is the first of a series protocols being developed by NCBN; Upcoming protocols, such as documenting and monitoring shoreline topography, will be implemented as they are developed by the NPS.
- Staff will seek training and annual refreshers as needed to maintain competency in:
 - Basic Coastal Geomorphology
 - Mission Planning (Seasonal timing/tides/storms/survey windows using long-term identification of neap tide conditions using NOAA tide gauge data)

- Conducting survey, dealing with shoreline perturbations, collecting benchmarks, preparation of equipment, and keeping informed of protocols and SOP changes and improvements
- Post-survey Processing of spatial data
- Update knowledge of improved and new sampling protocols and SOPs

Objective 1.2 Maritime Shrub and Maritime Forested Habitats

Table 15. Objective 1.2 Natural Community Types and Acres by Refuge Management Unit

NVCS - Natural Community	Unit #	Acres
Atlantic Coast Interdune Swale	I	0.3
	II	20.1
	III	15.8
	IV	30.5
Maritime Red Cedar Woodland	II	1.9
	III	7.8
	IV	66.2
Successional Maritime Forest	II	71.3
	III	90.6
	IV	22.0
Interdunal Switchgrass Brackish Depression	III	0.7
	IV	5.7
Mid-Atlantic Maritime Salt Shrub	I	10.8
	II	7.2
	III	1.5
	IV	40.4
Total Acres:		392.8

Table 16. Objective 1.2 Desired Future Condition/Prescription by Refuge Management Unit and Field Number

Habitat Management Prescriptions for all Units (HMP Map 12)				
Desired Future Condition	Unit #	Field Number	Current Condition	Size (acres)
Natural Succession to Shrubland/Red Cedar Woodland	IV	408	Interdunal Switchgrass Brackish Depression	6.0
		411	Northeastern Successional Shrubland	12.0
Total Acres:				18.0

Management Strategies and Prescriptions

- Maintain and/or enhance native vegetation communities using prescribed fire where appropriate; consult with Service Region 5 fire ecologist to determine, if, when, and where prescribed fire would be appropriate to reduce invasive species, or maintain shrub habitats, or maintain or enhance successional maritime forest community health.

- Prevent new invasive species from becoming established by utilizing Early Detection Rapid Response Techniques that detect newly established invasive species and immediately addresses those populations through the appropriate control measure;
- Permit natural succession to shrubland/red cedar woodland in prescribed fields (Table 16);
- Eliminate the use of mosquito adulticides over these habitats with the exception of a documented public health emergency, to reduce negative impacts on non-target invertebrates;

Monitoring Elements

Conduct appropriate monitoring and survey programs as funding and staffing permits to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or a reevaluations or a refinement of our objectives. Examples of monitoring or surveys that we may implement include:

- Re-evaluate Refuge breeding bird survey points to determine whether they are placed appropriately to monitor birds of conservation concern identified in DWAP, BCR 30, and PIF 44 plans, and establish spring, fall, and breeding landbird survey points in these habitats types, where needed;
- Monitor the little wife underwing moth as an indicator of healthy Red Cedar Woodland and Successional Maritime Forested habitats that contain southern bayberry as a vegetative component;
- Conduct annual habitat condition assessments, survey for invasive species problems, and prioritize treatment areas;
- To evaluate achievement of the objective for breeding and migrating birds conduct bird surveys for priority species. Utilize data to document the effectiveness of management activities and adjust management protocols as necessary;
- Prevent new invasive species from becoming established by utilizing Early Detection Rapid Response Techniques that detect newly established invasive species and immediately addresses those populations through the appropriate control measure. This will incorporate a combination of plant identification and inventories, maintaining updates of new invasive species present in the region, as well as having knowledge of the appropriate management techniques prior to conducting control efforts;
- Evaluate bird use by conducting point count surveys during spring and fall migration and breeding periods in these habitat types;
- To evaluate the effectiveness of prescribed burning to reduce invasive species or maintain shrub habitats conduct post-burn surveys to measure the area, the intensity, and the success of the burn.

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

Table 17. Objective 1.3 Natural Community Types and Acres by Refuge Management Unit

NVCS - Natural Community	Unit #	Acres
Spartina High Salt Marsh	I	75.2
	IV	7.8
Spartina Low Salt Marsh	I	982.0
	IV	774.8
Brackish Tidal Creek Shrubland	I	73.9
	II	3.3
	III	1.3
	IV	17.7

Total Acres: 1,936.0

Table 18. Objective 1.3 Desired Future Condition/Prescription by Refuge Management Unit and Field Number

Habitat Management Prescriptions for all Units (HMP Map 12)				
Desired Future Condition	Unit #	Field Number	Current Condition	Size (acres)
Salt Marsh Mitigation Potential	IV	405	Irregularly Flooded Eastern Tidal Salt Shrub/ Northeastern Successional Shrubland	9.3
		406	North Atlantic Low Salt Marsh/ Atlantic Coast Interdune Swale	19
Brackish / Salt Marsh Restoration Planned	II	N/A	Generic Marsh	2500
	III	N/A	Generic Marsh	1500
Total Acres:				28.3

Management Strategies and Prescriptions

- Assist with the development and use of Region 5’s “Salt Marsh Integrity Index” (SMI) that will result in the development of multi-metric salt marsh integrity (SMI) Index to score habitat condition; use the Index as a performance measure to improve annual habitat management planning and restoration actions when scores are low;
- Enhance/restore any degraded wetlands including salt marsh and adjacent upland habitats that buffer all Refuge salt marsh habitats, and including impounded wetlands within Unit II and Unit III;
- Restore the natural hydrology to tidal marshes whenever feasible and allow natural processes to occur that increase tidal flows to salt marsh habitats;
- Develop an Adaptive Management Framework for *Phragmites* control so that treatments are monitoring and evaluated for effectiveness. The refuge will be using an integrated approach to *Phragmites* control, which will consider restoration of natural processes, herbicides, prescribed burning, biocontrol, and other tools as they are developed;
- Control additional invasive species if and when they are encountered in the salt marsh
- Use obligate salt marsh passerines as indicators of biological integrity, diversity, and environmental health (BIDEH) for salt marsh habitats;
- Within 1-2 years of CCP approval, develop monitoring protocols and an annual biological monitoring and inventory program to document annual salt marsh condition, prescriptive management action taken and response to management actions; and,
- Consider continuing or resuming snow goose hunting to alleviate some snow goose use in salt marsh areas, to reduce salt marsh “eat-outs.”
- Mow fields 405 and 406 annually and keep in reserve as easy salt marsh restoration sites as possible mitigation sites for future Refuge road improvement projects and functional water control culvert replacements

Mosquito Control Strategies

- Modify mosquito Integrated Pest Management (IPM) strategies to conserve and protect nontarget species by eliminating the use of adulticides unless they are required during situations of documented public health emergency;
- Collaborate with Federal and state vector control personnel to develop specific action thresholds then are currently used that would trigger adulticide spray interventions and begin efficacy reporting of all spray events to compile with Service end-of-the-year reporting requirements;

- Prepare a Refuge Mosquito Management Plan in collaboration with the state to address human and wildlife health risks to mosquito-borne diseases and use action thresholds that trigger chemical interventions to be incorporated in a refuge decision-making response matrix;
- Allow populations of native mosquito species to exist unimpeded unless they pose a specifically identified threat to wildlife, domestic animals, and/or human health risks supported by documented data;
- Per Mosquito Management Plan thresholds, permit limited use of larvicides in OMWM systems if appropriate data supports the assertion that the OMWM system has failed to function properly and thus is ineffective for controlling mosquitoes;
- OMWM excavation will be limited to the maintenance of currently existing OMWM systems; OMWM projects may not be expanded nor any new projects initiated on Refuge lands until marsh elevation data is collected and analyzed. Additional studies that address effects on obligate saltmarsh passerines may be required before any decision will be made to resume construction of new OMWM treatments in previously grid ditched marshes.
- Educate refuge users and other public audiences about avian diversity and how it can help buffer human populations from mosquito borne and other diseases like Lyme's disease

Monitoring Elements

Conduct appropriate monitoring and survey programs as funding and staffing permits to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or a reevaluations or a refinement of our objectives. Examples of monitoring or surveys that we may implement include:

- Develop a salt marsh monitoring program which incorporates the R5 Salt Marsh Integrity (SMI) Index, in accordance with guidance still in development;
- Develop monitoring protocols and an annual biological monitoring and inventory program to document annual salt marsh condition, prescriptive management action taken and response to management actions;
- Prevent new invasive species from becoming established by utilizing Early Detection Rapid Response Techniques that detect newly established invasive species and immediately addresses those populations through the appropriate control measure. This approach will incorporate a combination of plant identification and inventories, maintaining updates of new invasive species present in the region, as well as having knowledge of the appropriate management techniques prior to conducting control efforts;
- Continue research using open marsh water management (OMWM) scoring data collected specific to PHNWR salt marsh habitat conditions and incorporate in SMI Index assessments;
- Develop habitat monitoring protocols in cooperation with other R5 refuges to quantify impacts (both positive and negative) of snow goose herbivory, like shorebird and waterfowl use of eat-outs, increases/decrease of moist-soil invertebrate production, loss of low marsh acreage, and quantify wintering carrying capacity of Refuge habitats;
- To evaluate achievement of the objective for obligate salt marsh passerines, conduct bird surveys during the breeding season. Utilize data to document the effectiveness of management activities and adjust management protocols as necessary;
- Develop appropriate monitoring elements for mosquito control, in cooperation with DNREC Mosquito Control Section

Climate Change and Sea Level Rise Adaptation Strategies and Monitoring:

- Within 1 to 2 years, establish a Refuge-wide marsh elevation and water monitoring program, to include the following components and steps:

- Establish 3 monitoring stations within each of two existing salt marsh areas (and an additional 3 stations in each area of impounded wetlands), with surface elevation tables (SETS) and marker horizons, in the same locations of 210Pb and 137Cs radiometric cores currently being monitored on the Refuge; Read SET measurements minimally four times per year (seasonally), but ideally once per month, to track seasonal and periodic storm effects on marsh elevation
- Establish a real-time USGS-type tide gauge on Slaughter Canal to begin to monitor localized storm effects on refuge
- Establish geodetic benchmarks in select upland refuge sites and calibrate to newly established SETS, tide gauges(s), and staff gauges located on water control structures, all to the same geodetic control (such as NAVD 88)
- Conduct RTK-GPS surveys using regional/national protocols to connect prior survey-data points (veg data, groundwater wells, bird points, etc) to same common geodetic control as used above
- After a minimum of 3 years, determine if areas of the marsh with SETS are experiencing shallow subsidence – i.e. is the upper marsh horizon, despite accretionary processes, still losing elevation relative to local Sea Level Rise?
- The stresses imposed by climate change and SLR will force a shift in quantity and quality of available waterbird habitat on local and regional scales. As a means to ameliorate the loss, the refuge will employ the protocols and directives of the Integrated Waterbird Management and Monitoring Project, now under development.
- Permit the natural replenishment of sediments (through overwash) to allow the Unit I marsh to keep pace with sea level rise.
- As new research and monitoring results on sea level rise and obligate salt marsh breeding birds come to light, we may in fact wish to fill/restore extant grid ditches and OMWM systems as an adaptation measure in response to climate change.
- Consult with federal and state coastal scientists and other subject matter experts regarding the most effective way to restore salt marsh within the Unit II (and possibly Unit III) wetland impoundments; Restoration options may include addition of supplemental sediment, use of wave attenuating devices or restoration techniques, planting of desirable species, or a host of other strategies. (See Objective 3.1)

Objective 2.1 (Mixed Hardwood Forest Communities)

Table 19. Objective 2.1 Natural Community Types and Acres by Refuge Management Unit

NVCS - Natural Community	Unit #	Acres
Southern Red Oak Heath	III	289.1
	I	49.6
Mesic Coastal Plain Oak Forest	II	99
	III	43.8
Mid-Atlantic Coastal Loblolly Pine	III	41.5
	IV	9.7
Successional Sweetgum Forest	I	31.2
	II	9.4
	III	88
Mesic Coastal Plain Mixed Hardwood Forest	III	19.2

NVCS - Natural Community	Unit #	Acres
Loblolly Pine-Sweetgum Semi-Natural Forest	III	39
Loblolly Pine Plantation	III	10.6
Pond Pine Woodland	III	7.2
Mesic Rich Forest	I	10.6
	III	24.5
Total Acres:		772.4

Management Strategies and Prescriptions

- Manage refuge forest stands to meet the habitat requirements of Delmarva fox squirrels which are similar enough to also meet habitat requirements of priority forest interior dwelling birds listed as focal forest bird species; Criteria described in Table 20.
- During forest inventories, conduct assessment of potential for each stand to harbor gypsy moth and southern pine beetle using a high, moderate, or low disease hazard rating; assessment should be correlated to habitat suitability for DFS (good, fair, poor);
- Maintain and/or enhance forest health through the development of monitoring protocols for insect/disease vectors
- Treating detected insect or disease infestations may include salvage cuts, thinning, and other mechanical techniques, prescribed fire, and insecticides (e.g., Bacillus thuringiensis var. kurstaki (Btk) or Gypcheck for gypsy moths);
- Participate with other refuges in developing Forest Integrity Index
- Use prescribed fire where appropriate to maintain and enhance habitat structural requirements for the DFS and migratory birds;
- Increase and/or improve active forest management to enhance habitat quality for targeted songbirds through sound silvicultural practices such as thinning, selective cuts, and other stand improvement techniques; These stand improvement techniques will occur in small patches less than 5 acres (2 ha);
- Minimize forest fragmentation; in all stand improvement activities avoid fragmenting larger forest patches when possible;
- Regeneration cuts should be designed in a pattern that minimizes edge; circular or square cuts have the least amount of edge produced;
- Leave uncut forested buffers along creeks, ditches, streams, and adjacent to wetlands habitats; the wider the buffer, the more benefit it will provide to forest interior birds.
- Utilize triggers outlined in Table 20 as thresholds for stand improvement interventions to maintain and enhance wildlife habitat needs for priority focal management species;
- Manage bald eagle nest sites in accordance with State and National Bald Eagle Guidelines (USFWS 2007c), utilizing forest management techniques and/or prescribed fire, and observing recommended time-of-year restrictions and buffer zone guidelines;
- Promote consistent annual mast production by using selection cuts where hard mast trees are greater than 15" dbh to develop larger, well-formed crowns and with a species composition target of 1/3 white oak, 2/3 red oak, and a mixture of hickory and walnut trees (McShea and Healy 2002);
- Den trees and trees adjacent to den trees will not be cut during silvicultural treatments. Adjacent trees provide shade the bole of the den tree, keeping it cooler;
- To promote establishment of den sites, trees interfering with mast tree crown development will be left standing and killed by girdling or using systemic herbicides (BNWR 1994);

- Explore opportunities to supplement the refuge DFS population through translocations; and,
- Field management prescriptions outlined in Table 21, and depicted in HMP Maps 8–11, will add to existing forested communities, and then be managed according to this objective.

