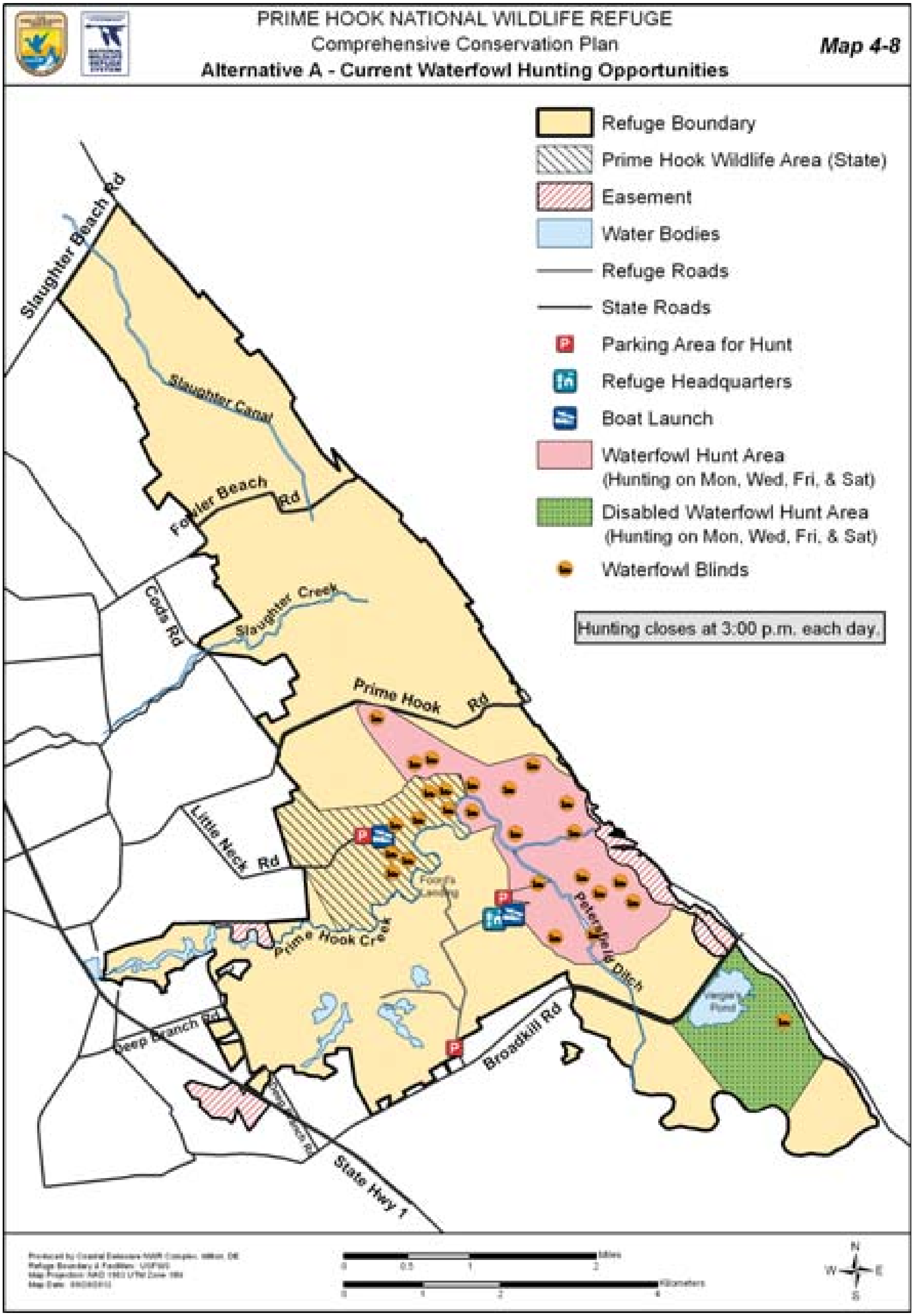
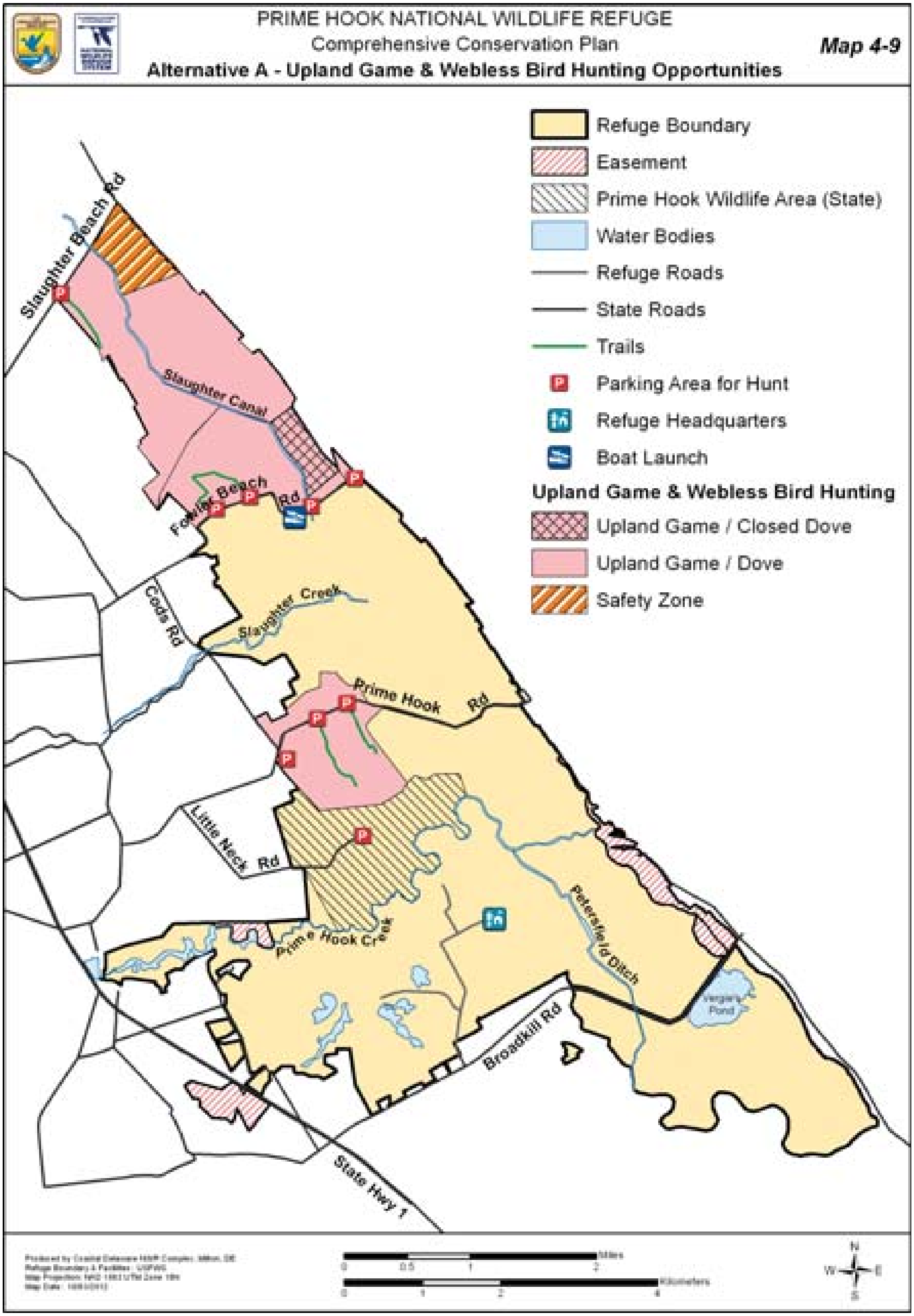
Map 4-8. Waterfowl hunting opportunities under alternative A



Map 4-9. Upland game and webless migratory bird hunting opportunities under alternative A.



(Affected Environment). Map 4-6 depicts wildlife observation and photography opportunities and infrastructure under alternative A.

Strategies
In addition to those strategies listed under Actions Common to all Alternatives affecting this program:

- The eastern portion of Prime Hook Creek (Unit III) is closed from Foord's Landing to the headquarters boat ramp from October 1 (sometimes earlier due to hunting of early teal season on state area) through March 15.
- Allow visitors to use the existing trail and observation platform overlooking Vergie's Pond on the south side of Broadkill Beach Road.

Objective 5.3 Recreational Fresh and Saltwater Fishing and Crabbing

Provide high-quality fishing and crabbing opportunities.

Rationale
Much of the basis for recreational fishing and crabbing under the existing program is described under Actions Commons to All Alternatives and chapter 3 (Affected Environment). Map 4-6 depicts fishing and crabbing opportunities and infrastructure under alternative A.

Strategies
In addition to those strategies listed under Actions Common to all Alternatives affecting this program:

- No refuge permit is required.
- The eastern portion of Prime Hook Creek (Unit III) is closed from Foord's Landing to the headquarters boat ramp from October 1 (sometimes earlier due to hunting of early teal season on state area) through March 15.
- Maintain the boat launching fee of $1.00 per boat at refuge boat ramps in the headquarters area.

Objective 5.4 Environmental Education and Interpretation

Provide high-quality environmental education and interpretation opportunities.

Rationale
Much of the basis for environmental education and interpretation is described under Actions Common to All Alternatives. Map 4-6 depicts facilities and infrastructure used to support environmental education and interpretation.

Strategies
Refer to strategies listed under Actions Common to all Alternatives affecting this program.

Objective 5.5 Other Recreational Use

Provide opportunities for the public to use and enjoy the refuge for traditional and appropriate non-wildlife-dependent recreation that is compatible with the purpose for which the refuge was established and the mission of the Refuge System.

Rationale
Much of the basis for other recreational use under existing management is described under Actions Common to All Alternatives and in chapter 3 (Affected Environment).

Strategies
In addition to those strategies listed under Actions Common to all Alternatives affecting this program:

- Continue to allow the following non-priority uses that have previously been formally evaluated and documented: commercial fishing, commercial trapping of muskrat, raccoon, etc., turtle trapping, picnicking, 5k road race, beekeeping, and waterfowl retrieval permits.

- The following uses were never formally evaluated and documented under current management: dog walking (required a ten-foot leash), roller blading, competitions or organized group events, non-competitive organized events. It is the professional judgment of current and former refuge staff that these historic uses, if found appropriate and compatible, are allowed.

GOAL 6. Outreach and Community Partnerships

Collaborate with the local community and partners to complement habitat and visitor service programs on the refuge and the surrounding landscape.

Objective 6.1 Community Outreach

Continue to provide community outreach by conducting programs or events each year, and initiate news articles to increase community understanding and appreciation of the refuge's significance to natural resource conservation and its contribution to the Refuge System, and to garner additional support for refuge programs.

Rationale
Much of the basis for community outreach is described under Actions Common to All Alternatives.

Strategies
Refer to strategies listed under Actions Common to all Alternatives affecting this program.

Objective 6.2 Private Landowner Assistance

Continue existing levels of technical assistance to private landowners to enhance their land management to improve wildlife habitat.

Rationale
Much of the basis for private landowner assistance is described under Actions Common to All Alternatives.

Strategies
Refer to strategies listed under Actions Common to all Alternatives affecting this program.

Objective 6.3 Regional and Community Partnerships

Continue existing partnerships with Federal, State, and local government agencies and regional and community organizations to fulfill natural resource conservation mandates and help us meet our wildlife, habitat, and visitor services objectives.

Rationale
Much of the basis for regional and community partnerships is described under Actions Common to All Alternatives.

