Chapter 5

©Chuck Fullmer

Eastern towhee

Environmental Consequences

Introduction

This chapter describes the environmental consequences we predict from implementing management alternatives presented in chapter 4. Where detailed information is available, we present a more analytic comparison between alternatives and their anticipated consequences. These consequences are described as impacts or effects. In absence of detailed information, we make comparisons based on our professional judgment and strategies of the three alternatives: current management/passive management or no action (alternative A); expanded public use incorporated with proactive habitat restoration management in the Service-preferred alternative (alternative B); and an attempt to return to earlier conditions and management approaches including some intensive engineering actions and continued human manipulation of refuge lands (alternative C).

We focus our discussion on the impacts associated with the goals and significant issues identified in Chapter 1, Purpose of, and Need for, Action. The direct, indirect, short-term, long-term, and cumulative influences of both beneficial and adverse effects likely to occur over the 15-year life span of this CCP are discussed. Beyond the 15-year planning horizon, we consider a more speculative description of environmental consequences with particular emphasis on climate change predictions and associated sea level rise impacts based on current models. We will also consider the relationship between short-term uses of the human environment and the enhancement of long-term productivity, potential irreversible and irretrievable commitments of resources, and environmental justice. At the end of this chapter, a matrix summarizes the effects predicted for each alternative and allows for a side-by-side comparison.

Regulations adopted by the Council for Environmental Quality and the Service on implementing NEPA require that we assess the importance of the effects of all alternatives based on their context and intensity.

The context of our impact analysis ranged from small scale to large, from the invertebrate community on the Refuge to the Atlantic flyway population for a migratory bird. For example, we considered direct and indirect impacts of insecticides on chironomid larvae and the consequences of this reduction in insect number on migratory birds; the direct impacts to soils of kiosk construction on the refuge; or the direct contribution to biodiversity through the protection of rare flora or fauna by the refuge to the populations of species at the State, regional, and global levels. Table 5-1 illustrates the range in scale, from a square meter to nearly 25 million acres, of the context of various Service actions.

Table 5-1. Impact Contexts for Service Actions Under CCP at Prime Hook NWR

Invertebrate/vegetation sampling size (m^2)	0.000247 acres (square meter)
Kiosk Footprint	0.001 to 0.5 acres
Pintail Potholes	0.1 to 200 acres
Refuge Management Units	1,111 to 3,823 acres
Prime Hook Impoundments	4,200 acres
Prime Hook NWR Refuge Lands	10,132 acres
Coastal Delaware NWR Complex Lands	26,110 acres
Delaware Bay	500,480 acres
Sussex County	600,320 acres
State of Delaware	1.6 million acres
Delmarva Peninsula	6.9 million acres
PIF Mid-Atlantic Coastal Plain Area 44 (Partners in Flight)	13.5 million acres
New England/Mid-Atlantic Coast Bird Conservation Region (BCR 30)	24.4 million acres

Although the area of the refuge only covers a small percentage of these larger geographical regions, it represents a hotspot of biodiversity across the regional landscape. Our proposed conservation objectives and strategies for focal species and habitat management actions are consistent with Delaware's comprehensive wildlife management plan and contribute to achieving state bird population objectives for bird species of greatest conservation need (Rosenberg 2004) and conserving tier 1 and tier 2 wildlife species in Delaware (DNREC 2005).

Significance also encompasses the magnitude of change or of an impact. It is not a value judgment, as some impacts can be beneficial for one species and adverse for another, or have a positive impact on visitor use but a negative impact on migratory birds. The following table defines this aspect of significance by giving more detailed information about the magnitude or level of intensity for each of the impacts topics which will be discussed in more detail in this chapter.