Guidelines listed below for desired future forest stand condition(s), suggest that to provide for regeneration of shade intolerant trees, one to three acre patches should be harvested on five to ten percent of the stands. Leaving 4 to 6 trees per acre within these small regeneration cuts will maintain some overstory and use of these harvested sites by forest birds will be more likely. Additionally, some of these “seed trees” may develop into super-canopy trees (defined as large trees > 35 inches dbh with big crowns above the plane of the forest canopy). Patches should be located where regeneration of shade intolerant tree species is present or highly likely. As a general guideline between 30 to 60 percent, preferably 40 to 50 percent, of most stands should be hard mast producing tree species.

Table 20. Objective 2.1 Mixed Hardwood Forest Community Maintenance and Enhancement Prescriptions

Objective 2.1 - Mixed Hardwood Forest Community Maintenance and Enhancement Prescriptions	
Target Forest Conditions	Condition to Trigger Mgmt Action
>80% canopy cover in the stand	< 80% canopy cover in the stand
Basal area 70 to 90 ft ² / acre (16 to 20 m ² /ha)	Basal areas > 100 ft ² /acres (> 28 m ² / ha)
60% to 80% stocking	> 100% stocking
Vines in overstory on 40%-60% of inventory (cruise) plots	Vines in overstory on < 30% of inventory (cruise) plots
“Super-canopy” trees on 10% to 20% of inventory (cruise) plots [= 4 to 6 super-canopy trees per acre]	“Super-canopy” trees < 5% of inventory (cruise) plots
Mid-story canopy cover on 30% to 60% of stand	Mid-story canopy on < 20% of stand
Vines in midstory on 50% to 70% of inventory (cruise) plots	Vines in midstory < 30% plots
Understory canopy cover less 30%	Understory canopy cover > 30% of stand
<30% ground cover occupancy average across inventory (cruise) plots	>30% ground cover occupancy average across inventory (cruise) plots
Regeneration of hard mast tree species (oaks and hickories) on 30% to 50% inventory (cruise) plots	Regeneration of hard mast tree species (oaks and hickories) on < 20% of inventory (cruise) plots
2 to 4 logs/acres that provide coarse woody debris	< 2 logs/acres providing coarse woody debris
4 to 6 cavity trees (snags) > 4 inches dbh/acres	< 4 cavity trees (snags) > 4 inch dbh/acres
1 to 4 large “den” trees or “unsound cull” trees per 10 acres	< 1 large “den” tree or “unsound cull” tree per 10 acres

We expect that many stands have current conditions or site capabilities that may warrant more restrictive forest management options, or multiple management actions, to achieve desired forest conditions. We recognize that there is no single recipe for achieving desired results. Focal species priorities and forest management objectives are going to require evaluation on a site by site basis that involve the skill of foresters and biologists working together to establish site-specific objectives, evaluate current stand conditions, write site-specific prescriptions, monitor pre and post habitat conditions and respective wildlife use of treatment sites, and evaluate results.

Monitoring Elements

Conduct appropriate monitoring and survey programs as funding and staffing permits to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or a reevaluation or a refinement of our objectives. Examples of monitoring or surveys that we may implement include:

- Prevent new invasive species from becoming established by utilizing Early Detection Rapid Response Techniques that detect newly established invasive species and immediately addresses those populations through the appropriate control measure. This approach will incorporate a combination of plant identification and inventories, maintaining updates of new invasive species present in the region, as well as having knowledge of the appropriate management techniques prior to conducting control efforts;
- Establish forest inventory schedules on PHNWR to document stand specific information of tree species composition, health of crown overstory trees, regeneration in stands, presence/absence of exotic insects at damaging levels, stocking levels, and map invasive plants to guide future Refuge forest habitat maintenance, management, and reforestation decisions;
- Improve point-count monitoring surveys for listed forest communities in Objective 2.1; include the monitoring of annual habitat condition and characteristics with associated points to assess bird use; monitoring should capture both breeding and migrating forest bird species;
- Monitor changing bald eagle nesting sites and make public use modifications or other habitat management actions necessary to protect sites during critical nesting periods;
- Use the presence of the long-horned beetle as an indicator species for patch size and environmental health of mature forest stands dominated by oaks; this beetle requires healthy, oak dominated mix-hardwood patch sizes of greater than 250 acres
- Coordinate with the Chesapeake Bay Field Office (CBFO) to implement improved Delmarva Fox Squirrel monitoring techniques, such as motion-activated cameras, as well as trapping and/or nest box checks, as recommended.

Climate Change and Sea Level Rise Adaptation Strategies and Monitoring:

- Reduce the impacts of stresses that can exacerbate the effects of climate change, particularly from wildland fire, insects, and diseases.
- Step up measures to prevent and control the spread of invasive species.
- Prevent or reduce barriers to species migration, such as forest fragmentation.
- Improve forest health monitoring for early detection of climate change impacts.
- Help forests regenerate after disturbances, e.g. through reforestation.
- Support research to better understand forest vulnerability to multiple stressors and to find ways to enhance forest resilience.
- Within one year of CCP completion, conduct a complete forest inventory of forest lands and repeat the monitoring every 10-15 years.
- Consider establishing a continuous forest inventory monitoring system

Objective 2.2 (Mixed Hardwood Forest Restoration)

Table 21. Objective 2.2 Desired Future Condition/Prescription by Refuge Management Unit and Field Number

Habitat Management Prescriptions for all Units (HMP Maps 8-11)				
Desired Future Condition	Unit #	Field Number	Current Condition	Size (acres)
Active Reforestation	II	204	Agricultural Field	10.8
		205	Agricultural Field	17.6
		206	Agricultural Field	9.7
		207	Agricultural Field	8.4
		208a	Agricultural Field	25.6
		208b	Northeastern Successional Shrubland	2.1
	III	301	Agricultural Field	18.5
		332	Agricultural Field	72.9
		351	Agricultural Field	24.2
		353	Agricultural Field	13.6
		354	Agricultural Field	8.5
		356	Agricultural Field	27.4
		357	Agricultural Field	60
Natural Succession to Upland Forest	I	109	Brackish Tidal Creek Shrubland / North Atlantic Low Salt Marsh	12
	III	302 -Lead Shot Site	Successional Sweetgum Forest	12.5
		303	Successional Sweetgum Forest	0.8
		304	Successional Sweetgum Forest	6
		305	Successional Sweetgum Forest	1.9
		306	Successional Sweetgum Forest	2
		307	Successional Sweetgum Forest	11.9
		315	Successional Sweetgum Forest	1.4
		317	Successional Sweetgum Forest	5.2
		318	Agricultural Field	20.4
		321	Agricultural Field	45.2
		324	Northeastern Successional Shrubland	4
		325	Northeastern Successional Shrubland	3.1
		327a	Successional Sweetgum Forest	11.8
		356a	Agricultural Field	8.3

Habitat Management Prescriptions for all Units (HMP Maps 8-11)				
Natural Succession or Reforestation (TBD) to Upland Forest	I	108b	Agricultural Field	10.2
		111	Agricultural Field/ Northeastern Successional Shrubland/ Irregularly Flooded Eastern Tidal Salt Shrub/ Successional Sweetgum Forest	21.7
	II	209	Agricultural Field/ Northeastern Successional Shrubland	24
	III	330	Agricultural Field	13.5
		331	Agricultural Field	6.1
		338	Agricultural Field	7.8
	Total Acres:			

Management Strategies and Prescriptions

- Reduce fragmentation of Refuge forested habitats through reforestation projects to improve management of area-sensitive wildlife, especially endangered DFS and breeding songbirds listed as Refuge Priority Resources of Concern in Appendix E of the CCP - Table 6;
- Use Population Viability Analysis (PVA) modeling data to set Refuge DFS population objectives, refine objectives as new data becomes available and to design core habitat patches for reforestation for the long term viability of Delmarva fox squirrels;
- Design reforestation projects to promote habitat connectivity on the Refuge and improve management of area-sensitive wildlife;
- Work with private landowners and partners to establish safe harbor agreements for DFS;
- Explore opportunities to supplement the refuge DFS population through translocations, as suitable forest habitat is restored;
- Install speed bumps in refuge entrance road to reduce DFS road mortalities on refuge
- Implement field restoration prescriptions outlined in Table 21 and depicted in HMP Maps 8-11;
 - Active reforestation will incorporate planting of seedlings and/or saplings, incorporating recommendations of experienced partners (e.g., USFWS Delaware Bay Coastal Program staff)
 - In the case of active reforestation, attempts will be made to reforest entire individual fields at one time, for efficiency
 - Passive reforestation will involve permitting natural succession, which relies on neighboring seed sources, avian dispersal, etc.
 - In some fields, additional local analysis will dictate if active reforestation or natural succession is more appropriate

Monitoring Elements

Conduct appropriate monitoring and survey programs as funding and staffing permits to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or a reevaluation or a refinement of our objectives. Examples of monitoring or surveys that we may implement include:

- Prevent new invasive species from becoming established by utilizing Early Detection Rapid Response Techniques that detect newly established invasive species and immediately addresses those populations through the appropriate control measure. This approach will incorporate a combination of plant identification and inventories, maintaining updates of new invasive species present in the region, as well as having knowledge of the appropriate management techniques prior to conducting control efforts;

- Continue to work with partners to fine-tune population monitoring methodology, habitat assessment techniques and habitat improvement projects;
- Coordinate with the CBFO to implement improved Delmarva Fox Squirrel monitoring techniques, such as motion-activated cameras, as well as trapping and/or nest box checks, as recommended.
- Assess landbird point count monitoring program and, as necessary, locate new points in areas undergoing reforestation, to monitoring bird community response.

Climate Change and Sea Level Rise Adaptation Strategies and Monitoring:

- Consider the impacts of climate change in selecting planting stock and choosing planting methods (e.g., emphasize sources from lower elevations or latitudes).
- Target riparian areas for reforestation to provide or increase buffers along streams, as well as promote vital habitat connectivity
- Keep careful inventory of acres reforested (amount and type) to quantify carbon sequestration contributions of the refuge into the future.

Objective 2.3 (Wetland Forested Communities)

Table 22. Objective 2.3 Natural Community Types and Acres by Refuge Management Unit

NVCS - Natural Community	Unit #	Acres
Red Maple-Seaside Alder Swamp	III	699.3
Atlantic White Cedar-Seaside Alder Woodland	III	9.8
Coastal Plain Depression Swamp	I	39.9
	II	47.2
	III	248.7
Coastal Loblolly Pine Wetland Forest	I	34.2
	III	56.3
Buttonbush Coastal Plain Pond	III	0.8
Swamp Cottonwood Coastal Plain Pond	III	1.5

Total Acres: 1,137.7

Management Strategies and Prescriptions

- Protect large patches (>250 acres) of habitat structural components required by Refuge priority resources of concern which include yellow-throated vireo, prothonotary warbler, and Acadian flycatcher. Management for these species will also provide critical late winter and early spring feeding habitats for the DFS, migrating landbirds, and other wetland-forest dependent wildlife;
- Schedule prescribed burns to sustain and enhance Atlantic White Cedar communities with adequate precautions to protect extant rare faunal and floral species. Consult with Regional Fire Ecologist for the best habitat management recommendations;
- Reduce and/or eliminate factors contributing to site eutrophication of Swamp Cottonwood Coastal Plain community. Enhance existing and create new forested buffer zones and reconnect fragmented blocks of all forested wetland cover-types to mitigate eutrophication inputs from off-refuge sources;
- Treat current areas infested with Japanese stiltgrass, *Phragmites*, and other problematic invasive plant species. Monitor all cover-types for invasive encroachment on an annual basis and treat when coverage exceeds 10% of the areas;

- For *Phragmites* control, develop an Adaptive Management Framework so that treatments are monitored and evaluated for effectiveness. The refuge will be using an integrated approach to phragmites control, which will consider restoration of natural processes, herbicides, prescribed fire, biocontrol, and other tools as they are developed;
- Restore natural hydrology of Coastal Plain Depressions Swamp communities (UNIT III south of Prime Hook Beach Road);
- Consider selective thinning or girdling trees adjacent to sensitive cattail-sedge (*Carex typhina*, S3) and slender blue-flag iris (*Iris prismatica*, S2) within the Coastal Plain Depression Swamp community;
- Utilize best management practices and other management actions to protect rare plant communities, such as the Red Maple/Seaside Alder community, southern twayblade orchid, and swamp cottonwood, as is feasible and consistent with other management objectives.