Strategies
Refer to strategies listed under Actions Common to all Alternatives affecting this program.

Alternative B. The Service-preferred Alternative

Alternative B is the alternative our planning team recommends to our Regional Director for implementation. It includes an array of management actions that, in our professional judgment, work best towards achieving the refuge's purposes, vision and goals, and would make an important contribution to conserving Federal trust resources of concern on the Delmarva Peninsula and in the Northeast region. It is the alternative that would most effectively address the issues identified in chapter 1. We believe it is reasonable, feasible, practicable, and the most timely, sustainable, and efficient alternative within a 15-year timeframe to achieve the desired future habitat conditions for the conservation of the greatest number of fish, wildlife, and plant resources, while enhancing biological resources of Delmarva coastal plain ecosystems. This alternative involves direct human actions and manipulations to restore degraded and manipulated habitats onto a trajectory that will ultimately allow them to persist naturally.

The biological and habitat goals, objectives, and management strategies of alternative B are based on the following underlying hypotheses and assumptions that were used to decide the future management direction for the refuge, including the desired habitat conditions depicted in Map 4-10 to Map 4-14:

- Focal species management would be the best approach to conserve continental migratory bird populations, while maintaining, enhancing, and restoring biological integrity, diversity, and environmental health of refuge lands.

- Managing upland habitats and improving refuge forest management are the best approaches to optimize Delmarva fox squirrel and forest interior bird conservation.

- Increasing avian diversity and abundance on refuge habitats is best accomplished by conserving, protecting and restoring native plant community cover types.

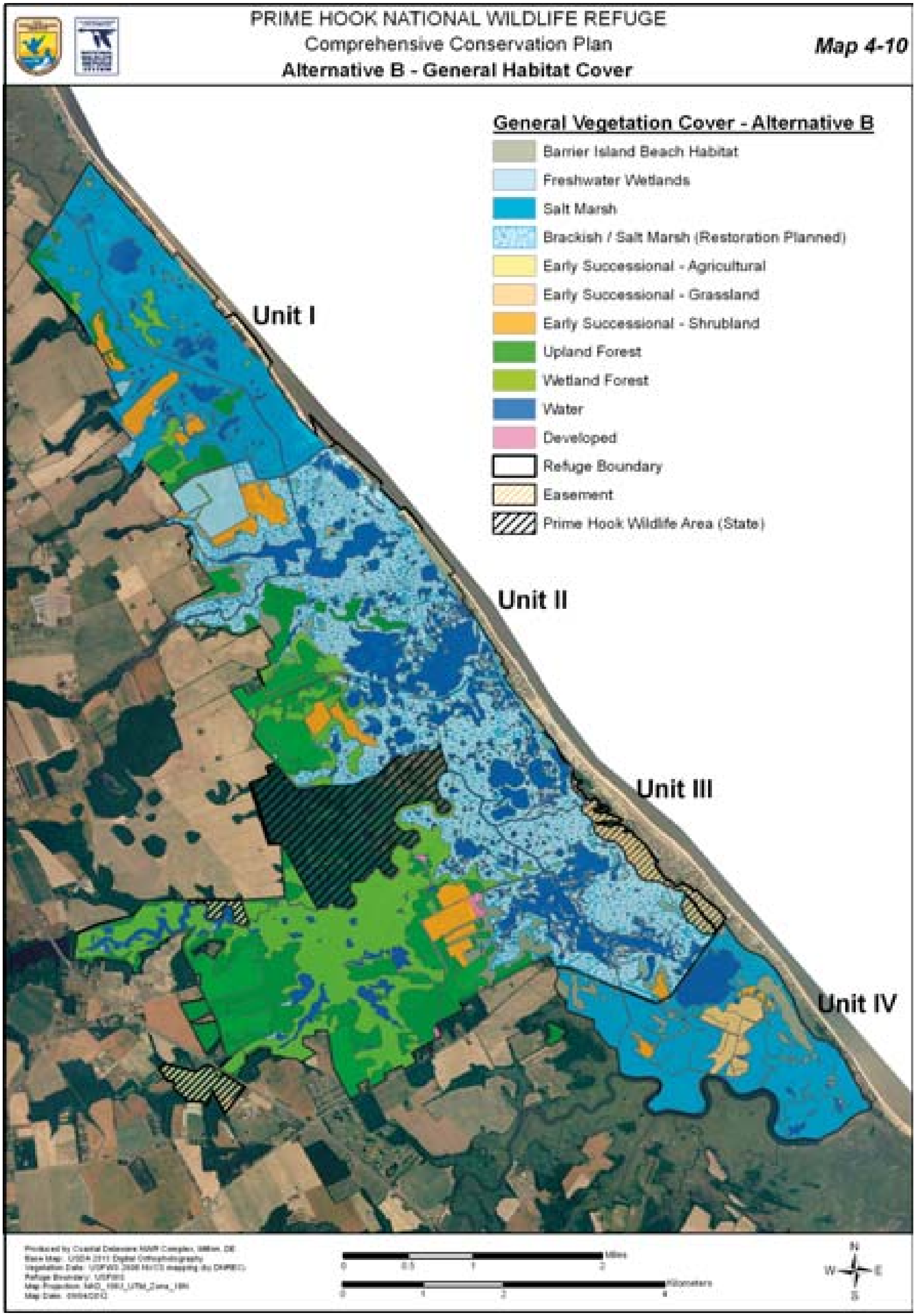
- Selecting certain focal bird, fish, and insect species as indicator and umbrella species and yardsticks to gauge ecosystem function, biological diversity, integrity, and environmental health, improves environmental health monitoring.

- Modify mosquito and integrated pest management (IPM) strategies to advance pollinator conservation and protection and reduce negative non-target impacts on refuge invertebrate resources.

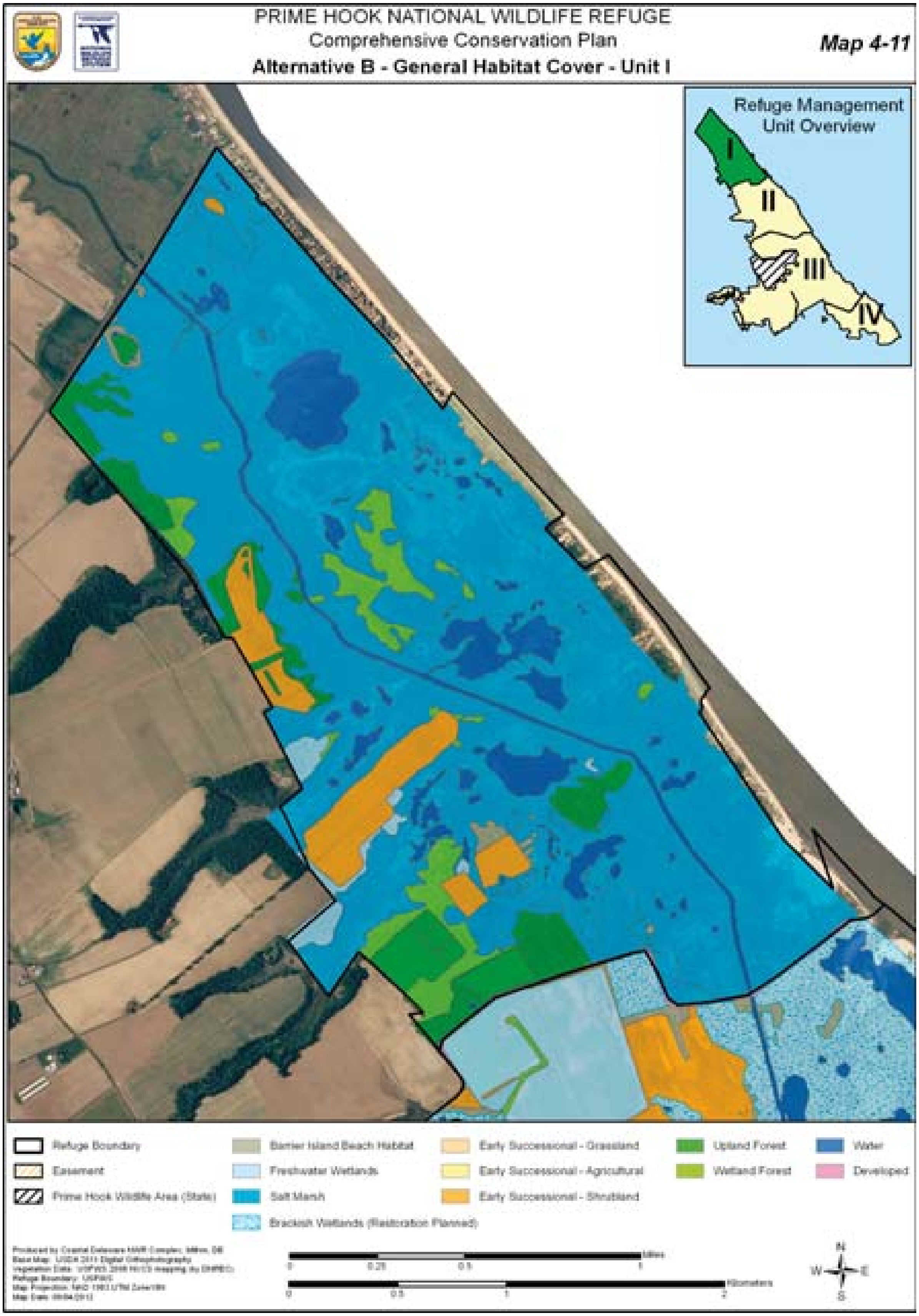
- Restoring healthy salt marsh systems in Units II and III, as well as degraded areas of Units I and IV, along with conserving appropriate vegetation communities in brackish and freshwater areas closer to streams and freshwater sources, will foster sustainable coastal habitats and contribute to biological integrity.

The Service is aware that physical forces in the changing climatic environment, and the biological responses that they generate, are rapidly altering our ability to follow management prescriptions designed just a few years ago. Accelerating climate change and its coastal manifestations—sea level rise, increased coastal storm activity and force, changes in plant and animal population distributions associated with changing temperature regimes—will necessitate revising management strategies for the long term, particularly where management of coastal wetlands and impoundments is concerned. This preferred alternative outlines a proactive habitat management approach in response to these changing conditions.