Table 5-2. Impact Significance Criteria Threshold Definitions

Impact Topic	Significance Criteria
Socioeconomic	Effects to socioeconomic elements would be considered significant if: • management actions would result in readily apparent changes to economic conditions. While there may be some apparent changes in social or economic conditions in nearby communities, if such effects are localized, they are considered not to be significant. Significant social or economic effects encompass measurable changes in social or economic conditions at the regional level.
Cultural and Historical Resources	Effects to cultural and historic resources would be considered significant if: • management actions would have a substantial, noticeable, and permanent effect on a site or group of sites. The action would severely change one or more characteristics that qualify the site(s) for inclusion in the National Register, diminishing the integrity of the site(s) to such an extent that it would no longer be eligible for listing in the National Register. For purposes of section 106, the determination of effect would be an adverse effect.
Air Quality	Effects to air quality would be considered significant if: • implementation of a proposed refuge action would result in: emissions equal to or in excess of the standards set in local implementation plans for the Clean Air Act; large areas of soil becoming routinely exposed and subject to wind erosion; or sensitive receptors being exposed to substantial pollutant concentrations, including air toxics such as diesel particulates. Significant indirect effects to air quality would occur if a proposed refuge action results in frequent heavy congestion on adjacent roadways. Significant cumulative effects would occur if the "de minimis" (minimum) thresholds developed by the EPA for proposed Federal actions in a nonattainment area are exceeded.
Soils	Effects to soils would be considered significant if: • management actions would result in the permanent loss or alteration of geologic features or soils in relatively large areas, such as 1,000 acres,or there would be a strong likelihood for erosion or mass movement of large quantities of soil, sediment, or rock as a result of the action. Mitigation measures to offset adverse effects would be necessary, extensive, and their success could not be guaranteed. • management actions would preserve or restore geologic features, geologic processes, or soil resources in relatively large areas, such as 1,000 acres.

Impact Topic	**Significance Criteria**
Water Quality and Hydrology	Effects to water quality and hydrology would be considered significant if: • actions would result in substantial increased flooding on- or off-site, accelerating flooding or further deviation from historical hydrological patterns above reasonably anticipated levels due to climate change or sea level rise, or a substantial reduction in the local groundwater table. • actions would violate any water quality standards or waste discharge requirements, substantially increase sedimentation, introduce persistent contaminants (nonpoint source pollution) into the watershed, or otherwise substantially degrade water quality. Water quality impacts could include increased loads of sediment, debris, chemical, or toxic substances, or pathogenic organisms. The impact could be easily visible to visitors. • restoration projects and best management practices would measurably improve water quality in most tributaries in the refuge, and overall effect would be clearly detectable.
Vegetation	Effects to vegetation would be considered significant if: • an action would result in a substantial change in the amount or quality of available habitat for a wildlife species. (For wintering waterfowl, other migratory birds, or native resident wildlife, a substantial reduction in habitat resulting in a significant adverse impact would be defined as a reduction of 30 percent or more of the available acreage or 50 percent of the quality of habitat for these species within the refuge; a significant beneficial impact would be defined as a 30 percent or greater increase in the quantity or 50 percent increase in the quality of habitat for wintering waterfowl, other migratory birds, or native resident wildlife). • a substantial portion of native habitat would be removed or otherwise modified as to accommodate a proposed action. The impacts would be substantial and highly noticeable and could result in widespread change. This could include changes in the abundance, distribution, or composition of a local vegetation community or regional plant population to the extent that it would be likely to be replaced by a different vegetation community. Significant ecological processes would be altered, and changes would be expected. • a refuge action causes mortality of greater than 30% of a regional or state population of a species. • management actions would restore or preserve vegetation or unfragmented forest blocks throughout much of the refuge. •management actions to remove invasive vegetation are not considered significant even if the result substantially decreases the abundance of the invasive species, if the result is the restoration or increase in quantity or distribution of native vegetation.
Threatened and Endangered Species	Effects to threatened and endangered species would be considered significant if an action would result in a substantial adverse effect; either directly or through habitat modifications, on any Federal threatened, endangered, candidate, or special concern wildlife or fish species. Also included would be species listed threatened or endangered by DNREC. Management actions could result in a noticeable change to a population or individuals of a listed or protected species or designated critical habitat. The change would be substantial and highly noticeable and would most likely result in a likely to adversely affect opinion from the U.S. Fish and Wildlife Service. Management actions would measurably increase a population or numbers of individuals of a listed or protected species or enhance designated critical habitat.