Monitoring Elements

Conduct appropriate monitoring and survey programs as funding and staffing permits to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or a reevaluation or a refinement of our objectives. Examples of monitoring or surveys that we may implement include:

- Prevent new invasive species from becoming established by utilizing Early Detection Rapid Response Techniques that detect newly established invasive species and immediately addresses those populations through the appropriate control measure. This approach will incorporate a combination of plant identification and inventories, maintaining updates of new invasive species present in the region, as well as having knowledge of the appropriate management techniques prior to conducting control efforts;
- Establish point-count monitoring surveys for each habitat cover-type listed in objective 2.3 to determine nesting landbird use of targeted wetland forest resources of concern;
- Obtain GPS location data from Delaware Natural Heritage Program (DNHP) to document rare flora and fauna locations on Refuge GIS database;
- Continue inventories for rare species to better determine their distributions on the Refuge through the establishment of monitoring plots and assess conservation status every 3-5 years.

Objective 3.1 – (Wetland-dependent breeding and migrating birds)

Table 23. Objective 3.1 Natural Community Types and Acres by Refuge Management Unit

NVCS - Natural Community	Unit #	Acres
Marsh	I	33.2
	II	918.9
	III	1,314.7
	IV	4.1

Table 24. Objective 3.1 Desired Future Condition/Prescription by Refuge Management Unit and Field Number

Habitat Management Prescriptions for all Units (HMP Map 9)				
Desired Future Condition	Unit #	Field Number	Current Condition	Size (acres)
Potential Wetland Restoration	II	201	Agricultural Field	62.3
		202	Agricultural Field	58.8
Brackish / Salt Marsh Restoration Planned	II	N/A	Generic Marsh	2500
	III	N/A	Generic Marsh	1500
Total Acres:				4,121.1

Management Strategies and Prescriptions

- Implement water level management and vegetation control strategies, to the extent conditions warrant and permit:
 - Unit III water levels, in accordance with deed restrictions, will not be permitted above a level of 2.8 ft mean sea level (MSL) between October and March 10th;
 - Manage water levels in the 200 acre brackish impoundment in Unit IV to maximize habitat benefits for migratory shorebirds and waterfowl.
 - Control invasive species using chemical control, prescribed fire and other techniques as appropriate so that 95% native vegetation is achieved. The exact number of acres treated will depend on funding and management capability;
 - Restore prior converted wetlands and riparian areas on approximately 250 acres;
 - Restore artificially drained and ditched upland areas to improve hydrology around vulnerable communities;
 - Consider planting of a green browse crop, such as clover, over managed areas when manipulating the soil to set back succession, in order to provide supplemental food for waterfowl;
- Utilize the R5 Impoundment Management Structured Decision Making Model in order to evaluate and validate management options for refuge impoundments.
- Discontinue all management and/or construction of dunes on private land
- In partnership with DNREC Coastal Programs and a private contractor, continue development of a model to predict the hydrodynamic response of the wetland complex under a variety of different potential restoration scenarios, such as: closed inlets, opened inlets, one inlet opening in response to a storm event, purposeful inlet deepening, Fowler Beach Road removed, Prime Hook Rd culverts closed, additional Prime Hook Rd openings installed, water control structure at Slaughter Canal/Fowler Beach Rd removed, etc. Model will help evaluate what hydrological and vegetation responses may be expected under each scenario.
- Continue consultation with a restoration advisory team consisting of State and Federal coastal scientists, non-profit organizations, engineering firms, academic scientists, and other subject matter experts, to further explore management options and develop a wetland restoration plan for refuge impoundments
- Host public forums during restoration planning and implementation to describe the process and techniques under consideration and provide the opportunity for public input.
- Within 1-3 years, implement short-term restoration strategies, even as large-scale and long-term restoration plans are developed. These strategies may include some or all of the following:

- Continue development of a hydrological model, as described above, to evaluate long-term restoration options.
- Partner with the PDE to plan and implement appropriate application of living shoreline techniques (e.g., coconut logs, Christmas tree fences, oyster shell breakwaters) within the Unit II interior along public roads and neighboring private property to slow wave fetch across large expanses of open water, which may reduce marsh erosion and facilitate the deposition of sediment and establishment of salt marsh vegetation.
- Further evaluate the potential applicability and installation of engineered wave dissipation devices, such as pyramid-shaped or spherical concrete structures designed explicitly for moderate or high-energy settings. Examples include GeoTubes, Wave Attenuation Devices, Beach Prisms, Artificial Reefs.
- Within 15 years, implement a comprehensive restoration plan to restore healthy self-sustaining wetlands in refuge impoundments, utilizing methods determined with the assistance of the restoration advisory team and other experts to be most appropriate and effective; Following establishment of healthy salt marsh, strategies outlined under Objective 1.3 would become applicable. Specific potential strategies include:
 - Explore the potential benefit of constructing temporary dikes or berms to create cells within the impoundments to foster sediment deposition and salt marsh vegetation establishment
 - Work with the Army Corps of Engineers and DNREC to assess the availability of suitable dredge material to assist in restoring lost elevation within Unit II and/or Unit III, necessary for the establishment of *Spartina*. DNREC maintains control over the placement of state resource sediment for beneficial use projects throughout the state.
 - Examine the financial and ecological feasibility of reintroducing sand from an outside source into the local sediment transport cycle through a modified beach nourishment project; it must be clear that such a project would not be conducted to create a static beach or dune, but would restore coastal sediment dynamics by replacing lost sand, which would then be naturally transported into the back barrier wetlands to improve elevations for vegetation growth;
 - If predicted from hydrodynamic modeling analysis to be beneficial for marsh restoration, work with DelDOT on the abandonment and appropriately-timed removal of Fowler Beach Rd to provide unimpeded tidal flow between Unit I and Unit II, or minimally the installation of large openings under the road to increase and improve tidal flow. DelDOT has sole authority over decisions regarding Fowler Beach Road.
 - Determine the potential benefit of clearing internal channels within Unit II, such as the old Slaughter Creek channel, with the cookie cutter, to improve tidal flow throughout the Unit.
 - As areas of suitable growing conditions are achieved in portions of the impoundment complex, through the management strategies above, consider supplementing the vegetation establishment through planting of salt marsh plants (e.g., *Spartina* spp.).
 - Cease the treatment of *Phragmites* in areas that are susceptible to marsh loss; although not a desired vegetation species, its presence in vulnerable areas will help retain sediment elevation and slow conversion to open water. *Phragmites* would still be treated in areas identified in the Fire Management Plan as “zero tolerance” zones.
 - Work with DelDOT to ensure that improvements to Prime Hook Rd. will permit optimal management and/or restoration of Unit III, based on the outcome of modeling analysis. DelDOT has sole authority over decisions to alter Prime Hook Beach Road.

Monitoring Elements

- Resurvey all water-control structure staff gauges to a single geodetic reference and accurately re-position gauges to reflect current mean sea level (msl)

- Within 1 to 2 years, establish a refuge-wide “elevation-capital” (marsh surface elevation) monitoring program across the two management units, as outlined in more detail in the climate change adaptation strategies under Objective 1.3; In addition to monitoring stations in existing salt marsh, 12 stations will be established in currently-impounded areas (6 in Unit II and 6 in Unit III) with surface elevation tables (SETs) and marker horizons
- Expand efforts to use RTK surveys and underwater sonar technology to monitor elevation throughout the wetland complex, which is less precise than SET measurements, but can be conducted on a broader geographic scale.
- As deemed necessary, continue to collect water quality samples through grab-sampling and automated sampling; samples are analyzed in partnership with DNREC through a cooperative agreement
- Implement the NPS Vital Signs Program’s “Shoreline Position Monitoring Protocol” and “Shoreline Topography Monitoring Protocol”. Coordinate refuge shoreline monitoring efforts with other coastal refuges to foster DOI-wide sharing of standardized monitoring data.
- Monitor the use of refuge impoundments by waterfowl, shorebirds, passerines, and other waterbirds, in all phases of transition and restoration, in accordance with established protocols such as IWMM; As feasible, coordinate research with academic partners, such as the University of Delaware, and with DNREC.
- Seek opportunities to monitor other species groups, such as fish, within the wetlands during all phases of transition and restoration, potentially through partnerships with academic institutions, such as Delaware State University, or other organizations.
- Utilize the Region 5 salt marsh integrity (SMI) index and other suitable monitoring programs as a measure of the success of restoration efforts over the next 15 years
- Update existing vegetation mapping within the wetland complex to reflect changing vegetation and open water conditions, and repeat as needed and practical; Explore the utility of archived satellite imagery for vegetation/open water change analysis.
- Utilize Early Detection Rapid Response Techniques that detect newly established invasive species and immediately addresses those populations through the appropriate control measure.
- Develop improved monitoring and inventory program, such as outlined in the Intergrated Waterbird Management and Monitoring (IWMM) Program, to assess annual habitat conditions created through management and restoration in all wetland areas, and associated bird use.
- Implement water/soil salinity monitoring to inform decisions about wetland response to management and restoration.
- Obtain location and distribution data of known rare plant and animal populations from DNHP and store on refuge GIS database;
- Continue research inventories and studies on the viability and persistence of existing rare plant populations and associated rare faunal species; determine life history requirements for rare plants and animals currently on the refuge to improve future habitat management.

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

Management Strategies and Prescriptions

- Repair, replace, and upgrade water control structures, fish weirs, flapgates, flaplogs, and conventional logs as needed;
- Conserve and improve tidal flows into the salt marshes Units I and IV;

- Continue to provide and improve optimal fish passage capability for anadromous fish in Units II and III;
- Create new or widen existing vegetated riparian buffers greater than 300 feet comprised of native vegetation (trees & shrubs), by connecting isolated or disjunctive patches around refuge creeks, waterways, and marshes, through assisted reforestation projects or allowing natural succession to occur;
- Retrofit road culvert systems connecting Units II to III to protect and maintain the Refuge’s freshwater resources and aquatic habitats;
- Maintain and/or restore water movement and circulation within existing drainage networks of the Refuge’s impoundment complex to improve water level management capabilities by developing a rotational cleaning schedule between Unit III & IV impoundments every 5 years; drainage networks include up to 6.2 miles of ditches in Unit II Impoundment, up to 7.5 miles in Unit III Impoundment, and up to 3,300 linear feet in Unit IV Impoundment;
- Participate in partnerships with other state and Federal agencies to address interjurisdictional fish and State rare fish issues;
- Participate in Spill Prevention, Control, and Countermeasure Plans or other environmental emergency action plans as related to protection of Prime Hook’s aquatic and terrestrial resources; and,

Monitoring Elements

Conduct appropriate monitoring and survey programs as funding and staffing permits to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or a reevaluation or a refinement of our objectives. Examples of monitoring or surveys that we may implement include:

- Conduct refuge fishery inventories every five years to assess fishery health and water quality of aquatic habitats. Document information such as species composition, class size and distribution, abiotic conditions and other information to adjust management prescriptions as needed and recommended by the Service’s Fishery Division. Surveyed areas should include Turtle, Fleetwood, Goose, and Flaxhole Ponds, and Prime Hook Creek. Analyze data and provide management recommendations (seasonal closures, creel size and species limits or catch and release) to adjust public fishing permitted on these closed systems;

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

Table 25. Desired Future Condition/Prescription by Refuge Management Unit and Field Number

Habitat Management Prescriptions for all Units (HMP Maps 8-11)				
Desired Future Condition	Unit #	Field Number	Current Condition	Size (acres)
Maintain Young Shrubland	II	203	Marsh	12.4
		211	Northeastern Successional Shrubland/ Successional Maritime Forest / Marsh	15
		212	Northeastern Successional Shrubland/ Irregularly Flooded Eastern Tidal Salt Shrub/ Marsh	25
Maintain Transitional Shrubland	II	210	Northeastern Successional Shrubland	19.5