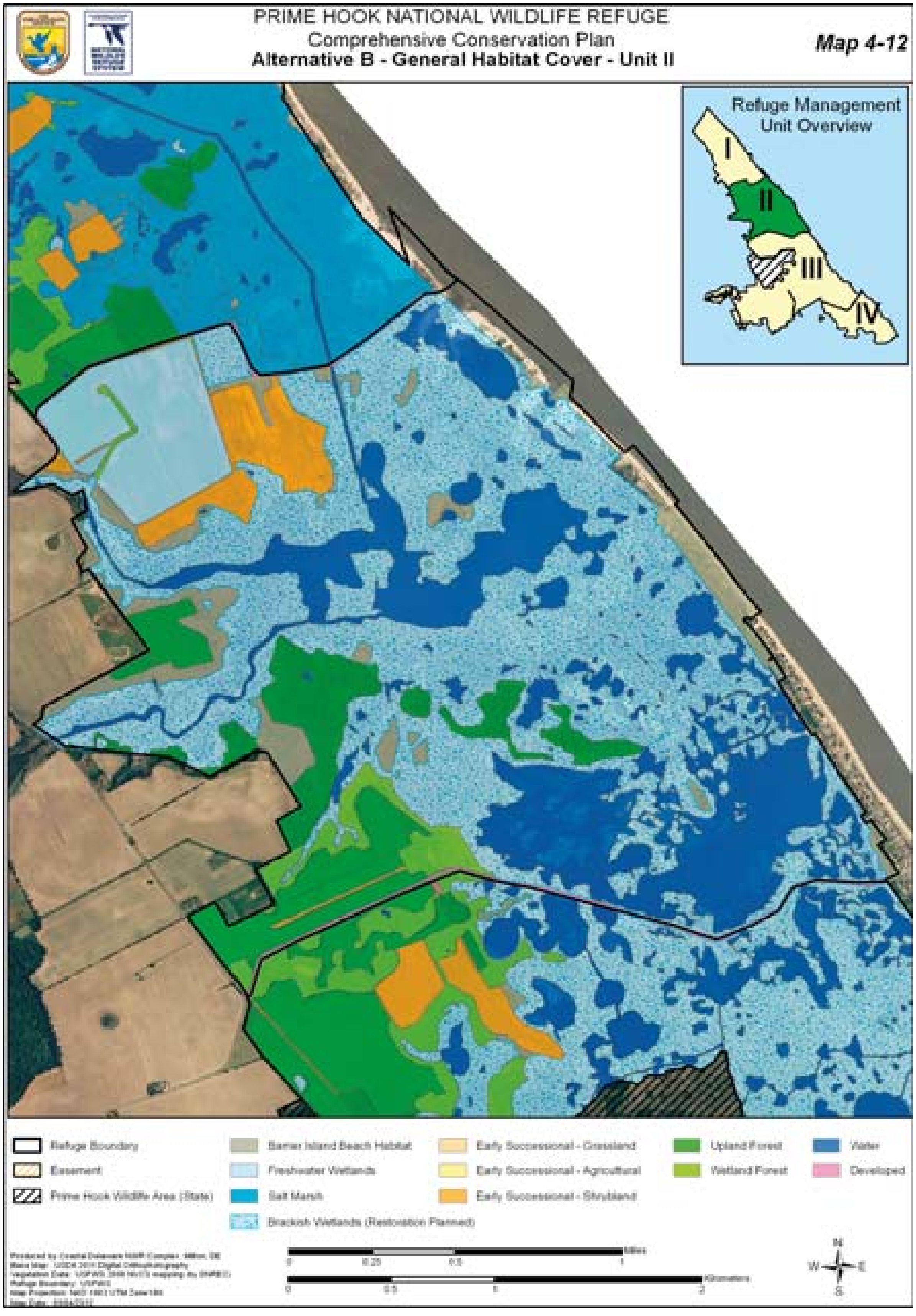
Map 4-10. Overview of general habitat cover under alternative B



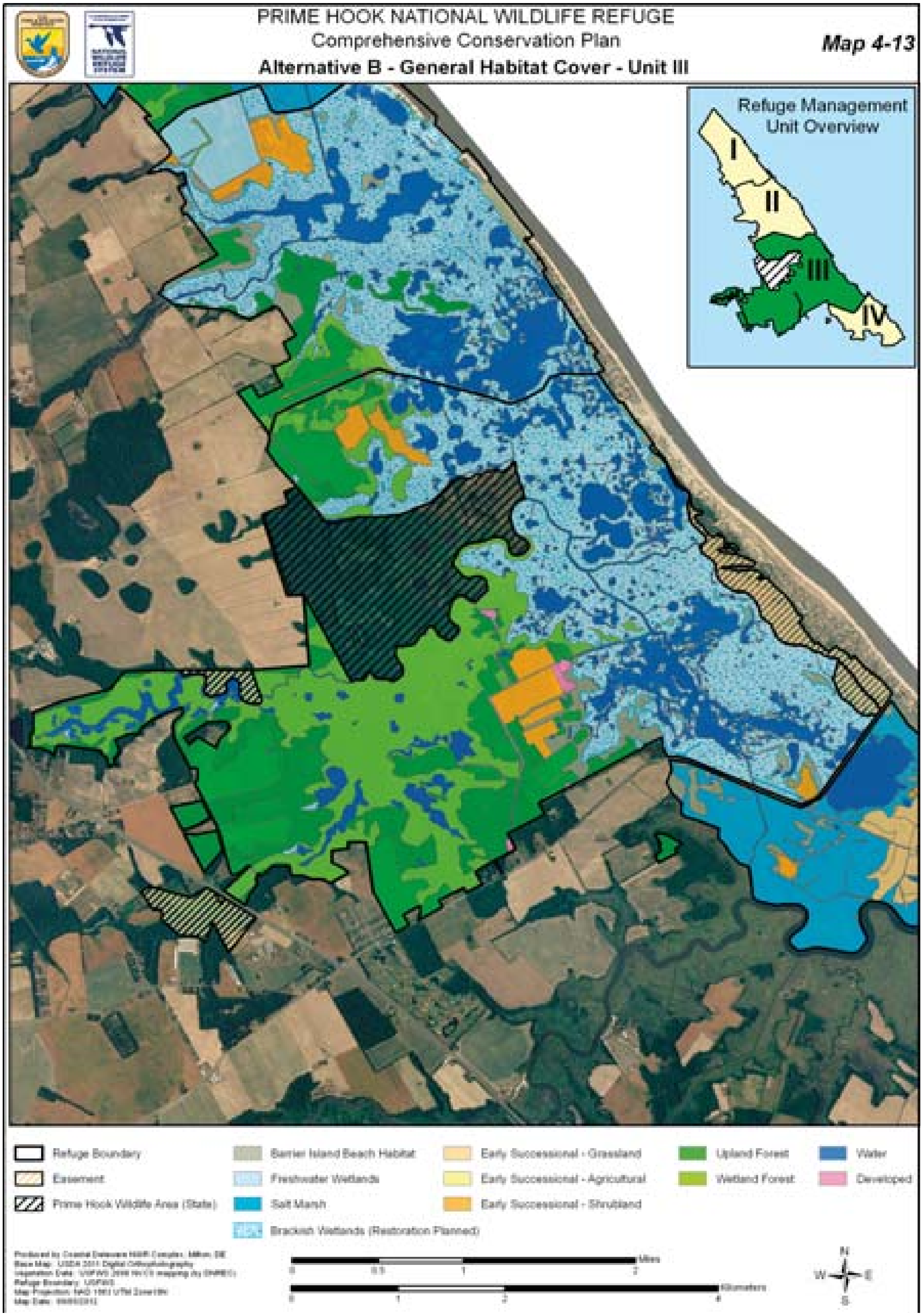
Map 4-11. General habitat cover in Unit I under alternative B



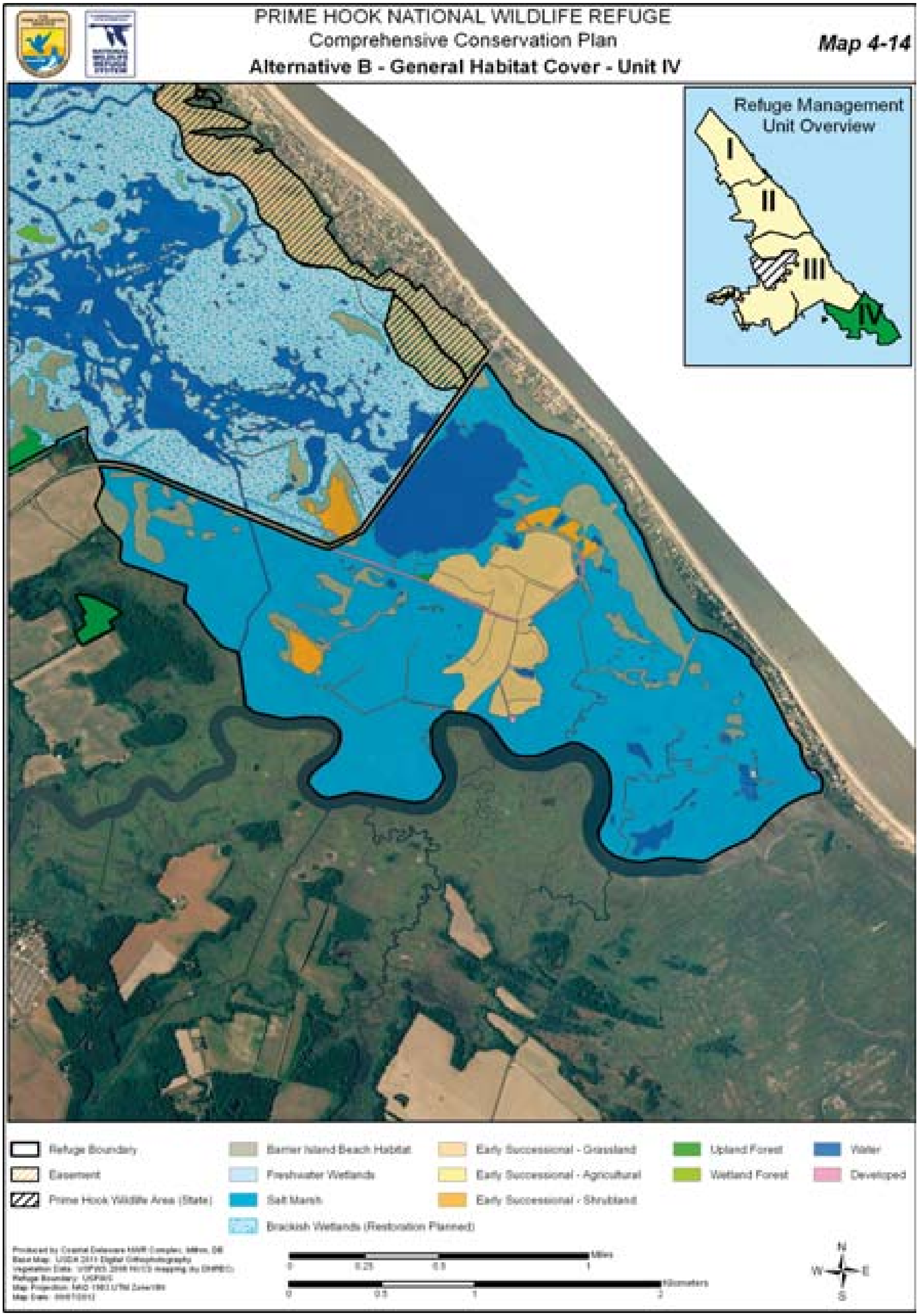
Map 4-12. General habitat cover in Unit II under alternative B



Map 4-13. General habitat cover in Unit III under alternative B



Map 4-14. General habitat cover in Unit IV under alternative B



Most notably, for salt marsh enhancement where intrusion of tidal waters and the collapse of the peat substrate has occurred, we will pursue strategies to compensate for lost marsh platform elevation, in order to support the growth of salt marsh vegetation. This may include the addition of dredged sediment through a carefully planned restoration project, and/or smaller actions to encourage natural accretion of sediment. Additional sediments may also be needed to enhance overwash flats and to potentially create low dunes or islets within the marsh. However, the purpose of these actions is not to rebuild a barrier island in the same alignment as the former barrier island but to allow for a diverse array of maritime habitats which would naturally occur in a mid-Atlantic bay, marsh, and beach/spit system. In upland habitats, there will be an emphasis on restoring native forest cover in previously farmed or otherwise open fields.

For public use under alternative B, we would expand existing opportunities for all six priority public uses, with additional emphasis on hunting and wildlife observation and photography. Map 4-15 depicts the public use facilities proposed under alternative B.