Habitat Management Prescriptions for all Units (HMP Maps 8-11)				
Manage as Young Shrubland	III	322	Agricultural Field	11
		323	Agricultural Field	16.5
Maintain Old Shrubland	II	213	Northeastern Successional Shrubland	2
Manage as Old Shrubland	III	329	Northeastern Successional Shrubland	8.9
Recently Afforested	III	309	Mid/Late Successional Loblolly Pine-Sweetgum Forest	12.5
		310	Successional Sweetgum Forest	9.9
		311	Successional Sweetgum Forest	6.9
		312	Northeastern Successional Shrubland	18.8
		313	Northeastern Successional Shrubland	9.5
		314	Northeastern Successional Shrubland	12.6
		326	Agricultural Field	18.7
		328	Successional Sweetgum Forest	14.8
Natural Succession to Shrubland	I	106	Northeastern Successional Shrubland	18.9
		107	Northeastern Successional Shrubland	11.9
		110	Northeastern Successional Shrubland/ North Atlantic Low Salt Marsh	12.5
		112	Northeastern Successional Shrubland	6
		113	Northeastern Successional Shrubland	10
	III	333	Agricultural Field	20.8
		334	Agricultural Field	8.2
		339	Successional Sweetgum Forest	2.5
		340	Agricultural Field	9.8

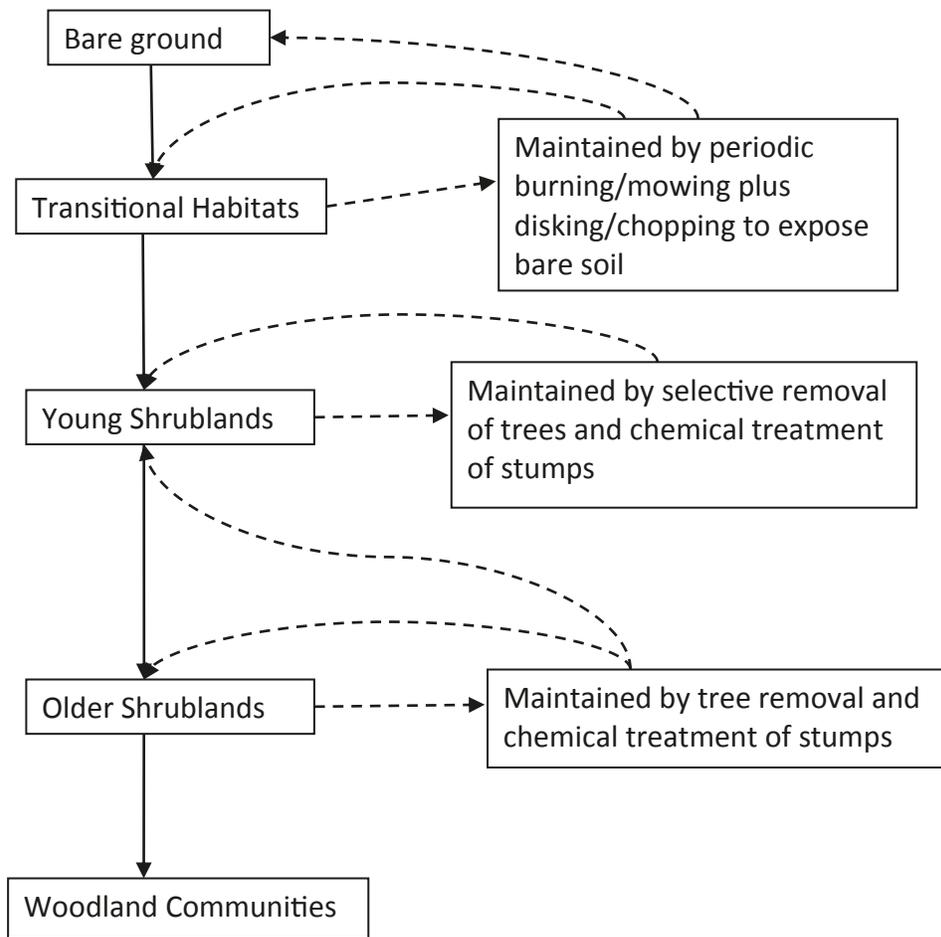
Total Acres: 328.6

Management Strategies and Prescriptions

- **Transitional Shrublands:** represent the earliest seral stage community transitioning from bare soil. To maintain this stage the following trigger points are used → Open Field characteristics > 50% annual herbs and native grasses and < 50% of scattered shrubs and saplings less than 1 meter (3 feet) in height covering the field. To maintain this stage will require the following treatments as necessary: burning and/or mowing; disking to expose bare soil every 2-4 years;
- **Young Shrublands:** woody vegetation is dominant but patches of herbaceous vegetation remain. To maintain this stage calls for open field with 50 to 75% of woody plants less than 3 meters (10 feet) tall dominated by shrubs and vines. To maintain this stage will require the following treatments as necessary: hand removal of saplings to maintain shrubs; chemical treatment of stumps and sprouts every 3-5 years;
- **Older Shrublands:** To manage older shrubland habitats in Unit III, characterized by nearly complete cover of woody vegetation (> 90%), will require the following treatments as needed: hand removal of saplings to retain open canopy and shrub dominance; chemical treatment of stumps and sprouts every 3-5 years;
- Implement field management and restoration prescriptions outlined in Table 25.

- These proactively restored or naturally succeeding areas will occur as a shifting mosaic of patches across the Refuge’s landscape (Figure 2) as we implement decisions to allow open fields to grow to shrub, and young forest, maintain early successional grassland patches near salt marsh habitats, or retain field openings adjacent to upland mature forests;
- Increase shrubland and forested buffered areas (> 200 m) adjacent to Refuge creeks, depressional swamp and emergent wetland habitats, and/or restore prior converted wetlands for targeted species in both Objectives 4.1 and 4.2.
- Use the USGS publication “Conceptual Ecological Model for Management of Breeding Shrubland birds in the mid-Atlantic Region” (Peterjohn 2006) as a guide to restore and/or maintain shrubland habitats;
- Engage the public in outreach and education about the benefits of pollinators, instilling a greater appreciation for invertebrates and their essential links to biological integrity, diversity, and environmental health;
- Engage the public in outreach and education about the benefits of pollinators, instilling a greater appreciation for invertebrates and their essential links to biological integrity, diversity, and environmental health.

Figure 2. Scheme of management decisions and habitat management actions concerning development of secondary successional shrubland habitats on PHNWR



Monitoring Elements

Conduct appropriate monitoring and survey programs as funding and staffing permits to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or a reevaluation or a refinement of our objectives. Examples of monitoring or surveys that we may implement include:

- Prevent new invasive species from becoming established by utilizing Early Detection Rapid Response Techniques that detect newly established invasive species and immediately addresses those populations through the appropriate control measure. This approach will incorporate a combination of plant identification and inventories, maintaining updates of new invasive species present in the region, as well as having knowledge of the appropriate management techniques prior to conducting control efforts (see Appendix C for an Inventory of Vegetation documented in Old Fields during 2004, 2005, and 2006);
- Develop monitoring protocols for targeted breeding and migratory birds dependent on early successional habitats;
- Conduct annual habitat condition assessments to determine what habitat management actions should be prescribed in AHWP; and,
- Develop GIS monitoring layers (e.g. RLGIS or similar) needed to document restoration and habitat management actions by field number, along with RMAD to tract shifting mosaics of transitioning habitats.
- Explore the possibility of applying current arthropod index of biological integrity for shrubland landscapes (Karr et al. 2003) and other shrubland metrics, in consultation with other Refuges, as a standardized multi-metric index tool to assess the condition and restoration efforts of early successional upland habitats

Objective 4.2 (Grassland Bird Habitat Management)

Table 26. Objective 4.2 Desired Future Condition/Prescription by Refuge Management Unit and Field Number

Habitat Management Prescriptions for all Units (HMP Maps 10, 12)				
Desired Future Condition	Unit #	Field Number	Current Condition	Size (acres)
Manage Grassland Adjacent to High Salt Marsh	IV	401	Northeastern Successional Shrubland	6.9
		402	Northeastern Successional Shrubland/ Irregularly Flooded Eastern Tidal Salt Shrub/ Marsh	8.4
		403	Irregularly Flooded Eastern Tidal Salt Shrub	12
		404	Northeastern Successional Shrubland	5.9
		407	Northeastern Successional Shrubland/ Irregularly Flooded Eastern Tidal Salt Shrub	15.9
		407a	Atlantic Coast Interdune Swale	4.6
		409	Northeastern Successional Shrubland	22.5
		410	North Atlantic Low Salt Marsh	3
		412	Irregularly Flooded Eastern Tidal Salt Shrub	3

Habitat Management Prescriptions for all Units (HMP Maps 10, 12)				
Grassland management or Reforestation (TBD)	III	350a	Agricultural Field	8.5
		350b	Agricultural Field	9.8
		352	Agricultural Field	19.1
Total Acres:				119.6

Management Strategies and Prescriptions:

- Implement field management prescriptions outlined in Table 26 and depicted in HMP Maps 10 and 12 ;
- Increase shrubland and forested buffered areas adjacent to Refuge creeks, depressional swamp and emergent wetland habitats, and/or restore prior converted wetlands for targeted species in both Objectives 4.1 and 4.2. These proactively restored or naturally succeeding areas will occur as a shifting mosaic of patches across the Refuge’s landscape as we implement decisions to allow open fields to grow to shrub, and young forest, or maintain early successional grassland patches near salt marsh habitats or retain field openings adjacent to upland mature forests;
- Native grassland maintain in Unit III will require mowing and disking strips on a rotational basis once or twice a year and prescribed fire about every 3 to 5 years to maintain short grass vegetation less than 30 meters mixed with forbs and 20-30% bare ground or create various mosaics with short, medium, and tall grassland patches; annually monitor for invasive plants and treat as needed
- Manage Unit IV open field areas adjacent to salt marsh habitats by maintaining moderately tall vegetation (> 30 cm) with well-developed litter layer and less than 10% woody species encroachment;
- Mow fields 405 and 406 annually and keep in reserve as easy salt marsh restoration sites as possible mitigation sites for future Refuge road improvement projects and functional water control culvert replacements;

Monitoring Elements

Conduct appropriate monitoring and survey programs as funding and staffing permits to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or a reevaluation or a refinement of our objectives. Examples of monitoring or surveys that we may implement include:

- Prevent new invasive species from becoming established by utilizing Early Detection Rapid Response Techniques that detect newly established invasive species and immediately addresses those populations through the appropriate control measure. This approach will incorporate a combination of plant identification and inventories, maintaining updates of new invasive species present in the region, as well as having knowledge of the appropriate management techniques prior to conducting control efforts (see Appendix C for an Inventory of Vegetation documented in Old Fields during 2004, 2005, and 2006);
- Develop monitoring protocols for targeted breeding and migratory birds dependent on early successional habitats;
- Conduct annual habitat condition assessments to determine what habitat management actions should be prescribed in AHWP; and,
- Develop GIS monitoring layers (e.g., RLGIS or similar) needed to document restoration and habitat management actions by field number, along with RMAD to tract shifting mosaics of transitioning habitats

Appendix A

List of Potential Habitat and Wildlife Management Strategies and prescriptions for Prime Hook National Wildlife Refuge

- Native Wetland and Aquatic Vegetation Management
- Early Successional Upland Habitats
- Invasive Plant Management
- Forest Management
- Integrated Pest Management
- Biological Mosquito Control = Open Marsh Water Management (OMWM)
- Control of Over-Abundant or Non-Native Waterfowl Populations
- Predator Control and Nuisance Wildlife Management

4.1) NATIVE WETLAND AND AQUATIC VEGETATION COMMUNITIES

a) Water Level Management: Water level manipulation is the most important technique used to set back succession and manage freshwater wetland plant communities. The main objective in water level control is to maximize wildlife habitat diversity by using various drawdown and reflooding schedules. Drawdown simulates the natural flood-dry cycle of natural wetlands. As the marsh dries, dead emergent and other plants oxidize and decompose, releasing nutrients into the soil (Payne 1998).

Hydrological and seasonal variables influence the schedules for water-level manipulations. Hydrological variables include frequency and duration of flooding, water-depth, water temperature, dissolved oxygen within and outside the impoundment, turbidity, and salinity. Seasonal factors include local weather patterns, storm events, lunar phases and tidal amplitudes. Wind speed and direction also influence tidal amplitudes. The key to producing nonpersistent annual grasses and maintain freshwater conditions, is precluding salt water tidal flow into management units.

Drawdowns can be cyclic or non-cyclic, complete or partial, fast or slow, early or late (Fredrickson & Taylor 1982, Payne 1998). For example, Unit III can be drawn down completely by the last week of May to volunteer major moist-soil plants (mainly wild millet, beggarticks, fall Panicum & smartweeds) and reflooded beginning September 30 to feed migrating shorebirds in the spring and then feed migrating and wintering waterfowl, while Unit IV could be completely drawdown by July 15th and slowly reflooded after October 15th so migrant waterfowl and wading birds can feed on marsh purslane and other moist-soil seeds, invertebrates and minnows, and Unit II could be drawdown completely by August 15th to raise spikerush and fall Panicum.

To maintain a dominance of annual plants, a non-cyclic, rotating schedule between management units will be used to diversify water level regimes. This will be done by practicing asynchronous drawdown and reflooding schedules between years and among the three impounded management units. Prescriptions will be based on annual site specific capabilities, strategies needed to control invasives and knowledge of the area.

Slow drawdowns (greater than 2-4 weeks in duration) are more desirable for moist-soil plant establishment, maintaining the productivity of an impoundment and subsequent wildlife use. Slow drawdown rates generate the best seed production, lengthen the period for optimal foraging by priority bird species, and place a larger portion of invertebrates within foraging ranges of a wider array of wetland species. If salinities tend to be high within an impounded areas, slow drawdown regimes should be scheduled during late winter or early spring, when ambient temperatures and evaporation rates are lower. Slow reflooding schedules also maximize habitat heterogeneity for waterfowl utilization. Annual

water level prescriptions will be specified at the end of each year for the next management cycle in Annual Habitat Work Plan (AHWP) documentation.

b) Moist-soil Management: The dynamic nature of moist-soil management demands regular inspection and appropriate annual monitoring to track success and fine-tune management prescriptions to adjust for problems. With a scientific approach and adaptive management, moist-soil and impoundment objectives 3.1 and 3.2 can be consistently met or exceeded. Frequent monitoring and recording of plant and wildlife responses (weekly), natural conditions, weather and management actions taken are essential. The most important factors that will determine and/or limit plant responses (desirable vegetation) and annual seed yields are 1) successional stage of the native plant community; 2) soil temperature; 3) soil moisture; 4) soil chemistry; and 5) water level manipulations.

Generally, the most prolific seed producers and therefore the most “desirable plants” for waterfowl are annuals that dominate early successional seral stage. Moist-soil manipulations over a series of years tend to result in the predominance of annuals if disturbance has been frequent, or of perennials if disturbance has been lacking. Without disturbance, plant succession after several years proceeds to perennial plants that are less desirable for waterfowl food production. It will be necessary to have plant succession set back by burning, prolonged flooding or some form of soil disking every 3 to 5 years to stimulate the growth of annuals. More often than not, this disking service has been provided annually by extensive snow goose herbivory.

As it relates to the timing of drawdowns, soil temperature has a great effect on the species of plants that germinate. In moist-soil management literature, timing of drawdowns are presented as early, mid-season, and late. Fredrickson (1991) describes early drawdowns as those that occur during the first 45 days of the growing season and late drawdowns as those that occur during the last 90 days of the growing season. That suggests that a mid-season drawdown is a variable length depending on the location and length of time between average first and last frosts.

Annual moist-soil plants respond differently to wet, cool conditions verses dry, warm conditions, and to varying ground water table depths. In one year, impoundments may drain within a few days, while in another year a drawdown may extend several weeks. The resulting annual vegetation growth and production will differ accordingly. However, 25 years of scientific literature suggests moist-soil vegetation responses are fairly predictable based on type of drawdown schedules (early, mid-season, or late) that are executed each year (See Summary Table Below). Characteristics of selected moist-soil plants, including successional stage, germination dates, potential seed production, food and habitat values for wildlife are helpful information when crafting AHWP prescriptions each year (See page 8, Fredrickson & Taylor 1982).

Drawdown Date	Soil Temperature	Rainfall	Evaporation	Expected Plant Response
Early (first 45 days after average last frost)	Cool to Moderate	High	Low	Wild millet, smartweed, chufa, Fall panicum, spikerush
Mid-season	Moderate to Warm	Moderate	Moderate to High	Redroot sedge, panic grasses, wild millet, marsh purslane, spikerush

Drawdown Date	Soil Temperature	Rainfall	Evaporation	Expected Plant Response
Late (last 90 days before average first frost)	Warm	Low	High	Sprangletop, beggarticks, crabgrass, panic grass, redroot sedge, spikerush

Maintaining high soil moisture (True Moist-Soil Conditions) throughout the growing season is key to producing large quantities of desirable waterfowl foods (smartweeds, millet, chufa, sedges, panic grasses, sprangletop, etc.) consistently every year. Conducting slow drawdowns is the most effective way to conserve soil moisture throughout the growing season.

Without the ability to re-flood an impoundment artificially during the growing season, experience has shown that a better plant response is achieved by keeping water control structures closed to hold any additional rainfall after drawdowns have been completed to allow water to more slowly evaporate. The practice of opening structures to dewatering the impoundment and then leaving it dry all summer generally results in poorer moist-soil seed production.

Low soil and water salinity values provide the best growing conditions for desirable moist-soil plants. However, within the Refuge's large coastal impoundments (Unit II = 1,500 acres; Unit III = 2,500 acres; Unit IV = 200 acres), water with moderate levels of salinity can be tolerated and used as a management tool to discourage salt-intolerant invasive plants or control mosquitoes in unique situations, by timing the opening of water control structures to flood certain impounded areas.

4.2) EARLY SUCCESSIONAL UPLAND HABITAT MANAGEMENT

Grassland Management: Most of the grasses found in the state and northeast are non-native cool-season grasses, growing best during the spring and/or fall when soil and air temperatures are cool. Grasses in this group include smooth brome grass, Kentucky bluegrass, tall fescue, and orchardgrass, which will not be managed for in Refuge habitats.

Native warm-season grasses, those present in the region prior to European settlement will be encouraged to grow in designated grassland management areas. These predominant native grasses include switchgrass, bushy bluestem, silver bluestem, broom sedge, foxtail barley, and purple top. Warm-season grasses provide a multitude of ecological benefits and management opportunities (Rothbart 2006):

- They are well adapted to a variety of site conditions;
- Maintenance costs are low once stands are established;
- They provide dependable forage production, are less influenced by severe weather fluctuations, more disease and insect tolerant than cool-season species;
- Native grasses are tolerant of and stimulated by fire. They are easily maintained with prescribed burning and yield excellent nesting and brood-rearing habitats for migratory birds of conservation concern;
- Warm-season grass root systems are extensive, growing 5-15 feet deep. Root systems completely regenerate every 3-4 years increasing soil fertility, organic matter, and carbon sequestration. Most native species are "bunch grasses" that grow in clumps. The clumping nature of these plants results in more bare ground under and between individual plants, providing excellent dusting and travel areas for birds and their broods. Bunchy structure also allows a diversity of forbs, legumes, wildflowers, and insects to colonize the areas, creating excellent foraging conditions.

Although established stands of native warm-season grasses require minimum maintenance, periodic manipulations are required to reduce competition from woody plants and/or invasives. Prescribed burning is the most effective management tool to maintain and rejuvenate native grasslands with mowing as a second alternative to setting back succession. Mowing every other year at the end of the nesting season with prescribed burns applied every 3 to 5 years will be a starting point to assess and evaluate bird use and habitat response to maintain designated Refuge grassland areas.

Managing Shrubland Succession: Transitional, Young, and Old Shrubland Habitat Management

Prescriptions: At the Refuge level, managing succession to produce and/or maintain the desired density and height of different stages of shrubland habitats (transitional, young, and old) can be achieved using two management approaches. These approaches are based on the Peterjohn (2006) breeding shrubland bird model in the mid-Atlantic region, and differ primarily in the amount of management effort required to maintain these seral stages. The presence of most shrubland bird species largely reflects moisture regimes and the physical structure of successional communities, so that the dominant plant species are less important. Key physical components to manage for include presence of bare ground, densities of shrubs and herbaceous cover, height of woody vegetation, and presence of a partial or complete canopy of saplings. More detailed descriptions of the three seral shrubland stages follow.

Transitional shrublands are relatively ephemeral with woody vegetation rapidly replacing herbaceous cover in unmanaged areas. Maintaining early seral stages will require cyclic mowing and/or prescribed burning to prevent establishment of dense woody vegetation, combined with mechanical disturbance (disking) to expose bare soil and allow emergence of “colonist” plants. Transitional shrubland breeding birds prefer more open fields where shrubs are scattered among dense cover dominated by forbs and grasses and small trees are scarce or absent.

Fields with transitional shrublands represent the earliest seral stage community transitioning from bare soil to shrublands, beginning with dominance by annual forbs and grasses which are rapidly replaced by perennial forbs. Woody vegetation begins to emerge during the last seral stages of transitional shrublands with scattered shrubs and saplings generally less than 1 meter (3 ft) in height covering less than 50% of the area. The avian communities in these habitats are the least diverse of all shrubland bird communities.

Young shrublands: At this stage of succession woody vegetation becomes dominant, but patches of herbaceous vegetation remain. Woody plants continue to encroach on the herbaceous vegetation as these habitats advance in age. Woody plants are less than 3 meters tall (10 feet) and dominated by shrubs and vines. This stage may naturally be maintained by specific wet or dry hydrologic conditions that inhibit establishment of trees. Young shrubland habitats will require proactive maintenance to prevent succession into young forests. These management activities are labor intensive, including the selective removal of young trees combined with chemical treatment of stumps.

Older Shrublands: This late seral stage is characterized by nearly complete (> 90%) cover of woody vegetation. Initially, these habitats are dominated by shrubs with very few saplings. As they mature, saplings expand at the expense of the shrubby cover. These habitats are featured by a partial canopy of saplings over shrubs and herbaceous layers. Saplings out grow and rapidly succeed into second-growth woods within 3 to 5 years. Composition of breeding bird communities tend to be the most diverse at this stage.

These three successional stages can be managed using two approaches: “Low management” and/or “repeated management.” The low management approach implies setting aside fields where secondary succession occurs at natural rates at staggered intervals. Initiation is staggered between fields at 3 to 5

year intervals so that all seral stages (transitional, young, & old) are represented (See Figure 1). Once natural succession advances to second growth forests, these woodland areas are set back.

The advantage of this approach is that active management is not required as secondary succession advances across designated open field areas. However reverting secondary succession into the earliest shrubland stages requires extensive management activities. Reverting second-growth woods into early seral stages will require removal of all live and dead timber, repeated chemical treatment of stumps, and disking or chopping the soil to expose bare ground for by colonizing herbs.

The alternative to “low management” is the “repeated management” approach. At a designated site allow secondary succession to advance to the desired seral stage and then proactively manage the area to retain that stage of vegetation. Maintaining early seral stages requires mowing and/or prescribed burns at 2-4 year intervals combined with disking or chopping the soil to expose bare ground to allow colonizing herbs to become established. Maintaining later successional communities aims at preventing closed canopies from developing and requires labor-intensive activities like removing selected saplings combined with chemical treatment of stumps and sprouts, at 3 to 5 year intervals to maintain desired shrubland seral stages (Peterjohn 2006).

Annual maintenance will also be necessary in areas prone to support invasive species. Early detection and rapid response is the best strategy to deal with invasives before they become dominant. Eliminating invasives requires chemical treatment and/or hand removal, depending upon the characteristics of a particular invasive plant. In summary, “repeated management” approach to shrubland habitat maintenance would include:

Transitional Stage:

- Burning and/or mowing
- Disking/chopping to expose bare soil every 2-4 years
- Early detection/rapid response for invasives (annually).

Young Shrubland Stage:

- Hand removal of saplings to maintain shrubs
- Chemical treatment of stumps and sprouts every 3-5 years.
- Early detection/rapid response for invasives (annually).

Older Shrubland Stage:

- Hand removal of saplings to retain open canopy
- Chemical treatment of stumps and sprouts every 3-5 years.
- Early detection/rapid response fro invasives (annually).

Figure 1. "Low Management" approach for establishing and maintaining successional shrubland communities in Prime Hook National Wildlife Refuge.