As compared to Alternative A, which represents current hunting and fishing opportunities, opportunities for hunting and fishing will be enhanced under Alternative B. These enhancements consist of expanding fishing and hunting areas, increasing the number of hunt days, reducing the administrative burden of the hunts, eliminating permit hunting fees except for lottery hunts, providing better outreach and information materials, phasing out the permanent hunting structures, and providing opportunities for preseason lottery hunts for waterfowl and deer. We will expand new areas and provide new opportunities for wildlife viewing, photography, and interpretation primarily by opening existing roads and trails and providing new infrastructure. In addition, a photography blind overlooking a restored wetland site is proposed. Furthermore, new visitor infrastructure, including additional building space for environmental education programs, an interpretive auto tour route using advanced technology, and additional guided field trips would be developed.

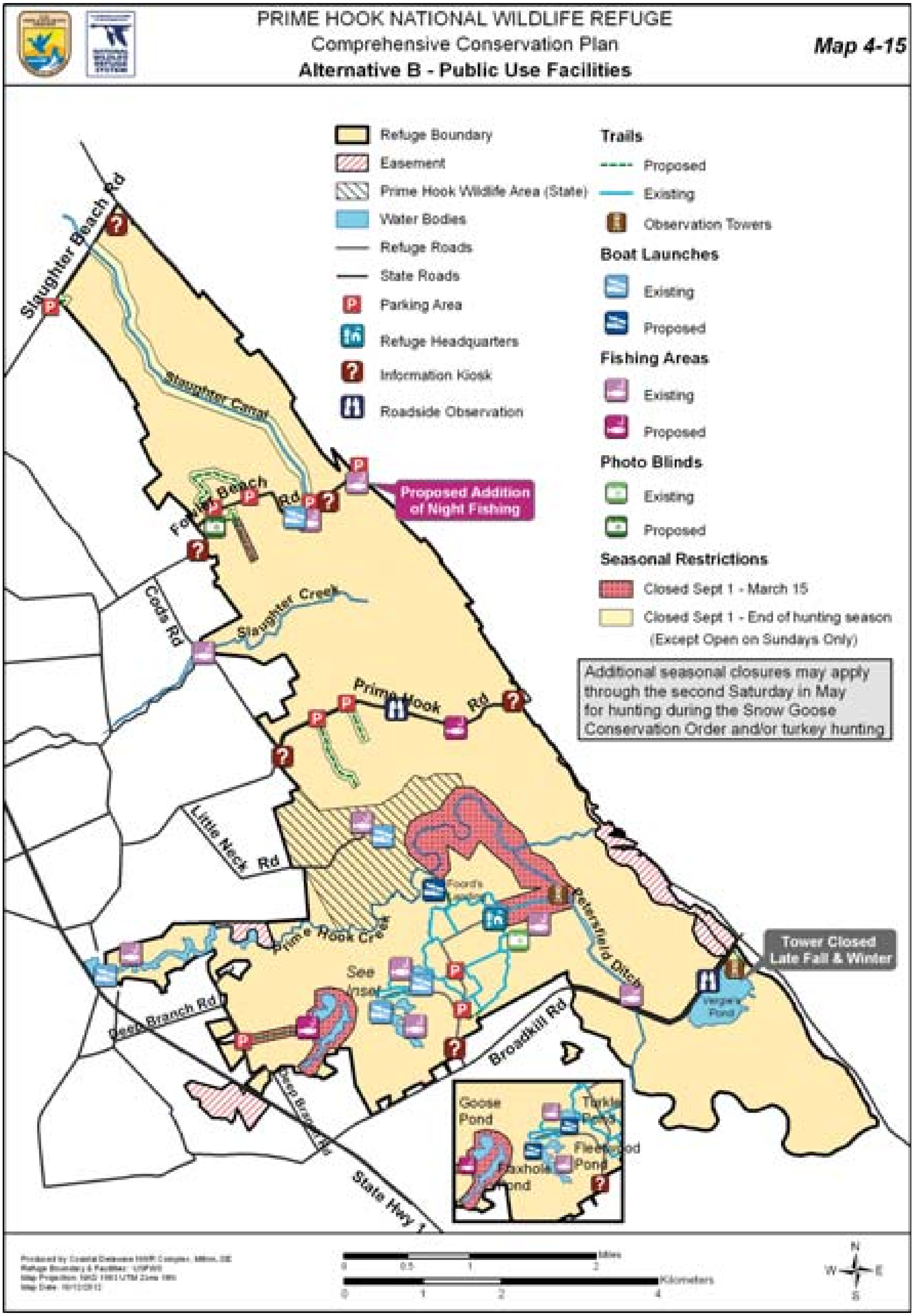
- Concerning other refuge uses, we would continue to allow wildlife observation, wildlife photography, hunting, fishing, environmental education, environmental interpretation, limited mosquito control, research, and use of the Federal Aviation Administration tower. Commercially guided birding and canoeing trips and commercial photography would be permitted with a signed special use permit and fee. Activities evaluated by the refuge manager and determined not to be appropriate on refuge lands can be found in appendix E.

We would also enhance local community outreach and partnerships, continue to support a Friends Group, and continue to provide valuable volunteer experiences. As described under goal 6, we would pursue establishing demonstration areas on the refuge to promote research, and developing applied management practices to benefit the species and habitats identified in this alternative.

Under this alternative, we propose to achieve a staffing level that meets minimum requirements for a refuge of this size and stature, potentially adding five new positions (clerk, biological technician, maintenance worker, law enforcement officer, and public use specialist). Any staffing increases would be based on available permanent funding sources, and would be considered in the context of regional and refuge priorities.

We would seek to expand the current office building to accommodate additional visitors for environmental education and interpretive programs. This office

Map 4-15. Public use facilities under alternative B



expansion would also provide needed space for storage of visitor services, supplies, and biological equipment. We would continue the use of travel trailers, which are used for interns, researchers, volunteers, and temporary employees.

In the discussion that follows, we describe in detail the goals, objectives, and associated rationales and strategies that we would use to implement alternative B habitat management and public use objectives. We have provided additional discussion and strategies specifically regarding our response to climate change and sea level rise.

GOAL 1. Barrier Beach Island and Coastal Salt Marsh Habitats

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

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

Permit the natural evolution and functioning of sandy beach, overwash, dune grassland, and mudflat habitats along approximately 1.5 miles of refuge coastline in Unit I to conserve spawning horseshoe crabs and listed BCR 30 migratory bird species. Over time, permit the development of these features and communities along an additional approximately 1.5 miles of the shore of Unit II, as salt marsh restoration is pursued. Barrier beach communities are characterized by the following attributes:

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

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

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

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

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

On the refuge, barrier beach island habitats are comprised of five natural community types:

- Overwash dunes
- Beachgrass/panicgrass dune grassland
- Atlantic coastal interdune swale
- Maritime red cedar woodland
- Successional maritime forest

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

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

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

Immediately parallel to the Delaware Bay, Unit I habitats have increasingly become more important for both migrating and breeding shorebirds in the face of beach development along bayshore areas. The highest quality dunes remaining along the Delaware Bay shore occur from Big Stone Beach (about 7 miles north of the refuge) south to Beach Plum Island (about one mile south of the refuge) (Clancy et al. 1997) and have been identified as a key wildlife habitat of special conservation concern in the State plan and the BCR 30 plan. Beach strand habitats along the bay are migrating landward as a result of storm surges and sea level rise. Storms and high tides deposit wrack composed of algae, vascular plant fragments, assorted mollusk shells, whelk casings, and remnants of clams, crab, and fish. This rich organic debris provides important feeding and breeding sites for a variety of invertebrates. Coupled with spawning sites for horseshoe crabs, wrack lines provide nutritious and plentiful natural food resources for migrating birds year-round and for nesting birds in the spring and summer.

Strategies

- Allow the natural processes of inlet formation, sand migration, and overwash development.

- Avoid artificial dune stabilization where tidal flow from Delaware Bay is naturally restoring Unit I salt marsh habitats or transitioning refuge impoundments into a salt marsh.

- Develop site-specific restoration recommendations for Unit II, with the continued input of a diverse group of wetland management and restoration experts, state and Federal officials, academic scientists, and community representatives for short-term and long-term shoreline management to maximize the success of salt marsh restoration efforts.

- Control invasive plant species (mostly *Phragmites australis* and *Salsola kali*).

- Seasonally protect beach berm, wrackline and associated dune edge, and overwash from human disturbance to protect listed and candidate breeding and migrating shorebirds, establishing and enforcing nesting area closures from March 1st to September 1st.

- Use high visibility law enforcement patrols to implement beach closures.

- Develop a refuge-specific piping plover contingency management plan should piping plovers establish nesting sites on refuge overwash areas.

- 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.

- Fence and post areas annually to protect breeding and migrating shorebird species at critical times from human disturbance. In years when piping plovers, American oystercatchers, or least and common terns nest, maintain suitable nesting habitat through beach closures, predator management, and public education.

- Eliminate dog use of refuge beach strand habitats to protect nesting and migrating shorebirds during the same time frame.

- Assess red fox, raccoon, feral cat, and other predator problems along refuge beach strand habitats and implement predator control in collaboration with USDA Wildlife Services. Work with State and Federal endangered species specialists to determine the number of American oystercatcher, least and common terns, and piping plover that can be supported by these refuge habitats.

Monitoring Elements

Develop a comprehensive monitoring and survey programs to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or a reevaluation or refinement of our objectives. Details of planned monitoring will be developed in a subsequent inventory and monitoring plan. Examples of monitoring or surveys that we may implement include:

- Determine the 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 to detect newly established invasive species and immediately address those populations through the appropriate control measure. This approach will incorporate a combination of plant identification and inventories, maintain updates of new invasive species present in the region, and provide knowledge of the appropriate management techniques prior to conducting control efforts.
- Establish annual habitat assessment protocols of overwash areas and mini-inlet openings and closures along Unit I and Unit II beach strand habitats to monitor expansion and contraction of overwash acreages, creation and plugging of mini-inlets, and tidal flow changes feeding Unit I salt marshes using GPS/GIS tools.
- Use presence or absence of the beach dune tiger beetle as an indicator species of healthy overwash, dune grassland, and sandy beach habitats.
- Conduct shoreline position and topography monitoring along the full length of refuge coastline, consistent with National Park Service protocols and in coordination with other Northeast Region refuges.
- Conduct surveys to determine presence or absence of northeastern beach tiger beetles to assess the health of overwash, dune grassland, and sandy beach habitat.
- Develop and implement weekly bird monitoring protocols. Utilize data to document the ongoing effectiveness of water level management activities and adjust management protocols as necessary.
- Continue monitoring of rare flora and fauna and work on establishing BIDEH metrics to evaluate annual habitat condition of barrier beach island habitats on refuge and State lands.
- Monitor habitat impacts from public use and impacts to resources of concern during the spring and summer periods.
- 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 Delaware's 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.

- 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 Rationale
The shoreline on the western side of the Delaware Bay, which includes coastal areas within the refuge boundary, is characterized as a lagoon-barrier-marsh shoreline (Kraft et al. 1976). 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 and John 1976b). This is caused by several geological processes:

- The continental shelf and coastal plain are known to be experiencing deep subsidence

- Global sea level rise

- Erosion and redistribution of sediments as shorelines shift in a landward and upward direction in response to the rise in relative sea level.

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 that allow 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 and John 1976a, Drew 1981, Riggs and Ames 2007, Defeo et al. 2009).

Even non-storm tidal surges can produce waves that overtop beach berms on the Delaware Bay shoreline, resulting in overwash fans on the marsh side of the shoreline. Through time, overwash events bury the marshes and associated peat deposits, fill in old inlet channels, or create new ones. 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 and John 1976a, Drew 1981, Defeo et al. 2009, Pilkey and Young 2009). Shoreline transgression enables wetlands behind shorelines to accrete sediments and keep up with sea level rise. Restored tidal flows also 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.