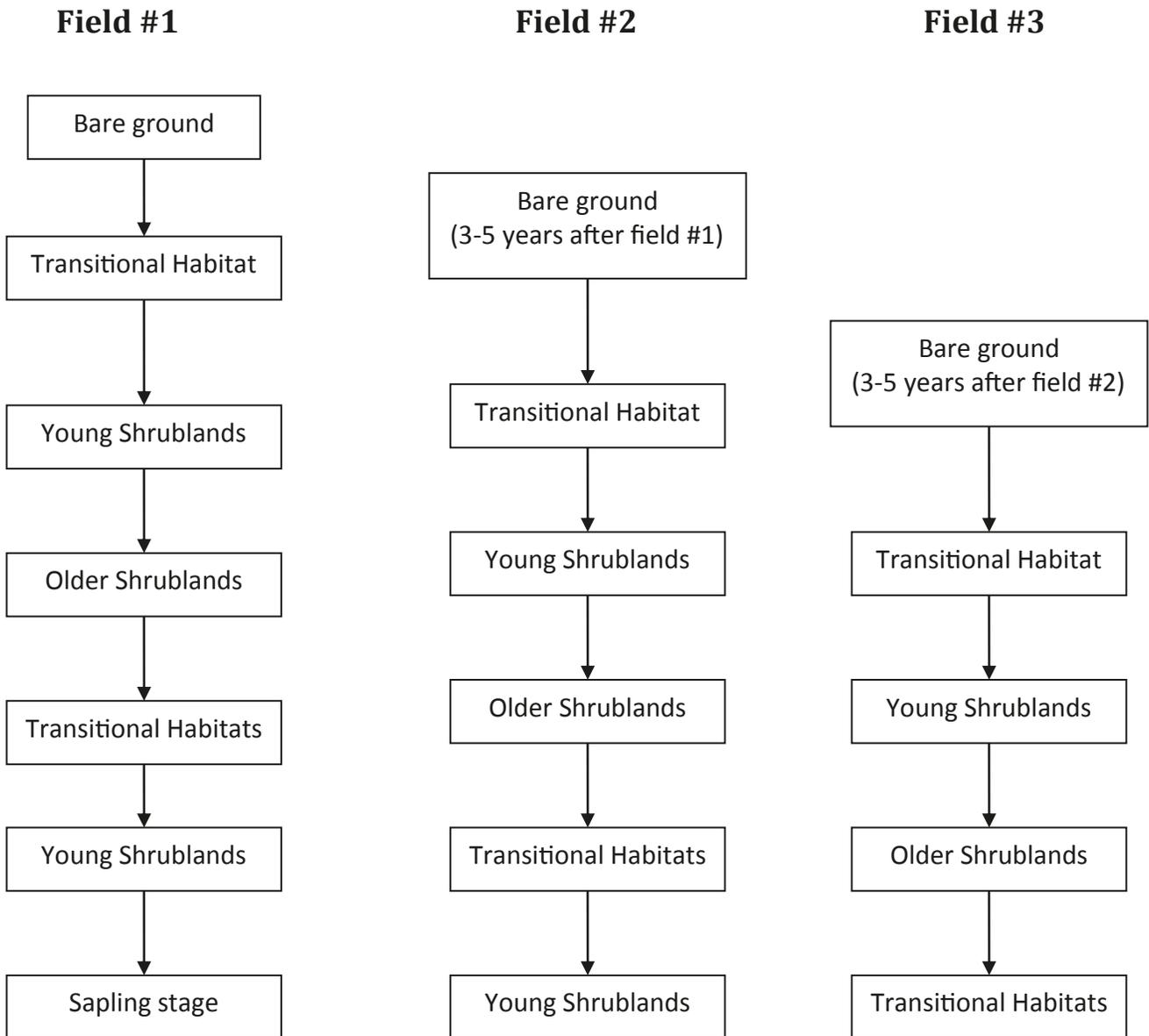
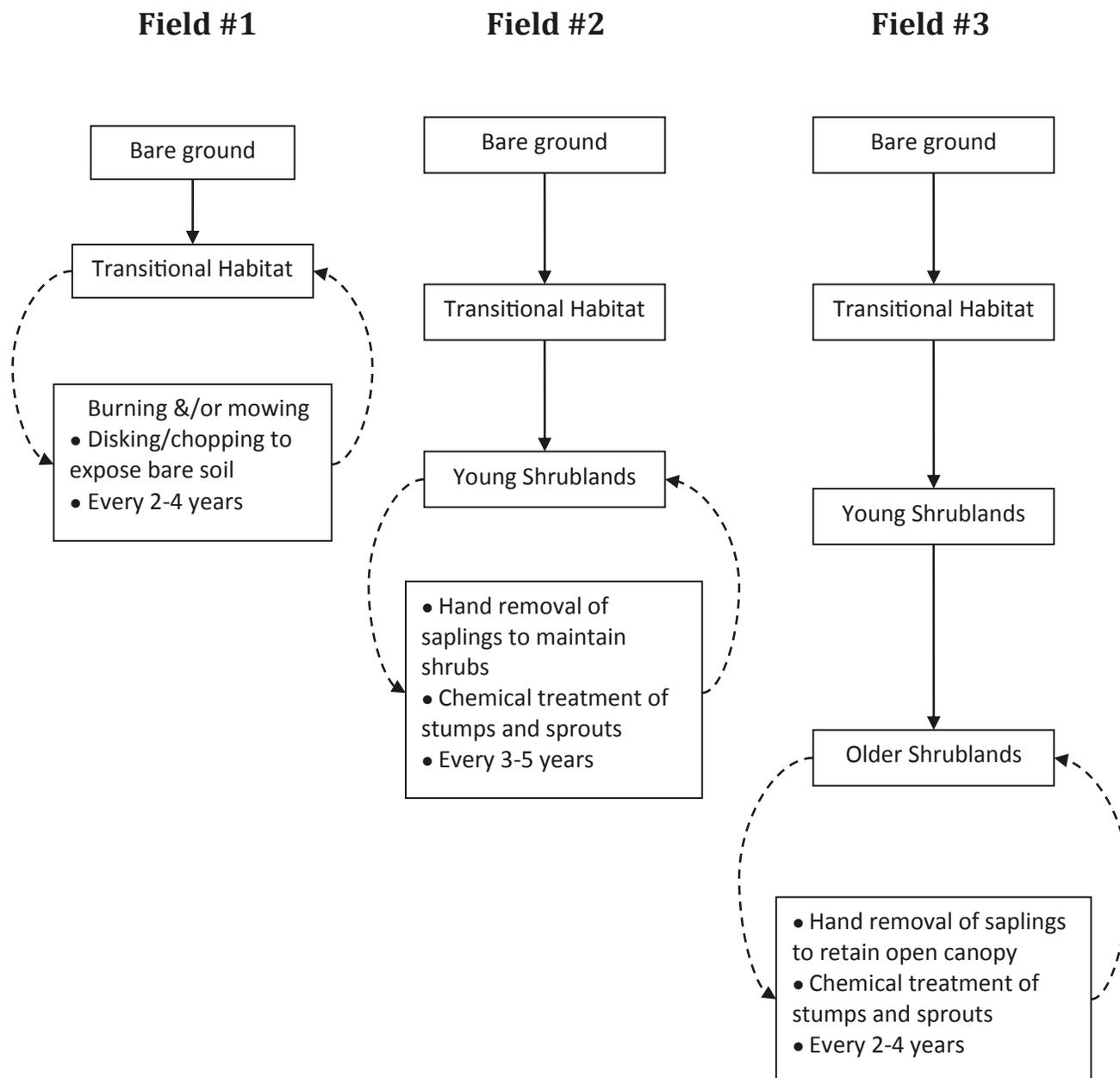


Figure 2. “Repeated Management” approach for establishing and maintaining successional shrubland communities in Prime Hook National Wildlife Refuge.



Patch Size Considerations When Creating Shrubland Habitats: Unlike grassland birds that prefer landscapes with larger patch sizes and open vistas, shrubland birds are not deterred by smaller patch sizes (Tefft 2006). An important factor to consider is the width of newly created shrubland habitats. Corridors less than 30 m (100 ft) wide will be occupied by ubiquitous shrubland birds. If managing for field specialists, then the minimum corridor width should be 50-70 m (165-230 ft) (Peterjohn 2006).

Effects of patch size on occupancy vary among shrubland bird species. Ubiquitous species require only enough suitable habitat to support their breeding territories. Patch sizes of 1-2 ha (2.5-5.0 acres) are sufficient to support most breeding pairs. However, fields smaller than 2 ha (5 acres) support few field

specialists. While available data on patch size preferences of these birds is still sparse, the few studies conducted to date indicate minimum sizes of 4-5 ha (10-12 acres) are required to attract most field specialists, assuming these habitats are at least 50-70 m (165-230 ft) wide. Patch sizes up to 20 ha (50 acres) is sufficient to attract breeding shrubland birds (Peterjohn 2006)

Prescribed Burning: Fire can either suppress or encourage any given plant species, but great care should be taken to understand the ecosystem and the life histories of the native and invasive plants of the site before using this tool. Prescribed fire as a habitat management tool is most effective when it is used to mimic natural fire regimes. Traditionally, spring and fall burns are usually conducted that are low in severity and intensity in the dormant seasons for most plants in early successional habitats. However, historical fires had no such constraints and fire effects were likely more severe than prescribed burn effects are now (Simmons 2006)

Many rare floral and faunal species depend on the effects of severe and intense burns. One way to achieve better ecological results is to apply growing season fires to achieve objectives in the long term by balancing growing season burns with habitat needs of breeding animals. In most early successional habitats, the timing, frequency, and size of fires can be adjusted so minimal damage is inflicted on populations of rare plants and animals.

Burning is more costly and requires greater planning efforts than mechanical treatments such as logging, brush hogging, mowing, and disking, which all perform well as disturbance agents capable of creating required habitat conditions in a particular habitat objective. However, fire performs some functions that these other tools cannot. Fire removes dead vegetation and recycles it into ash, smoke, and steam, and provides nutrients that are immediately available to plants.

Dead grass, thatch, and leaf litter are often completely consumed and serve to carry fire across an entire habitat patch. The removal of thatch, and leaf litter allows greater sunlight penetration to the ground surface and prepares a seed bed for naturally colonizing or planted native grasses and forbs, while other desirable native seeds require scarification by fire for germination to occur (Simmons 2006).

Fire has historically been used on Refuges in BCR 30 to maintain early successional habitats for Bobwhite and Woodcock. Prescribed fire can be used to maintain grasslands by increasing grass biomass and eliminating woody shade plants, extend the growing season by removing litter, and buffering soil chemistry and selectively controlling tall forbs or fire-sensitive woody plants (by topkilling or causing mortality), mineralize litter, and increase community diversity (by altering the composition of early-flowering plants).

Grasslands: Prescribed fire is the most effective management tool to maintain and rejuvenate native grasslands. Burns should be conducted between March 1 and April 15, or later in the summer (after September 1) to reduce woody plant invasion. Burning increases forb diversity, promotes vigorous warm-season grass growth, releases nutrients back to the soil, and suppresses invasive competition (Rothbart and Capel 2006). However, cyclic burning removes accumulation of vegetative litter from the ground which would not benefit Henslow sparrows that require thick litter accumulation. Rotational schedules between mowing with periodic burning would be best.

Shrublands: Prescribed fire may also be used to maintain an interspersed of shrub and/or grass-dominated communities attractive to shrubland passerines, by topkilling shrubs in old fields, and allowing them to re-sprout into thickets. Fire may be used to help eradicate exotic, invasive plants from open habitats, in some cases precluding the need to use chemical herbicides (Simmon 2006).

When using prescribed fire to alter woody plant cover in early successional habitats it is important to consider that many woody plants, especially shrubs, are adapted to disturbance, regenerating new shoots prolifically. Fire can increase or decrease shrub stem density in a habitat. Use of fire can either help eliminate (through direct mortality) or maintain shrub-scrub habitat structure, by pruning tall woody plants back, killing trees that are less-fire adapted, and encouraging shrub sprouting. If the goal is to decrease shrub stems, a high severity, growing season fire is best. If the goal is to increase shrub stem density, a moderate severity, dormant season fire would work better.

The key to predicting fire effects on woody plants is fire regime (frequency, seasonal timing, severity, and geographic size of fire). The regime will affect differential shrub and sapling mortality (which species die and which doesn't), mortality vs. top-kill effects, and post-fire vegetative regeneration. These are several principles that should be considered when employing prescribed fire to control woody plants in early successional habitats:

- Plant mortality is strongly tied to death of “growth points” (meristems/buds), which are more sensitive to heat damage when actively growing, and when tissue moisture is high. Applying Rx fire during the spring when target woody plants are mobilizing water and nutrients and breaking dormancy of leaf/flower buds, or during fall cold-acclimation periods, is more likely to kill growth points than during dormant periods.
- Total plant mortality is often the result of injury to several different parts of the plant. Fire applied in the dormant season “top-kill” shrubs, but fail to kill the entire plant that later re-sprouts from dormant buds. New shoots can originate from dormant buds located above ground (epicormic sprouts, root collar sprouts), and from various levels within the litter, duff, and mineral soil layers (rhizomes, root crowns).
- Fires severity (depth of fire and ground char) directly affects shrub re-sprouting capability. Moderate severity (shallow ground char, consumes litter layer and partially consumes duff layer) causes the greatest increase in stem numbers from root sprouters. High severity fires (deep ground char) remove duff layer and large woody debris and eliminate re-sprouting from shallowly buried tissues. Prolonged heating, as is generated during a slow, backing fire (verses a fast-moving head-fire) causes greater burn severity, and plant tissue death. In general, backing fires cause more woody damage than rapid head-fires (Miller 2000).
- Concentrations of metabolic compounds (sugars, salts, & lignins) vary seasonally, and have seasonal effects on shrubs. Timing of treatments may be more important than the type (cutting vs. burning) in controlling shrubs when taking total non-structural carbohydrate (TNC) levels. To maximize the reduction of woody stems, fires should be applied during periods of low below-ground carbohydrate storage (early spring growth) followed by a second treatment (mowing, herbicide) before total non-structural carbohydrate levels are replenished. Repeated burning (several consecutive years) during the low point of a shrub's TNC cycle is most effective.
- Fire reduces cover and thickness of organic soil layers. This can increase light and temperature at the soil surface, causing an increase in sprouting from woody rhizomes, so to control shrubs, a follow-up treatment (mowing, herbicide) is almost always required post-fire.

Mowing: Mowing has long been used to manage grasslands as a means to suppressing invading hardwoods. Timing is critical. Mowing should generally be scheduled outside the bird-nesting season of target species (April 15 to August 30). Utilize standard wildlife conservation mowing practices such as raising the mower blades to at least 10 inches or more, which permits the grass to recover quickly.

Force-account Farming: When grasslands, moist soil fields, and/or shrublands need succession setback, force account farming may be used. The staff will prepare and plant the fields to a cover crop such as winter wheat. This is an interim measure to keep fields open and to set back succession in preparation for

conversion to native plants and as a means to provide time to adequately plan the proper establishment of newly converted early successional habitats which would include either grassland, shrubland, or forested patches.