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. Shoreline position information has high data value because 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 yields a better understanding of local sediment budget cycles, trends, and storm episode influences (Psuty et al. 2010). Collecting a record of the changes in the shoreline position over time will monitor variations 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 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 the 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 that results in wave action and longshore drift systems helps 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 deeper than 5 feet and no more than several hundred feet wide), dominated by inlet and overwash processes (Kraft et al. 1976a).

Climate Change and Sea Level Rise Adaptation Strategies and Monitoring
Management to maintain beach habitats requires long-term mitigation and adaptation strategies. Adaptation would allow the beach to migrate inland as the sea rises. Adaptive measures accept the reality of sea level rise and coastline retreat and seek to increase coastal resilience, a concept with ecological, morphological, and socioeconomic components (Carpenter and Folke 2006). Measures to promote resilience include the protection, vegetation, and maintenance of sediment supply to beach habitats, and the provision of buffer zones that allow the landward migration of the coastline. Monitoring is an important component of managing this dynamic system. Strategies include those listed above plus:

- Conduct shoreline surveys according to National Park Service protocols (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 standard operating procedures that are intended to ensure scientific consistency and repeatability. Minimally, conduct these surveys in early spring (mid-March to late April) and early fall (mid-September to late October), periods that coincide with the peak expression of seasonal beach variability.

- Coordinate refuge shoreline monitoring efforts with other coastal refuges to integrate the NCBN database to foster Departmentwide sharing of standardized monitoring data. Implement the vital signs program's shoreline position monitoring protocol and shoreline topography monitoring protocol.

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 approximately 60 acres of Atlantic Coast interdune swale, more than 70 acres of maritime red cedar, and more than 180 acres of successional maritime forest communities for migrating passerines and other maritime shrub and forest-dependent species. This approach would allow us to maintain existing shrub and forest habitats or to plant the appropriate native species as invasives are removed or disturbed areas are restored to accelerate the pace of natural native species regeneration.

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—*Catocala muliercula*
- Southern broken dash—*Wallengrenia otho*
- Delaware skipper—*Anatrytone logan*
- Little glassywing—*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 or shrub-dominated communities, to red cedar woodlands and maritime shrub-forested areas.

Prime Hook NWR's maritime red cedar community is recognized 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 the refuge's NVCS alliance and association descriptions (Prime Hook NWR 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 (McCann 1993, Clancy et al. 1997).

The McCann study demonstrated that often these habitats support more than twice as many migratory landbirds as 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 stopover place where migratory passerines congregate to forage in dense mid-Atlantic shrub and maritime forested habitats that have significant populations of invertebrates and high 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 Prime Hook NWR and along the Delaware Bay also support the importance of maintaining and managing healthy maritime shrub and forested habitats. High densities of migratory songbirds during fall migration events along the Atlantic Coast and Delmarva Peninsula have been attributed to a higher proportion of hatching year birds and 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 (Mizrahi 2006, Dawson and Butler 2010).

Strategies

- Maintain or enhance native vegetation communities using prescribed fire where appropriate; consult with the Service's regional fire wildlife biologist to determine, if, when, and where prescribed fire would be appropriate to reduce invasive species, 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.

- In an effort to minimize non-target affects on-refuge, the Service will permit the use of adulticides as a management tool once the Section's surveillance program has detected a mosquito-borne human health threat on the refuge or within the flight range of vector mosquitoes, the average of which, according to the Rutgers Center for Vector Biology, is generally considered to be less than 5 miles for the eastern saltmarsh mosquito, Ochlerotatus sollicitans.

Monitoring Elements

Conduct appropriate monitoring and survey programs as funding and staffing permit to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or reevaluations or refinement of our objectives. Details of planned monitoring will be developed in a subsequent inventory and monitoring plan. Examples of monitoring or surveys that we may implement include:

- Reevaluate existing refuge breeding bird survey points to determine whether they are placed appropriately to monitor birds of conservation concern identified in the Delaware wildlife action plan, BCR 30, and Partners in Flight 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.

- Evaluate the effectiveness of prescribed burning to reduce invasive species or maintain shrub habitats by conducting post-burn surveys to measure the area, intensity, and success of the burn.

Objective 1.3 North Atlantic Low and High Salt Marsh Habitats

By 2020, enhance the ecological integrity of 2,200 acres of existing salt marsh by 10 percent over baseline condition, as quantified by the regional salt marsh integrity index. Maintaining a mix of North Atlantic high and low salt marsh vegetation composed of less than 5 percent invasive plant cover and pool, panne, and irregularly flooded tidal salt shrub communities consistent with local reference sites will ensure that the quality and natural function of the marsh and tidal hydrology are restored and sustained. This will provide food resources and habitat for nesting species (e.g., seaside sparrow, salt marsh sharp-tailed sparrow, coastal plain swamp sparrow, Henslow's sparrow, sedge wren, black rail, clapper rail, least tern, gull-billed tern, black skimmer, willet, American black duck), migrating and wintering habitat for 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 percent 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 maritima, 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 1985). Protective legislation helped to slow 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 20 acres per year (Hadisky and Klemas 1983). Other states in the region experienced similar trends.

Habitat analysis mapping for Delaware shows less than 7 percent of herbaceous wetland habitats remain on the landscape (appendix A) while salt marsh communities are listed as habitats of conservation concern in the DNREC (2005b). 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, with less than 85 acres of high marsh compared to 1,756 acres of low marsh (McAvoy et al. 2007).

BCR 30 and Partners in Flight 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 in the region, State, and 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.

Salt marshes provide neighboring communities with flood protection. The presence of salt marsh vegetation in coastal marshes can reduce shoreline erosion by completely dissipating wave energy within 100 feet of the shoreline, which in turn increases the potential for sediment deposition (Morgan et al. 2009, Knutson 1988, Broome et al. 1992).

The regional salt marsh integrity index is a measure of ecological integrity, which includes both physical and biological factors and provides a basis for comparing and monitoring the health of salt marsh units on individual refuges and regionwide.

Mosquito Management in Salt Marshes

The Delaware Mosquito Control Section (hereafter referred to as the 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. Prime Hook NWR is adjacent to residential beach communities where nuisance issues are amplified. Conflicts arise among 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. The refuge acknowledges a responsibility to permit management of mosquitoes when it is in the documented interest of public health to do so. 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. These mosquito management methods were described in detail in chapter 3, under the discussion of invertebrates. Control of mosquitoes on refuges will be guided by the national Service mosquito management plan, which has not been finalized as of preparation of this CCP. In the interim, we look to the draft policy for guidance.

Integrated Pest Management Approach

The Section currently uses thresholds to determine how, when, and where to conduct mosquito control treatments. These thresholds may require revision under the mosquito management plan to bring them in line with refuge management policies.

Pest management strategies for mosquito control will be implemented by using a tiered risk-assessment decision making process that reduces the use of adulticides.We will not permit the use of adulticides solely for nuisance relief. Use of adulticides will be permitted in instances of an elevated public health threat from mosquito-borne disease . The refuge acknowledges this public responsibility. We are also choosing to employ Bti products over methoprene products, when possible. By favoring the larvicide that would have the least adverse impacts on nontarget invertebrates, we would produce fewer disruptions to food webs critical for migratory birds.

Strategies

- Assist with the development and use of the region's salt marsh integrity index to develop a multi-metric method to score condition of the salt marsh community; use the index as a performance measure to improve annual habitat management planning and restoration actions when scores are low.

- Enhance or restore any degraded wetlands, including salt marsh and adjacent upland habitats that buffer all refuge salt marsh habitats.

- 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 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 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, such as the seaside sparrow, as indicators of biological integrity, diversity, and environmental health (BIDEH) for salt marsh habitats.

- Within 1 to 2 years of CCP approval, develop monitoring protocols and an annual biological monitoring and inventory program to document annual salt marsh condition, prescriptive management actions taken, and response to management actions.

- Consider continuing or resuming snow goose hunting to alleviate some snow goose use in salt marsh areas, to reduce salt marsh.

Mosquito Control Strategies

- Modify mosquito integrated pest management strategies to conserve and protect non-target species by restricting the use of adulticides unless they are required during situations of an elevated public health threat.

- Collaborate with State vector control personnel to develop specific action thresholds that would trigger chemical larvicide treatments; begin efficacy reporting of all treatment events to comply with Service end-of-the-year reporting requirements.

- Prepare a refuge mosquito management plan in collaboration with State mosquito control officials, to address human and wildlife health risks from mosquito-borne diseases and use action thresholds that trigger chemical interventions to be incorporated in a refuge decision making response matrix.

- Per mosquito management plan thresholds, permit limited use of larvicides in OMWM systems if appropriate data supports the assertion that the system has failed to function properly and is ineffective for controlling mosquitoes.

- OMWM excavation will be limited to the maintenance of currently existing 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 the effects on obligate salt marsh passerines may be required before any decision will be made to resume construction of new open marsh water management treatments in previously grid ditched marshes.

- Educate refuge users and other public audiences about avian diversity and how it may help buffer human populations from mosquito-borne and other diseases.

Monitoring Elements

As funding and staffing permits, conduct appropriate monitoring and survey programs to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or reevaluations or refinement of our objectives. Details of planned monitoring will be developed in a subsequent inventory and monitoring plan. Examples of monitoring or surveys that we may implement include:

- Establish ongoing salt marsh monitoring program utilizing the region's salt marsh integrity index.

- 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 measures. This strategy will incorporate a combination of plant identification and inventories, maintaining updates of new invasive species present in the region, and knowing the appropriate management techniques prior to conducting control efforts.

- 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.

- Continue research using OMWM, scoring data collected specific to refuge salt marsh habitat conditions, and incorporate in salt march integrity index assessments.

- Develop habitat monitoring protocols in cooperation with other refuges to quantify impacts (both positive and negative) of snow goose herbivory, increases or decreases of moist-soil invertebrate production, loss of low marsh acreage, and wintering carrying capacity of refuge habitats.

- 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.

- Monitor elements for mosquito control.

Climate Change and Sea Level Rise Adaptation Rationale

Delaware Bay wide average salt marsh accretion rates have been estimated to range from 3.0 to 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 sea level rise may ultimately exceed and overwhelm the rate of marsh accretion, resulting in stress and potential loss of existing marshes. .

Delaware'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 to 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 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 indicate that the refuge's unimpounded salt marsh in Unit I is keeping pace with sea level rise. Based on radiometric sediment core analysis, estimated annual accretion over the past 50 to 100 years ranged from 3.1 mm/year to 6.9/mm/year. This is evidence that the processes discussed in objective 1.1 should be allowed to proceed naturally (Ashton et al. 2007). However, for Unit II and northern Unit III, these preliminary results showed that the marsh accretion rate was only about 1.6-1.7 mm/year, or about half the rate of recent local sea level rise. Since the breach occurred, this Unit has been largely inundated by bay waters and it is likely that it will require an infusion of sediments and/or strategies to accelerate natural accretion to support extensive, viable salt marsh. Thus, an effective monitoring program is necessary to develop an appropriate marsh restoration plan. For further discussion refer to the rationale under objective 1.1.

Climate Change and Sea Level Rise Adaptation Strategies and Monitoring
Strategies include those listed above and under objective 1.1, plus the following:

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

  - Establish three monitoring stations within each of two existing salt marsh areas (and an additional six stations in each area of impounded wetlands), with surface elevation tables and marker horizons; read surface elevation table 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 U.S. Geological Survey-type tide gauge on Slaughter Canal to begin to monitor localized storm effects on refuge hydrology.

  - Establish geodetic benchmarks in select upland refuge sites and calibrate to newly established surface elevation tables, 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 or national protocols to connect prior survey data points (vegetation data, groundwater wells, bird points, etc.) to the same common geodetic control as used above.

  - After a minimum of 3 years, evaluate surface elevation table data to determine if the sampled areas of the marsh 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 sea level rise will force a shift in quantity and quality of available waterbird habitat on local and regional scales. 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 marsh to keep pace with sea level rise. Where it is determined this will not be sufficient to overcome elevational capital deficits, the use of artificial renourishment or assisted accretion may be appropriate.
- Continue to review new research and all monitoring results, seeking ways to adjust our management or restoration as deemed necessary, e.g., as new research and monitoring data on sea level rise and obligate salt marsh breeding birds come to light, one option to explore may be to fill or 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 adding supplemental sediment, planting desirable species, or other techniques (see objective 3.1).

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 and increase quality habitat for the endangered Delmarva fox squirrel, forest interior breeding and wintering landbirds, reptiles, amphibians, and other forest-dependent 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 to be conducted on approximately 1,679 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 4-1.

Table 4-1. Future refuge forest habitats envisioned in next 100 years, and silvicultural management expected over the next 15 years on wetland and upland forest habitats

Forest Habitat Cover-types	Forested Acres with Projected Restored Acres	Silvicultural Management Expected over the Next 15 Years?
Southern red oak/heath	295	Yes
Mesic coastal plain oak	193	Yes
Northern coastal plain basic mesic hardwood	35	Yes
Successional sweetgum	181	Yes
Mid-Atlantic mesic mixed hardwood	20	Yes
Red maple/seaside alder swamp	799	No

Forest Habitat Cover-types	Forested Acres with Projected Restored Acres	Silvicultural Management Expected over the Next 15 Years?
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 that minimally takes 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 will surround red maple-seaside alder and Atlantic white cedar swamp, and the second core area will be restored to upland forest surrounding depressional swamp habitats (Map 4-10).

Restoring additional upland forested habitats is essential to increasing the refuge population size of Delmarva fox squirrels and providing larger forest tracts for breeding, area sensitive forest interior dwelling species. 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 Delmarva fox squirrel and using silvicultural prescriptions as determined necessary through monitoring to meet the desired conditions criteria.

- Sustain and enhance mast producing trees (e.g., white and red oaks, hickories, walnuts) greater than 12 inch dbh to comprise at least 40 percent of the total canopy cover and with shrub canopy closure of less than 30 percent, providing suitable habitat structure for Delmarva fox squirrel.
- Sustain mature canopy closure 80 percent or greater, with a multi-layered tree species profile and canopy gaps to maximize annual mast production and ensure regeneration of shade-tolerant tree species (e.g., oaks).
- Sustain oak-dominated mixed hardwood patch sizes of greater than 250 acres. Use the presence of long-horned beetle 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. 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 (Statewide habitat gap analysis map, CCP appendix A). Extensive forest habitat loss and fragmentation provided the impetus for the state to designate upland forested blocks larger than 250 acres as key wildlife habitats in its wildlife action plan. While the Delaware Department of Agriculture's Forest Service owns and manages 9,000 acres, 81 percent of the State's remaining forested cover-type is in private ownership (ELI 1991, DNREC 2005b).

The loss of upland forest 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, severe habitat fragmentation and loss had caused the extirpation of the Delmarva fox squirrel from Delaware (ELI 1999). Many of the songbirds that have experienced regional and State declines are bird species that are area sensitive to forest fragmentation and its associated impacts, such as increased nest parasitism by edge species, increased rates of predation, and loss of quality nesting and wintering forested habitats. The Delaware Natural Heritage Program estimated that 41 percent of Delaware's historically common forest-dependent birds have been extirpated or today are extremely rare.

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 provide higher quality forest patches (DNREC 2005b).

The federally endangered Delmarva fox squirrel 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 Delmarva fox squirrel, forest interior dwelling birds, 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, juxtaposed 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 Delmarva fox squirrel 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; we expect that it will take at least 100 years to fully implement some of our forest management goals and objectives. This timeframe is based on our prediction of how long it will take to achieve the desired forest matrix composition and structure of existing stands. 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 mature forest stands will have mature trees (greater than 30 cm dbh) and a closed canopy (greater than 80 percent), suitable for the Delmarva fox squirrel (Dueser et al. 1988, Dueser 2000, Morris 2006). They may have patches of shrubs in the understory, which would be suitable for forest interior dwelling species of interest, such as Kentucky warbler (Table 4-1).

Silvicultural management can also be used to reduce the potential impact of gypsy moth and southern pine beetle threats to Delmarva fox squirrel habitat. The gypsy moth and southern pine beetle are the two most significant potential disease threats of the forests at the refuge. 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 percent 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 Delmarva fox squirrel habitats.

Upland forest management enhancement will also benefit nesting and migrating bald eagles on the refuge. In July 2007, the Service removed the bald eagle from the list of endangered and threatened wildlife. 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 there are 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 and summer roosts average between 5 to 10 birds and winter refuge roosts may contain 15 to 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.

Strategies

- 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 (Table 4-2).

- 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 Delmarva fox squirrel (good, fair, poor).

- Maintain or enhance forest health through the development of monitoring protocols for insect and disease vectors.

- Treat detected insect or disease infestations using 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 Delmarva fox squirrel and migratory birds.
- Increase 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 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 4-2 as thresholds for stand improvement interventions to maintain and enhance wildlife habitat needs for priority focal management species. A time of year restriction. April 1 through July 31 would preclude any forest stand improvement as this is the main breeding season for the birds that utilize the refuge.
- Manage bald eagle nest sites in accordance with State and national bald eagle guidelines (USFWS 2007c), utilizing forest management techniques 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 inches dbh to develop larger, well-formed crowns and with a species composition target of one-third white oak, two-thirds red oak, and a mixture of hickory and walnut trees (McShea and Healy 2002).
- Do not cut den trees and trees adjacent to den trees during silvicultural treatments. Adjacent trees provide shade the bole of the den tree, keeping it cooler.
- To promote establishment of den sites, leave trees interfering with mast tree crown development standing and kill by girdling or using systemic herbicides (BNWR 1994).
- Explore opportunities to supplement the refuge Delmarva fox squirrel population through translocations.
- Implement field management prescriptions outlined in the habitat management plan (appendix B).

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 reevaluation or refinement of our objectives. Details of planned monitoring will be developed in a subsequent inventory and monitoring plan. 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 strategy will incorporate a combination of plant identification and inventories, maintaining updates of new invasive species present in the region, and knowing the appropriate management techniques prior to conducting control efforts.

- Establish forest inventory schedules on Prime Hook NWR to document stand-specific information of tree species composition, health of crown overstory trees, regeneration in stands, presence or 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 mixed hardwood patch sizes greater than 250 acres.

- Coordinate with the Chesapeake Bay Field Office to implement improved Delmarva fox squirrel monitoring techniques, such as motion-activated cameras, trapping and nest box checks, as recommended.

Table 4-2. Objective 2.1 mixed hardwood forest community maintenance and enhancement prescriptions

Target Forest Conditions	Condition to Trigger Management Action, as feasible
>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

Target Forest Conditions	Condition to Trigger Management Action, as feasible
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

Climate Change and Sea Level Rise Adaptation Rationale

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 Service 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 percent of forest bird species show high vulnerability to climate change. However, more than half 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 which incorporates 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 carbon dioxide concentrations. Some forest species identified by NABCI to be especially vulnerable to climate change are predicted by the Forest Service atlas to increase in Delaware, perhaps presenting future conservation opportunities, even if they are not currently priority resources of concern (NABCI 2010, Matthews et al. 2007). Examples include chuck-will's-widow and hooded warbler. Species 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.

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 that are applicable on a local scale. For example, the refuge seeks to protect its largest patches of forest, which are the areas that are most buffered against 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 recommends that forest management also focuses on processes (such as fire regime and hydrology) rather than strictly on structure and composition, which will increase the resilience of forests to accommodate gradual changes (NABCI 2010). 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.

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 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).

Climate Change and Sea Level Rise Adaptation Strategies and Monitoring
In forests, climate change will likely result in shifts in forest composition and structure (Iverson and Prasad 1998) that will greatly change the availability of habitat for many species. Shifts in the dominant vegetation type or even small changes in the understory composition may result in significant changes in animal communities. The goal of adaptation is to reduce the vulnerability of ecosystems to climate change and increase their resilience to climate-induced changes in ecological conditions.

Forest management strategies include those listed above, as well as the following:

- 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 1 year of CCP completion, conduct a complete forest inventory of forest lands and repeat the monitoring every 10 to 15 years
- Consider establishing a continuous forest inventory monitoring system

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 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 squirrel. Create approximately 870 additional acres of forested habitats to maintain at least two core habitat patches (approximately 435 acres/patch) with connecting corridors.

Rationale

Population numbers and refuge acreage to improve Delmarva fox squirrel 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 this species will simultaneously conserve and protect migratory birds of greatest conservation concern.

Contemporary human activities and land use changes have extirpated Delmarva fox squirrel from Delaware's landscape through the loss of forest, while habitat fragmentation of the refuge's upland habitats has been one of the primary factors in limiting the expansion of its numbers (ELI 1999). Although refuge populations have been stable since the reintroduction of squirrels in 1986 and 1987, this small population of an estimated 20 to 30 squirrels has little probability of being sustained for the long term with current refuge habitat acreage and without supplementing the population.

The most recent population viability analysis data have been incorporated into reforestation objectives. From it, a minimum viable population on the refuge of 130 individuals would be the smallest number of individuals required to maintain a population with a 95 percent probability of persisting for 100 years. This provides a quantitative measure for sustaining Delmarva fox squirrel on the refuge for the long term. Reforesting 700 to 800 acres and creating new habitat, whether by active planting or natural succession, would take 50 to 100 years for areas to mature with the potential of providing habitat for at least 250 individuals.

The loss of upland forests has also 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. Many of the songbirds that have experienced regional and state declines are those bird species that are sensitive to forest fragmentation. The Delaware Natural Heritage Program estimated that 41 percent of Delaware's historically common forest-dependent birds have been extirpated or 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 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 data since 1966 there has been a 60 percent decline in occurrence of individual birds of neotropical migrant species in Maryland and an 83 percent 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, including on the Delmarva Peninsula, are playing a critical role in these declines (Jones et al. 2001).

The conservation of forest interior dwelling species requires the inclusion of their nesting requirements including minimal area and 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 (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 Delmarva fox squirrel acts as an umbrella species not only by encompassing the structural nesting characteristics of forest interior dwelling species, but also by providing for a wide variety of other forest-dependent species. Although the squirrel does not necessarily require interior forest habitat, it does require more forest cover acreage than the refuge currently contains in order to achieve and maintain a viable local population for the longer term. Expanding forest acreage and baseline habitat to meet Delmarva fox squirrel life history requirements 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 goose during the fall, winter, and spring. A secondary objective of the farming program was duck production, in which croplands in grass or clover stages of rotations were designed to provide nesting habitats for ducks. In recent years, it has been apparent from anecdotal observations that duck species seldom or never used cropland field habitats, likely due to wetland and aquatic habitats being readily available on the refuge. 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. 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 2007a), 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.

Strategies

- Reduce fragmentation of refuge forested habitats through reforestation projects (planting) to increase forest habitat available to the endangered Delmarva fox squirrel and improve management of area-sensitive wildlife, such as many of the breeding songbirds listed as refuge priority resources of concern in appendix D, table 6.