4.3) INVASIVE PLANT MANAGEMENT

Controlling and managing invasive species is a strategy for maintaining the biological integrity and diversity of all habitats. The *Fulfilling the Promise* National Invasive Species Management Strategy Team developed a national strategy for management of invasive species for the National Wildlife Refuge System in 2002. The strategy recommends the following priority order of action for invasive species management:

- 1) Prevent invasion of potential invaders.
- 2) Eradicate new and/or small infestations.
- 3) Control and/or contain large established infestations.

Potential management strategies for preventing invasive species, prioritizing control efforts for established invasive species, and controlling invasive species are described in detail below. Prior to the initiation of invasive species control efforts, Refuge staff must understand the biology of the species to be controlled. A number of resources are available on the internet to assist with this. Some sources are included below:

- National Invasive Species Information Center: <http://invasivespeciesinfo.gov/index.shtml>
- National Biological Information Infrastructure Invasive Species Information Node: <http://invasivespecies.nbii.gov/>
 - The Global Invasive Species Initiative: <http://tncweeds.ucdavis.edu/control.html>
 - USGS Invasive Species Program: <http://biology.usgs.gov/invasive/>
 - Weeds Gone Wild: <http://www.nps.gov/plants/alien/index.htm>
 - Invasive Species Mapping in Delaware by DNHP:

Refuge Staff should conduct appropriate and applicable pest detection, environmental surveillance, and monitoring before, during and after any management activity to determine whether pest management goals are achieved and whether activity caused any significant unanticipated effects. The lowest risk, most targeted approach for managing invasive species should always be utilized.

Early Detection and Rapid Response

Where prevention is not possible, early detection and rapid response is the next best strategy. Success will depend in part on participation by all Refuge staff, contractors, volunteers, and visitors in efforts to report and respond to invasions. The Refuge Manager must have access to up-to-date reliable scientific and management information on invasives and invasives management. The Delaware Invasive Species Council (DISC) of the Delaware Department of Agriculture (DDA) is an important source for information <http://www.delawareinvasives.net>.

Prioritizing Invasive Species Control Efforts

The first step in prioritizing invasive species control efforts is to determine the abundance and distribution of invasive species on the Refuge or management unit. However, control efforts should not be delayed to collect statistically rigorous survey data. Baseline data regarding the location of many invasives on the Refuge already may be available from observations of staff, volunteers, contractors, and Refuge visitors. These observations should be documented and mapped on Refuge GIS. If a more formalized mapping procedure is desired the North American Weed Management Association (<http://www.nawma.org>) has information on mapping procedures.

There are a number of ranking tools to assist land managers with the daunting task of prioritizing their invasive plant control efforts. The *Fulfilling the Promise* National Invasive Species Management Strategy Team recommends using the following order of priority to determine appropriate actions:

- 1) Smallest scale of infestation.
- 2) Poses greatest threat to land management objectives
- 3) Greatest ease of control.

When limited resources prevent the treatment of entire populations, the following order of priority is recommended:

- 1) Treat the smallest infestations (satellite populations).
- 2) Treat infestations on pathways of spread.
- 3) Treat the perimeter and advancing front of large infestations.

The following ranking systems are available for prioritizing plant species control:

- Morse, L. E. et al 2004. An Invasive Species Assessment Protocol: Evaluating Non-Native Plants for Their Impact on Biodiversity. Version 1. NatureServe, Arlington, Virginia, *Website: <http://www.natureserve.org/getData/plantData.jsp>*
- R.D. Hierbert and J. Stubbendieck, *Handbook for Ranking Exotic Plants for Management and Control* Natural Resources Report NPS/NRMWRO/NRR-93/08), U.S. National Park Service, Midwest Regional Office, Omaha, Nebraska, 1993.
- APRS Implementation Team 2000. Alien plants ranking system version 5.1. Jamestown, ND: Northern Prairie Wildlife Research Center Online. (Version 30 SEP2002). *Website: <http://www.npwrc.usgs.gov/resource/literatr/aprs>*

Incorporate Invasive Species Prevention in All Facilities and Construction Projects

Minimize ground disturbance and restore disturbed areas. Require mulch, sand, gravel, dirt, and other construction materials to be certified as free of noxious weed seeds. Avoid stockpiles of weed-infested materials.

To prevent the spread of invasives along transportation corridors, maintain invasive species-free zones along trails, around parking lots and boat launches, and at other related facilities. Inspect these areas often and control new infestations immediately. Minimize the number and size of roads on the refuge. Remove all mud, dirt, and plant parts from all equipment between projects or when equipment is moved from one location to another.

Incorporate Invasive Species Prevention in Impoundment Habitats

Minimize infrastructure development in managed wetland units to reduce unnecessary dikes, waterways, and access roads. These often are sources of infestation and pathways of spread. Plant a native cool season grass mix that will establish quickly to stabilize banks and dikes and to prevent the establishment of invasive species. Include in any native grass mix adding annual ryegrass (*Lolium perenne*) so bare soil is not exposed to erosion or to invasive plant seeds and rhizomes. This non-native plant will establish quickly and then drop out of the mix after one or two years.

Timing water manipulation activities, such as flooding and drawdowns, to minimize the germination and spread of invasive plant seeds and encourage the growth of native species. Prolonged flooding can be used to stunt the growth of some invasive species. Water level management can also be used to control invasive plants. Robust plants such as *Phragmites* require air pockets (carbon dioxide) to survive. Flooding the impoundment through all or part of a growing season, particularly after mowing or chemical application, discourages vegetative re-growth of robust invasives like *Phragmites*.

Mechanical removal of invasive organisms can be effective against some herbaceous plants, shrubs and saplings, and aquatic organisms. This is particularly effective for plants that are annuals or have a taproot. Care should be taken to minimize soil disturbance to prevent creating conditions ideal for weed seed germination. Repeated cutting over a growing period is needed for effective control of many invasive plant species. Care should be taken to properly remove and dispose of any plant parts that can re-sprout. Treatments should be timed to prevent seed set and re-sprouting. The following methods are available: hand-pulling, pulling with hand tools (weed wrench, etc.), mowing, brush-hogging, weed-eating, stabbing (cutting roots while leaving in place), girdling (removing cambium layer), mulching, tilling, smothering and flooding.

The advantages of mechanical treatment are low cost for equipment and supplies and minimal damage to neighboring plants and the environment. The disadvantages are higher costs for labor and inability to control large areas. For many invasive species, mechanical treatments alone are not effective, especially for mature plants or well-established plants. For some invasive plants, mechanical treatments alone exacerbate the problem. Mechanical treatments are most effective when combined with herbicide treatments (like girdle and herbicide treatment).

There are a wide variety of chemicals available to control invasive plants. They may work in different ways and be very target specific, or affect a wide range of species. Herbicides may be “pre-emergent,” i.e., applied prior to germination to prevent germination or kill the seedling, or “post-emergent: and have various modes of action (auxin mimic, amino acid inhibitor, mitosis inhibitor, photosynthesis inhibitor, lipid biosynthesis inhibitor). Products may come in granular, pelleted, dust or liquid forms. Common application methods include foliar spray, basal bark, hack and squirt, injection, and cut stump. The timing of applications is critical to achieve good control, as the growth stage at which an invasive plant will be most effectively controlled varies with different species.

The advantages are that the right chemicals, applied correctly, can produce desired results over a large area for a reasonable cost. The disadvantages are that the chemicals may affect non-target species at the site and/or contaminate surface or groundwater. Proper planning includes using the most target-specific, least hazardous (humans and the environment), and most effective chemical for the job. Additionally, one should research minimum effective dosage, as the chemical labels often give higher than necessary concentrations. Herbicides often are most effective when used in combination with mechanical methods.

On Refuge lands, all chemicals including adjuvants designed to enhance effectiveness are covered by Service and Departmental regulations. A Pesticide Use Proposal (PUP) is required for all pesticide applications. Attention to protective gear, licensing requirements and other regulations is essential.

Fire is a critical tool to managing ecosystems. It recycles vital nutrients, stimulates growth, provides quality habitat for a variety of species, especially when it is used to destroy invasive plants like *Phragmites*, when used in conjunction with other techniques like herbicides and mechanical removal. Regular fires, part of nature’s design, also helps check the risk of catastrophic fire by reducing accumulations of hazardous fuels by clearing underbush and dead vegetation.

Over 90 percent of hazardous fuels reduction on PHNWR has been accomplished through strategic use of fire in conjunction with herbiciding to reduce large stands of *Phragmites*. A comprehensive monitoring plan was established in 2002 with 45 transects spread across all 4 management units as part of the initiation of a large Wildland Urban Interface project conducted in 2002 through 2004 (See WUI Project Maps and Monitoring Plan in Appendix) These established transects will be monitored to continue to track *Phragmites* control activities and results in relationship to original 2002 treatment sites.

Biological control is the use of animals or disease organisms that feed upon or parasitize the invasive species target. Usually, the control agent is imported from the invasive species' home country, and artificially high numbers of the control agent are fostered and maintained. There are also "conservation" or "augmentation" biological control methods where populations of biological agents already in the environment (native) are maintained or enhanced to target an invasive species. The advantages of this method are that it avoids the use of chemicals and can provide relatively inexpensive and permanent control over large areas. Appropriate control agents do not exist for all invasive species. Petitions are submitted and approved by the USDA Technical Advisory Group on weed biological control before any proposed biological control agent can be released.

4.4) FOREST MANAGEMENT

Regeneration Cutting is the removal of an entire stand of trees in one cutting with reproduction obtained naturally or artificially (i.e., planting, broadcasting seeding, or direct seeding). Two common methods of regeneration cutting is patch clearcuts and strip clearcuts. These methods are considered to be even-age management. Clearcut size does have an effect on regeneration. As clearcuts increase in size they tend to favor shade intolerant species. As they become smaller they gravitate towards encouraging intermediate tolerant and tolerant species. The size and shape of the clearcut can have an effect on bird species richness as well as influence herbivore utilization.

- Patch Clearcut: can be many different shapes and sizes depending on management objectives, forest type, terrain, or boundaries. Natural regeneration from the adjacent stands is not heavily relied upon, but can have varying degrees of influence depending on patch size. All stems 2" dbh and greater should be removed unless some advanced regeneration of desired species exists.
- Strip Clearcut: is used to promote natural regeneration and growth in the harvested strips through the adjacency of the unharvested area. In harvested strips, all stems > 2' dbh are removed. The unharvested strips act as a seed source and protection for the harvested areas. Concerns related to wind damage are warranted when using this method because of the increased amount of exposed edge. This can be avoided by minimizing the width of the strips being harvested (50-100 feet on stable soil and 30-50 feet on wet soil), ensuring at least one end of the strip is closed, and harvest as soon as cleared strips are regenerated. Strip clearcuts are more successful when applied to healthy forests found on deep, well-drained soils.

Single Tree Selection is the removal of individual trees uniformly throughout a stand. This technique is used to promote the quality and growth of the remaining trees and can also result in the regeneration of mostly shade tolerant species due to the small canopy openings created during the harvest. Use of this technique, on a continual harvesting cycle, is considered an-even aged management.

Actively managing a stand in un-even ages can result in reducing the stands' natural ability to resist insect, disease, and other debilitating health issues. Careful extraction of the trees is necessary to help limit residual stand damage, which can create an opportunity for insects and disease to attack otherwise healthy trees. Root damage by soil compaction also needs to be considered. This technique can also be used during even-aged management and when done so is commonly referred to as an intermediate thinning. Single tree selection can be used to mirror a small scale disturbance. When only large trees are selected, the large opening in the canopy will typically be utilized quickly by the crowns of adjacent older trees.

Group Selection is the removal of small groups of trees to maintain an un-even forest. Normally to be considered a group selection, as opposed to a patch clearcut, the size of the harvest group should be less than or equal to twice the height of the adjacent mature trees. This method will encourage regeneration of intermediately tolerant and tolerant species, but some intolerant species can appear towards the center of the harvest areas when the groups are at the maximum size.

The likelihood of the harvest areas regenerating combined with the ability to schedule continual harvest entries, results in this technique being a method of choice to convert even-aged stands into un-even aged stands when desired. Actively managing a stand in un-even ages can result in reducing the stands natural ability to resist insect, disease, and other debilitating health issues. Careful extraction of the trees is necessary to help limit residual stand damage, which can create an opportunity for insects and disease to enter an otherwise health stand. Root damage by soil compaction also needs to be considered.

A shelterwood System is a series of harvests carried out with the intent of regenerataing a stand utilizing mature trees that are removed at the end of the scheduled rotation. This technique is typically used to regenerate intermediately tolerant (mid-successional) and tolerant (late-successional) species, but in certain instances can be used for intolerant (early-successional) species.

Use of this technique is considered even-aged management, although variations more often found in the irregular shelterwood system can result in a multi-aged stand. In order for a shelterwood system to be considered, a stand should be reasonably well stocked with a moderate to high component of the species desired for regeneration.

Irregular shelterwood system consists of an initial harvest used to encourage regeneration, optional intermediate harvests used to encourage supplemental regeneration, and an overstory removal harvest once regeneration is established. This technique usually results in regeneration with a higher component of intermediately tolerant or tolerant species. This technique differs from other shelterwood systems by introducing the concept of leaving a component of the original stand that can either be removed during subsequent harvests or left throughout the series of harvests and beyond. The long-term residual component can be left singularly or in groups. Harvests can be applied in a variety of fashions including harvesting uniformly, in groups, or strips. The harvest would focus on undesirable species, suppressed, co-dominant, and unhealthy dominant trees. This would provide the greatest potential for seed production and resiliency to windthrow.

Seed tree system is the removal of the majority of a stand while retaining a minority of seed producing trees, left standing to retain some component of the desired species in the regenerating stand. Seed trees can be left singularly and/or in groups, and should be distributed as uniformly as possible throughout the stand. This technique is prescribed when desired species are lacking as a seed source in the overstory (negating shelterwood as an option), or regeneration composition is not a primary objective. This technique could be used to convert species composition to an earlier successional variety while retaining a small component of desired species of mixed hardwoods. Desired species that are healthy, dominant, large crowned, and well-rooted should be targeted to leave standing. The rest of the stand is removed in its entirety (2" dbh and greater). The residual trees/groups can be removed after regeneration is established or may be left to accomplish other stand objectives.

Stand Improvements consist of entering an even or uneven aged stand at any stage of development with the intent of tending to habitat needs through thinning, weeding, cleaning, liberation, sanitation, or other improvement methods. The primary function of this method is to control species composition and reduce an overabundance of stems per acre to a more desired stocking level. This translates into thinning young stands to control species composition, conducting intermediate thinnings in middle aged stands to maintain accelerated growth and remove unwanted vegetation, and control stocking levels of habitat features such as snag trees, cavity trees, den trees, downed wood and other features.

Two techniques are used to benefit wildlife; retain or create snags and the provision of coarse woody debris (CWD). Snags or live trees that fall to the forest floor are known as CWD, which can range in size from branches to bole to entire trees, and adds structural diversity, serving as hiding and thermal cover,

den sites, foraging substrate, and winter access to subnivean habitats. As the wood decays essential nutrients such as sulphur, phosphorous, and nitrogen are released. The need for creating CWD depends on the forest type, stage of succession, and management history. Allowing snags to fall naturally, felling and leaving live trees, and/or leaving tops, limbs, and other debris during stand improvement operations can augment CWD levels.

Snags play an important ecological role for at least 149 bird species, 73 mammals, and 93 herpetiles (Thomas 1979). Based on the state of decomposition, snags can be hard (sound sapwood, rotting heartwood) or soft (rotting sapwood and heartwood). There are several ways to “create” snags, or initiate the decomposition process. Each is an effort to damage a healthy tree’s integrity by creating a pathway for fungal infection. These include girdling, topping, branch removal, fungal inoculation, and herbicide injection. The density and size of suitable snags depends on the individual forest types and natural disturbance patterns.

Many treatments and numerous types of equipment are available for mechanically manipulating upland sites from one covertype to another. Selection of the type of mechanical treatment will depend on site habitat objectives. All of these tools can be used with varying degrees of effectiveness, depending on what is being cut. Special consideration needs to be given to ground disturbance when using heavy equipment. Soils may be compacted and rutted which can cause a change in vegetation component of the area. Disturbed soils are also more likely to promote germination of invasive species, an undesirable outcome of any habitat management activity. Examples of shrub and tree cutting equipment include:

- Drum mowers for removal of small trees.
- Geo-Boy to cut trees up to 6-8” dbh. Woody material is reduced to fine chips, often finer than those resulting from a roller mower.
- Roller Chopper Mower, used to knock down and chop up shrubs and trees. This technique causes significant disturbance to the soil and should be reserved for situations where the area is going to be seeded after treatment.
- Mowing and Brush Hogging: mowing is an appropriate treatment for grass, forbs, and small shrubs and saplings. Vegetation > 4 inches often needs a higher powered machine.
- Girdling: can be appropriate to remove single trees or groups of trees to open up the canopy and/or create snags. It can also cause stump sprouting.
- Chainsaw: can be used to remove single trees or groups of trees to open up the canopy. Stump sprouting may occur.
- CWD Management: different prescriptions will leave differing amounts of woody debris. Objectives will drive the best management technique for dealing with the debris. It can be left to decay on forest floor, however, if conversion to another habitat type is desired (grassland or shrubland), woody debris may be burned or removed. WCD can be chipped and broadcast on site. Depth of chips should not exceed 2-3 inches. Removal from site can be in form of chips, or whole logs and shrubs.

(Maryland PIF Committee. 1997. Habitat Management Guidelines for the benefit of landbirds in Maryland and A Guide to the Conservation of Forest Interior Dwelling Birds in the Chesapeake Bay Critical Area. 2000)

4.5) Integrated Pest Management (IPM)

Integrated pest management (IPM) is defined as “...a decision-based process involving coordinated use of multiple tactics for optimizing the control of all classes of pests (insects, pathogens, weeds, vertebrates)

in an ecologically and economically sound manner” (Ehler 2006). The term ‘integrated’ implies incorporation of natural predator levels into decision-making, and use of compatible, non-disruptive tactics to preserve natural predators associated with pest species. IPM is used to avoid the indiscriminate use of pesticides to avoid such problems as pest resistance, target pest resurgence, negative impacts on non-target species and environmental contamination.

On national wildlife refuges (IPM) is an interdisciplinary approach utilizing methods to prevent, eliminate, contain, and/or control pest species in concert with other management activities on Refuge lands and waters to achieve wildlife and habitat management goals and objectives. It is also a scientifically based, adaptive management process where available scientific information and best professional judgment of the Refuge staff as well as other resource experts would be used to identify appropriate management strategies that can be modified and/or changed over time for effective, site-specific management of pest species.

A tolerable pest population (threshold) must be determined before using chemicals. The ecology of pest species will be considered when using one or more control methods that are feasible, efficacious, and most protective of non-target resources, including native species (fish, wildlife, and plants) and Service personnel, Service authorized agents, volunteers, and the public. Staff time and available funding would also be considered when determining feasibility/practicality of various treatments.

In accordance with 517 DM 1 and 7 RM 14, an (IPM) approach to all Refuge Management activities must be utilized, where practicable, to eradicate, control, or contain pest and invasive species (herein collectively referred to as pests) on the Refuge. IPM would involve using methods based upon effectiveness, cost, and minimal ecological disruption, which considers minimum potential effects on non-target organisms and biological integrity, diversity, and environmental health of Refuge lands. Pesticides may be used where physical, cultural, and biological methods or combinations thereof, are impractical or incapable of providing adequate control, eradication, or containment.

Furthermore, pesticides would be used primarily to supplement, rather than as a substitute for practical and effective control measures of other types. If a pesticide would be needed or used on the Refuge, the most specific (selective) chemical available for the target species would be used unless considerations of persistence or other environmental and/or biotic hazards would preclude it. For example, if larval mosquito monitoring generates action thresholds of species specific mosquito larval densities indicative of an increased health risk, *Bacillus* products would be utilized as the preferred or primary method of mosquito control, due to its greater specificity to control identified mosquito disease vector species, and to minimize negative impacts that other larvicide products have on non-target invertebrate species, migratory birds, amphibians and other wildlife.

4.6) Biological Mosquito Control/Open Marsh Water Management:

Open Marsh Water Management (OMWM) is defined as any type of physical manipulation in the form of pond construction and marsh ditching which alters coastal saltmarsh habitat to accomplish source reduction and biological control of mosquitoes. OMWM evolved as a new ditching technique to replace grid-ditching that had been practiced for thirty plus years from 1930 to 1960s. OMWM is based on the following assumptions: 1) not all parts of a tidal marsh breed mosquitoes; 2) that mosquitoes are greatly reduced or absent from portions of the marsh where tidal action circulates water over the marsh surface and removes excessive water; 3) that biological control in the form of predation of marsh fishes will biologically reduce mosquito populations; and 4) that permanent pools of water on the marsh surface serve as reservoirs for mosquito-eating fishes, which can forage among the grass stems at high tide. The mummichog (*Fundulus heteroclitus*) is the dominant predator, along with other fishes, on Refuge salt marsh habitats.

Various marsh excavations and alteration methods are used with the OMWM technique to control mosquitoes. In Delaware OMWM systems are typically blends of open (tidal), sill (semi-tidal), and closed (non-tidal) alterations, using selective excavations of ponds and ditches to treat identified mosquito-breeding habitats (Meredith et al 1985). The Service has listed several unacceptable practices in Region 5 which include: OMWM excavations in unditched salt marshes; disturbance of natural pannes; low salt marsh alterations; excessive pond depth (≤ 30 to 36 inches deep). OMWM excavations on Refuges should be directed to disturbed high marsh areas where mosquito breeding occurs and control is necessary (Taylor 1998).

Spoil management in all OMWM excavations is critical. OMWM best management practices identified by Meredith et al (1985) emphasize the need to insure that excavations do not cause the mean subsurface water table to drop more than six inches below local marsh surface elevation. Delaware research data has found that the mean water table of zones of *Iva*, *Baccharis*, and robust *Phragmites* is usually 6 inches or more below local marsh surfaces. This creates a soil condition that is drier and more aerated than soils in salt hay or short-form cordgrass zones, where the water table is much closer to the surface (Meredith, Saveikis, & Stachecki 1983).

Conditions that result in establishing the growth of marsh shrubs and *Phragmites*, include excessive subsurface drainage and/or excessive spoil deposition, either separately or in combination that will lower water tables. Delaware-OMWM BMPs state that spoil from ditches and ponds should be spread over the marsh surface at initial depths no greater than 3 inches. After a period of spoil settlement, any permanent increase in surface elevation should be less than two inches (Meredith et al 1985).

4.7) Control of Over-abundant or non-native Waterfowl Populations

Controlling invasive or over-abundant waterfowl, such as mute swans, snow geese, and resident Canada geese is a strategy used to protect native water birds and fisheries, and prevent the destruction of wetland habitats on Refuges. Control methods include: harassment, egg addling, sterilization, removal, shooting, increased hunting pressure, and modifying historic habitat management practices.

The Atlantic Flyway Council's (2003), "*Atlantic Flyway Mute Swan Management Plan 2003-2013*," (<http://www.dnr.state.md.us/wildlife/afcmuteplant>) outlines the coordination of state (lead) and federal wildlife agencies "to reduce mute swan populations in the Atlantic Flyway to levels that will minimize negative ecological impacts to wetland habitats and native migratory waterfowl and to prevent further range expansion into unoccupied areas." Target populations of mute swans vary by state and range from 0 to 500 free-flying birds.

In the fall of 2005, the Service completed an Environmental Impact Statement that included a multi-faceted approach for managing resident Canada geese (<http://migratorybirds.fws.gov/issues/cangeese/deis.html>). Upon recommendations from the Atlantic Flyway Council, the Service approved the use of special regulations beginning in 2007 to help curb the growth of resident Canada goose populations in the eastern US which included the expansion of hunting methods during September seasons.

The Service released the Final Environmental Impact Statement for Light Goose Management in June 2007 that examined five alternatives for future management of over-abundant Greater Snow goose populations. The preferred alternative would: 1) expand hunting opportunities within the current migratory bird hunting-season framework; 2) establish a conservation order for expanded hunting methods; and 3) modify habitat management practices on National Wildlife Refuges to decrease the amount of food and sanctuary available for light geese. (<http://www.fws.gov/migratorybirds/issues/snowgeese/FINALEIS2007/>)

4.8) Predator Control and Nuisance Wildlife Management

Predator control and nuisance wildlife management are valuable strategies used to manage and mitigate habitat and/or wildlife damage and protect endangered and threatened species or species of conservation concern and their habitats. A comprehensive predator control and nuisance wildlife refuge program will address a range of management prescriptions from vegetation protection, control and/or nesting habitat enhancement to non-lethal and lethal predator and wildlife control. The most effective, selective, and humane techniques available to deter or remove individual predators or problem species will be used.

For example, control of Refuge problem species like beaver, nutria and muskrats, mute swans and/or resident Canada geese may be required when high concentrations of these species incur deleterious effects on native wetland habitats, aquatic vegetation, or refuge infrastructure. The control of mammalian and/or avian predators such as raccoons, foxes, gulls and crows, may be required that threaten or destroy nesting, breeding, or foraging habitats used by state or federally endangered species or species of special conservation concern. These species include but will not be limited to piping plovers, American oystercatchers, least and common terns, red knots and ruddy turnstones.

Trapping as a Management Strategy: Trapping and lethal control will be two major strategies used to control predators and to manage populations that negatively impact Refuge habitats or habitat infrastructure (like nutria and/or muskrats that burrow and destroy Refuge dikes, etc). Trapping and shooting to control nutria can also be used effectively to achieve desired interspersion of wetland vegetation. Trapping and shooting are important management tools that can be used for the following objectives:

- Habitat management or protection
- State or federally endangered species protection
- Migratory bird protection
- Wildlife Population Management
- Surveys or monitoring of wildlife
- Facilities protection
- Public Safety and health
- Feral Animal Control
- Disease Control

Alternative techniques to trapping and shooting will also be used to accomplish the above objectives. These include the use of electric fences, scare devices, screens and shields, and exclosures to deter predators. Any other new, effective, and selective techniques that become available to help prevent and/or mitigate habitat damage, maintain diverse and healthy wildlife populations, and protect endangered, threatened, and/or species of conservation concern, will also be considered.