- Use population viability analysis modeling data to set refuge Delmarva fox squirrel population objectives, refine objectives as new data becomes available and 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 Delmarva fox squirrel.

- Explore opportunities to supplement the refuge Delmarva fox squirrel population through translocations as suitable forest habitat is restored.

- Install speed bumps in refuge entrance road to reduce Delmarva fox squirrel road mortalities on the refuge.
- Implement field restoration prescriptions outlined in the habitat management plan (appendix B).

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 reevaluation or refinement of our objectives. Details of planned monitoring will be developed in a subsequent inventory and monitoring plan. 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, and knowing the appropriate management techniques prior to conducting control efforts.
- Continue to work with partners to improve population monitoring methodology, habitat assessment techniques, and habitat improvement projects.
- Coordinate with the Chesapeake Bay Field Office to implement improved Delmarva fox squirrel monitoring techniques, such as motion-activated cameras, trapping, and nest box checks, as recommended.
- Assess landbird point count monitoring program and, as necessary, locate new points in areas undergoing reforestation to monitor bird community response.

Climate Change and Sea Level Rise Adaptation Rationale
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 powerline rights-of-way, and invasive species. Because dispersal and migration become critical for species of all taxa as vegetation shifts and conditions change in response to climate changes, corridors also offer a key climate change adaption tool. Management of connectivity between protected habitats is an important conservation strategy (Hannah et al. 2002). Reforestation provides an opportunity to increase connectivity of forested habitats. In many areas, forested riparian corridors provide connectivity among conservation units.

Reforestation, rather than relying on local seed sources and natural succession, can proactively incorporate individuals from a wide range of localities, and perhaps should emphasize sources from low 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 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 mitigating 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 of sufficient 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). 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).

Climate Change and Sea Level Rise Adaptation Strategies and Monitoring
Forest restoration strategies include those listed above and in objective 2.1., as well as the following:

- 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 and 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 Forested Wetland Communities

Protect and manage approximately 1,200 acres of forested wetland cover-types with less than 10 percent invasive species for breeding and migrating birds of greatest conservation need. Improve habitat quality and manage appropriate patch sizes (greater than 250 acres) for breeding Acadian flycatcher, prothonotary warbler, yellow-throated vireo, migrating and wintering landbirds, and other species of conservation concern, such as carpenter frog and hydrangea sphinx.

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

Rationale
In the BCR 30 and Partners in Flight 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 2005b).

Yellow-throated vireos utilize a diversity of forest types from mixed upland forests to mature deciduous forests 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 and 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. This species 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 percent of maximum breeding densities in patches below 168 acres (70 ha) (Whitcomb 1981).

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 adapted to tolerate saturation of the root zone for varying duration and frequency throughout the growing season. Nationally and locally, forested wetlands have 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 of refuge forested wetland communities were contracted by the Service conducted by the DNHP in 2004 and 2005 (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 and 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 refuge forest community types listed above, except buttonbush coastal plain pond. A description of rare flora and fauna found within these habitats is located in chapter 3, Affected Environment; tables 3-6 – 3-7.

Strategies

- Protect large patches (greater than 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 Delmarva fox squirrel, 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 the regional fire wildlife biologist for the best habitat management recommendations.

- Reduce 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 percent 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 the 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 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 permit to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or reevaluation or refinement of our objectives. Details of planned monitoring will be developed in a subsequent inventory and monitoring plan. 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 strategy will incorporate a combination of plant identification and inventories, maintaining updates of new invasive species present in the region, and knowing 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 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 establishing monitoring plots and assess conservation status every 3 to 5 years.

Climate Change and Sea Level Rise Adaptation Rationale
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 entering the Delaware Bay and other bodies of water.

Climate Change and Sea Level Rise Adaptation Strategies and Monitoring
Forest wetland management strategies include those listed above and in objectives 2.1 and 2.2.

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, Migrating, and Wintering Birds

Provide up to 4,200 acres of healthy 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 and brackish 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 to 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 percent cover, once salt marsh vegetation is established
- Reestablishment of native salt marsh vegetation communities, with a moderate (20 to 25 percent) component of open water and 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 in area, which are attractive to wetland-dependent breeding and migrating birds 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 alternative is on active restoration of healthy salt marsh and brackish wetland conditions within wetlands formerly managed as freshwater impoundments. This objective represents the refuge's most significant and tangible shift in habitat management, and is covered here in detail. This shift in habitat management serves as an immediate response to local manifestations of climate change, and is a proactive adaptation in anticipation of likely 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) suggest changes in landcover and losses of tidal wetlands on the refuge in the next 50 to 100 years. Portions of the refuge's marshes 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 but was established in part using existing roads as dike infrastructure that had not been formally engineered for long-term water level management. In developing 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 indicates that the wetlands on the refuge were historically salt marsh, although there had always been areas of freshwater marsh due to natural freshwater inputs or altered hydrology resulting from human activity.

As information in chapter 3 outlines, portions of the managed impoundments are losing ground to sea level rise and other manifestations of climate change, such as shoreline erosion. 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 under current 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, makes greater contributions to vertical accretion (Cahoon et al. 2009). Impounded freshwater wetlands would be difficult and costly to reestablish, and more importantly are not sustainable in a dynamic coastal setting for the long term.

The reality of these various factors, operating in combination to create significant management challenges, requires a shift in refuge wetland management objectives and strategies. 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 CCP. It is neither responsible nor sustainable to indefinitely maintain freshwater impoundments along a coastal environment.

It has been determined through analysis of the many complex factors outlined in chapter 3 (influence of climate change on physical environment and refuge management) that continued management of freshwater impoundments for the long term is not appropriate. There is no inexpensive and practical way to freeze the dynamic nature of the impoundment complex at this ecologically and geologically unstable point. Continued freshwater impoundment management would simply not be sustainable. Management action will be necessary to stabilize the health of the degraded system. If no active restoration is undertaken, it is unclear how quickly or effectively the area, in Unit II in particular, would revert to salt marsh vegetation on its 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). In the absence of a healthy marsh community or sufficient wetland elevation within the interior of Unit II, the shoreline along the Bay will remain vulnerable to breaches and overwash during storm events. The most practical and economical management alternative to restabilize the impounded wetlands is carefully executed restoration. Furthermore, an established salt marsh will be able to migrate landward into adjacent refuge uplands, as sea levels rise, in a process that represents the natural adaptation of the coastal ecosystem.

Ultimately, restoration of the refuge impoundments to healthy brackish and salt marsh will encourage the conditions most resilient to sea level rise, while 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 reducing wave energy. Wave heights are reduced by 60% within the first twenty feet of the marsh, which in turn also 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 below-ground 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) and serve as 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 saltwater to a system that 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 achieving tidal flooding up to the spring high tide elevation in order to restore ecologically sustainable estuarine communities by restoring sufficient tidal exchange to flood and 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 establishing 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 from 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 compose only 20 percent 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) 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 Primary WUI Treatment Zone for the purposes of 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 depends 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 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 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 saltwater 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 Road by DelDOT, when and whether sediment from outside sources is added, etc. may all affect the pace and choice of restoration actions but not the long-term goal, which is 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 the Northeast Region 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 decisionmaking process and have technical expert review, and consistency with other refuges, Prime Hook NWR plans to use the coastal impoundment structured decisionmaking 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 wetland restoration plan is outside the scope of this CCP process. However, there have been a number of formal discussions regarding restoration options and strategies with a diverse group of wetland management and restoration experts, state officials, and the Army Corps of Engineers.

The refuge has been in contact with the Army Corps of Engineers and with DNREC since the summer of 2011 regarding the potential use of dredged sediment to restore wetland elevation in the impoundment complex. Such sediment could come from the Main Channel Deepening Project, maintenance dredging. Because the material is a state resource, DNREC has primary authority over how and where it is used. Marsh restoration at the refuge is only one of several beneficial use possibilities that are being considered.

In May 2011, 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. The group reviewed preliminary monitoring data and toured the refuge's shoreline and wetlands firsthand. They provided feedback and recommendations at the end of the meeting and during follow-up discussions. A similar follow-up workshop was held in April 2012, which included the participation of additional academic experts (e.g., Court Stevenson of the University of Maryland) as well as several community representatives. Participants examined the primary restoration options that the refuge faces, and also proposed restoration scenarios to be examined in more detail through hydrological modeling. A summary of this workshop can be found online *(http://www.dnrec.delaware.gov/coastal/DNERR/Pages/CTP%20Pages/Prime-Hook-Restoration-Workshop.aspx;* accessed August 2012).

Throughout the summer of 2012, the refuge continued discussions regarding restoration options with two engineering firms and with the Partnership for the Delaware Estuary (PDE), to further evaluate and develop restoration options and techniques, including actions that could be taken soon after the CCP is finalized. These partnerships will continue into the implementation phase of marsh restoration. These have included both large-scale wave attenuation strategies and products suitable for the high-energy shoreline interface, and small-scale living shoreline projects suitable for the marsh interior. The resulting suggestions from these various meetings and discussions have been incorporated into the CCP as potential restoration strategies, outlined below.

For example, although an infusion of additional sediment is critical for restoring lost elevation behind the fragile refuge shoreline, the refuge also considers strategies to encourage and accelerate natural accretion of sediment within the wetland complex. The refuge has examined both short and long term solutions, which vary tremendously regarding cost, deployment time, and engineering analysis requirements. Engineered solutions do exist for attenuating waves and encouraging sedimentation in moderate- and high-energy settings, such as various manufactured concrete structures (e.g., Wave Attenuation Devices, Beach Prisms, Reef Balls). These type devices are designed to attenuate wave energy thus reducing erosion and would be more effective than concrete structures not designed for these purposes, such as jersey barriers (designed specifically for traffic control). Relative to rock and rubble structures, these type structures can be designed to provide an effective means to stabilize the shoreline and breach locations. Although wave attenuation may be lower with manufactured structures than with rock and rubble structures, they can allow for passage of fish, crabs, and other species (Douglass et al. in press). One cost estimate obtained suggested at least$1 million for an installation of WADs near the mouth of the breaches that would be sufficient to have the necessary effect (Cardno JFNew Consulting, pers. comm.). The Coastal Engineering Manual (CEM) provides extensive design methodologies for implementing rock and rubble mound structures (USACE 2002). As with manufactured concrete structures, rock and rubble mound structures require hydrodynamic modeling to design properly and can be costly to implement on the scale necessary at the refuge. There are no means to attenuate wave energy through the breaches that would not require careful planning and engineering, to ensure that the water and energy do not simply scour around the structure(s) and impact the refuge potentially forming new breaches and inlets at other locations throughout the shoreline.

Geotubes are another structural technique that have some potential. However, geotubes do not contribute sand to the local sediment system, can affect adjacent shoreline negatively, are prone to failure and vandalism, and are not designed to withstand large-scale storms (McKenna 2001). Geotubes would also likely require the addition of sand to anchor the tubes, a nourished beach in front of the tubes, and may require frequent maintenance as sand is washed away (Gibeaut et. al 2003, McKenna 2001).

Living shoreline techniques using materials such as coconut logs, oyster shell breakwaters, and grass plantings are suitable in low energy settings and can help restore marsh in targeted areas (PDE 2012, PDE 2011). The refuge has been in close contact with the Partnership for the Delaware Estuary (PDE) regarding potential living shoreline projects on the refuge, and has already shared preliminary site information for consideration.

It has been the consensus of these diverse partners that the refuge has a number of potential restoration options, both big and small, which have been included here and evaluated in Chapter 5, but that additional hydrological modeling and analysis is important before the implementation of large-scale restoration efforts. The refuge proposes to continue working with diverse wetland management and restoration experts, state and federal officials, and community representatives as restoration short- and long-term plans are developed. Potential restoration strategies to be considered are derived from the salt marsh restoration scientific literature and consultation with wetland experts and other partners. 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). The impacts of the potential restoration strategies outlined below are evaluated within chapter 5, and some or all of the strategies may be implemented in some combination, as determined to be appropriate, feasible, and fundable, during later restoration planning.

Strategies

- Implement water level management and vegetation control strategies, to the extent conditions warrant and permit:

  - If feasible, seek to keep Unit III water levels, in accordance with deed restrictions, at or below a level of 2.8 feet mean sea level between October and March 10th, but if future storm events preclude the ability to manage water levels, then natural levels will prevail.

  - Control invasive species using chemical control, prescribed fire, and other techniques as appropriate so that 95 percent 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 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 Regional impoundment management structured decision making model in order to evaluate and validate management options for refuge impoundments.

- Discontinue all management and construction of dunes on private land.

- In partnership with DNREC Delaware Coastal Programs, and a private contractor, continue development of a model to predict the hydrodynamic response of the wetland complex under a wide variety different potential management and 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 Road culverts closed, additional Prime Hook Road openings installed, water control structure at Slaughter Canal/Fowler Beach Road removed, etc. The model will help evaluate what hydrological and vegetation responses may be expected under each scenario.

- Continue consultation with State and Federal coastal scientists, non-profit organizations, engineering firms, academic scientists, other subject matter experts, and community representatives 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.

  - Work with DNREC on shoreline stabilization with material from Delaware River Deepening project, maintenance dredging, and other sources within the Delaware Bay.Re-evaluate the easement limiting water level management to a height of 2.8 feet (MSL) with the impoundment, possibly renegotiating or removing the agreement.

- 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 or Unit III necessary for the establishment of *Spartina.*

  - 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 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 Road 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 through planting of salt marsh plants, such as *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 a Primary WUI Treatment Zone.

- Work with DelDOT to ensure that improvements to Prime Hook Road will permit optimal management 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 reposition gauges to reflect current mean sea level.

- Within 1 to 2 years, establish a refugewide 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 and marker horizons.

- Expand efforts to use real time kinematic (RTK) surveys and underwater sonar technology to monitor elevation throughout the wetland complex, which is less precise than surface elevation table 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 the State through a cooperative agreement.

- Implement the Park Service's vital signs program's shoreline position monitoring protocol and shoreline topography monitoring protocol. Coordinate refuge shoreline monitoring efforts with other coastal refuges to foster Departmentwide 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 integrated waterbird management and monitoring; 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 regional salt marsh integrity 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 and open water change analysis.

- Utilize early detection rapid response techniques that detect newly established invasive species and immediately address those populations through the appropriate control measure.

- Develop improved monitoring and inventory program, such as outlined in the integrated waterbird management and monitoring program, to assess annual habitat conditions created through management and restoration in all wetland areas and associated bird use.

- Implement water and 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 the State Natural Heritage Program and store on the 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

Over the next 15 years, protect and improve the water quality of 6,000 acres of impounded marsh and waterways and 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, blueback 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, 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's 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 blueback 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.

Restoring salt marshes that function naturally requires re-establishing desirable vegetation on the marsh plain, restoring a natural hydroperiod, and maintaining or creating elements of marsh habitat such as tidal creeks, ponds/pannes and vegetated areas. These tidal creeks are part of the intertidal drainage system that allow fish foraging and the exchange of sediments. So the natural function of salt marshes not only is tied to the vegetation on marsh plain but the well developed system of tidal creeks. Weinstein et al. 1997 and 200 outlined the importance restoring the hydrology by maintaining or creating tidal channels. The number of ditches quantified in the strategies below are for freshwater impoundment management. We may need to restore some of these ditches if determined they are no longer needed. The marsh restoration plan may tell us which ones to keep or restore.

Strategies

- 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 of Units I and IV by permitting natural coastal processes, such as overwash and inlet formation, to proceed unhindered.

- 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 composed of native vegetation (trees and shrubs), by connecting isolated or disjunctive patches around refuge creeks, waterways, and marshes, through assisted reforestation projects or allowing natural succession to occur.

- Maintain and/or restore water movement and circulation within existing drainage networks of the refuge's former impoundment complex to improve the hydrology of the salt marsh by developing as appropriate tidal drainage systems; drainage networks may 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. Ditches not needed for marsh restoration may be plugged or allowed to fill in.

- 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.

- Implement field management and restoration prescriptions outlined in the habitat management plan (appendix B).

Monitoring Elements

Conduct appropriate monitoring and survey programs as funding and staffing permit to measure our success with respect to our objectives. The results may trigger adjustments to management strategies, or reevaluation or refinement of our objectives. Details of planned monitoring will be developed in a subsequent inventory and monitoring plan. Examples of monitoring or surveys that we may implement include:

- Conduct refuge fishery inventories every 5 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 Turkle, 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 to public use regulations on these closed systems.

- When cleaning ditch systems ensure that at least 75 percent of the ditch depth is free of sediment along ditch courses and the entire length is free of obstructions that impede water flow.

- Conduct water quality monitoring, in cooperation with partners; parameters to measure include salinity, dissolved oxygen, ammonium, nitrate and nitrite, ortho-phosphorus, total dissolved nitrogen, phosphorus, and chlorophyll A/ pheophyton.

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 a mosaic of early successional habitats mixed with transitional forested areas to conserve migratory birds, breeding landbirds, and 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 stage distributions that mimic historic conditions. Transitional habitats will usually be small in size and imbedded within a habitat matrix of wetland 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 (included those areas planted in trees or transitioning through natural succession for Delmarva fox squirrel management purposes).

Maintain at least 20 percent of the above acreage in an early successional condition (shrubland 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, Partners in Flight 44, the State Wildlife Action Plan (2005) and Birds of Conservation Concern (USFWS 2008a) 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

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.

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 exemplifies 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 to 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 (see Figure 4-1).

Peterjohn (2006) suggests that it is more practical to direct management toward 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 (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 and juvenile mature-forest dependent birds during migrational periods. Dense shrub cover also decreases the need to move widely in search of food and reduces energy loss and exposure to predators. Fruits have high sugar content that aids in accumulating fat reserves to facilitate migration (Parrish 2000).

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. These species do not like later successional stages where shrubs or saplings form dense continuous tangles. By comparison, brown thrasher, eastern towhee, and blue-winged warbler prefer later-stage old fields with moderate to dense shrub cover, and white-eyed vireo and yellow-breasted chat also benefit (see CCP-appendix E, table 6 of focal species life history requirements for early sucessional habitats).

Review of the life history requirements of targeted birds shows 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 4-3).

- Field specialists: restricted to larger (2 to 20 ha/5 to 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.

Figure 4-1. Scheme of management decisions and habitat actions concerning development of secondary successional shrubland habitats on Prime Hook NWR

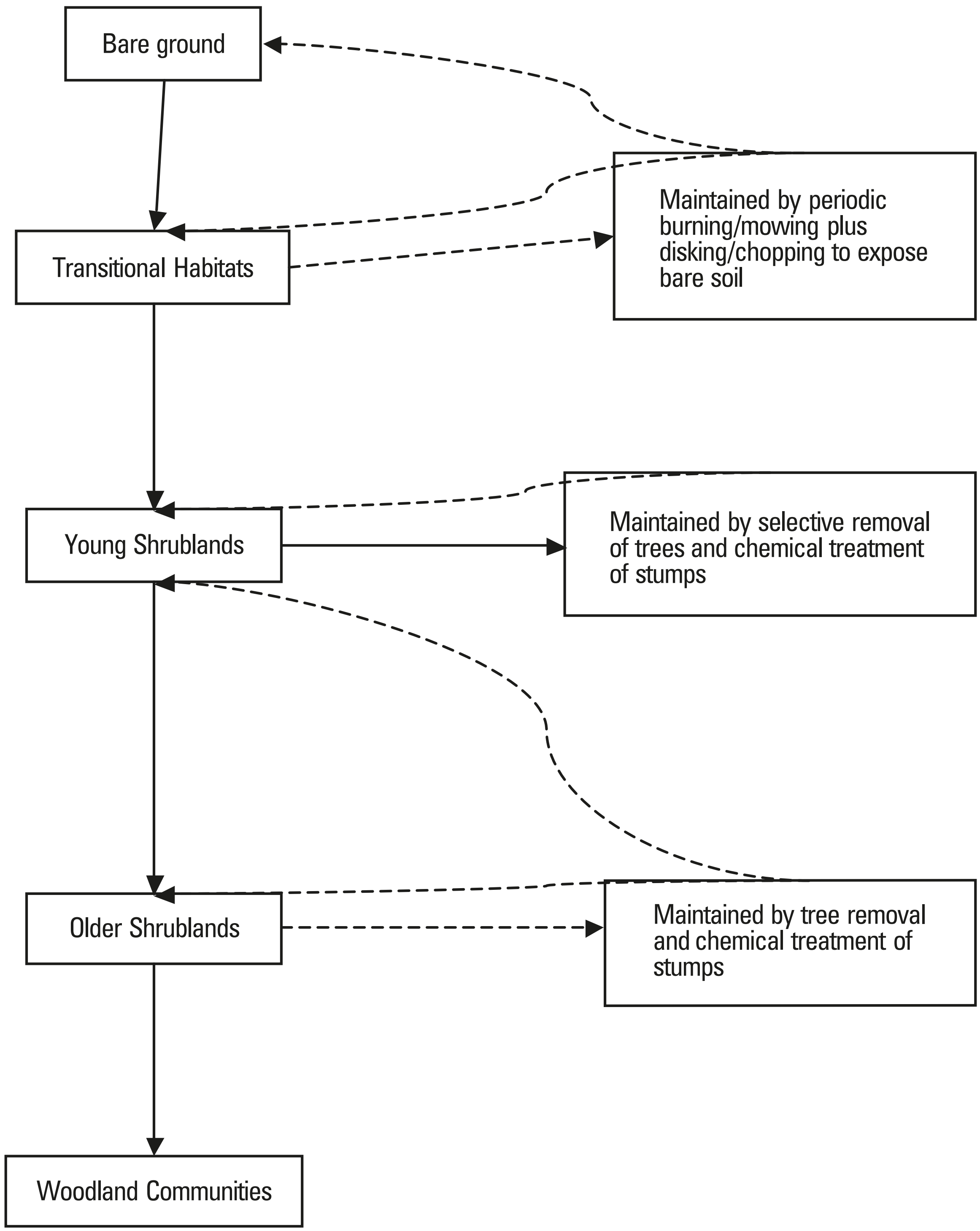


Table 4-3. Shrubland bird ecological requirements

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

The Vitz and Rodewald study (2007) results have shown that during the post breeding period, birds (especially red-eyed vireo, worm-eating warbler, ovenbird, hooded warbler, and scarlet tanager) seek out the structurally complex and low vegetation structure (greater than or equal to 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 post breeding season condition for migrants.

Strategies
See strategies listed under objective 4.2.

Objective 4.2 Grassland Bird Habitat Management

Manage for an interspersion of habitat structures for 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 124 acres (50 hectares) or more of grasslands adjacent to salt marsh habitat to meet the needs of priority species that would be especially attracted to such a landscape context, such as breeding Henslow’s sparrows and wintering northern harriers.

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

Rationale

Grassland birds are those birds that rely on grassland habitats 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 4-4). For each bird species, these grassland habitats can provide protective cover for nesting and brood rearing 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, and sow bugs 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 4-4. 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

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