Impact Topic	Significance Criteria
Terrestrial Wildlife Waterfowl, Shorebirds, Secretive Marsh and Waterbirds, Mammals, Reptiles and Amphibians, and Invertebrates	Effects to species would be considered significant if: • an action would result in a substantial change in the amount or quality of available habitat for a wildlife species. (For wintering waterfowl, other migratory birds, or native resident wildlife, a substantial reduction in habitat resulting in a significant adverse impact would be defined as a reduction of 30 percent or more of the available acreage or 50 percent of the quality of habitat for these species within the refuge; a significant beneficial impact would be defined as a 30 percent or greater increase in the quantity or 50 percent increase in the quality of habitat for wintering waterfowl, other migratory birds, or native resident wildlife). • a substantial portion of native habitat would be removed or otherwise modified to accommodate a proposed action. • a refuge action causes mortality of greater than 30% of a regional or state population of a species. • management actions would restore or preserve aquatic wildlife populations in large portions (1,000 acres) of the refuge. This could include changes in the abundance, distribution, or composition of local terrestrial wildlife populations.
Fisheries	Effects to fisheries would be considered significant if: • an action would substantially change the availability of habitat for fish. • an action would result in an obvious detectable effect to aquatic wildlife populations at the regional level. Extensive mitigation would be needed to offset any adverse effects, and their success would not be guaranteed. • an action would restore, improve, or preserve aquatic wildlife populations in large portions (i.e., 1,000 acres) of the refuge. This could include changes in the abundance, distribution, or composition of local aquatic wildlife populations.
Public Use and Access	Effects to public use and access would be considered significant if: • a proposed action resulted in substantial displacement of a wildlife-dependent public use (>25% of existing activities or opportunities moved to a different area or terminated at the refuge); • substantial reduction in the quality of the wildlife-dependent experience (crowding increasing by more than 50% or substantial anticipated losses of wildlife or habitat supporting the experience). • proposed actions resulted in substantial increase in opportunity for or quality of a wildlife-dependent public use (>25% increase over existing opportunity or quality of experience). • management actions would result in impacts that would be readily apparent and would likely be perceived as highly positive by visitors because they would obviously enhance the visitor experience by making access to most refuge resources and experiences very easy.

Some impacts are not considered major or significant, and are described as either negligible, minor, or moderate. The magnitude of such changes is defined as follows:

- Negligible—Management actions would result in impacts that would not be detectable or if detected, would have effects that would be considered slight, localized, and short-term.

- Minor—Management actions would result in a detectable change [i], but the change would be slight and have only a local effect on the community, the resource, or ecological processes. The change would be discountable, insignificant, and of little consequence and short-term in nature.

- Moderate—Management actions would result in a clearly detectable change. This could include changes to a local biotic population or habitat sufficient to cause [a] change in [the] abundance, distribution, or composition, but not changes that would affect the viability of regional populations or habitats. Changes to local ecological processes would be of a limited extent.

- Major—As described in more detail in Table 5-2, management actions would result in a clearly detectable change. The impacts would be substantial and highly noticeable and could result in widespread change. This could include changes in the abundance, distribution, or composition of a local or regional populations or habitats to the extent that it would not likely recover or continue in its previous condition or size. Significant ecological processes would be altered, and changes throughout the ecosystem would be expected.

In addition to the magnitude of impact (negligible, minor, moderate, or major) the impacts of the management action on some of the environmental attributes are also, at times, described as beneficial or adverse. Generally, an impact will be described as 'beneficial' if it results in a condition that improves the biological health, population size of native or naturally occurring species, or the robustness or sustainability of that characteristic. However, many times value judgments cannot be given for ecological change. A change in habitat that is beneficial for certain species of waterfowl may be adverse for others with different habitat preferences. Factors which reduce the population of a predator may be adverse for the predator and positive for the prey. Therefore, sometimes our impact assessments do not describe impacts as either positive or negative, or describe them specifically in term of what the impact applies to. The duration of identified effects and their consequences varies, from those occurring only once for a brief period in the 15-year period of this plan—for example, the effects of construction for expanding existing facilities—to those occurring more frequently during the year, like multiple salt water intrusion events into freshwater impoundments due to sea level rise with increased frequency and severity of coastal storms. The environmental consequences analysis provided in this chapter will also furnish the level of detail necessary to assess the compatibility of all proposed uses.

We based our evaluation of the frequency and intensity of the effects of the alternatives on these factors:

- Expected degree or percent of change in the resource from current conditions

- Frequency and duration of the effect

- Sensitivity of the resource to a particular effect or its natural resiliency to recover from such an effect

- Potential for implementing effective preventive or mitigating measures to lessen the effect

A matrix table at the end of this chapter (table 5-15) summarizes the different approaches to delivering refuge wildlife and habitat conservation actions and providing public access and recreational uses, ranging from the current management/passive management or no action (alternative A), to expanded public use incorporated with proactive habitat restoration management in the Service-preferred alternative (alternative B), and an attempt to return to earlier conditions and management approaches including some intensive engineering actions and continued human manipulation of refuge lands (alternative C). All three alternatives take an integrated approach that seeks to conserve wildlife and their associated habitats balanced with providing quality and diversified recreational and educational opportunities for visitors.

The environmental baseline: It is important to understand that while this EIS was under development, there were major habitat changes within the Refuge. As explained in Chapter 3, the formerly freshwater impoundments in Units II and III (particularly in Unit II) have undergone significant change, due to breaches in the barrier island allowing for the free exchange of salt water in the formerly maintained freshwater marshes. The rapid inundation of salt water killed substantial amounts of freshwater vegetation and has increased the salinity of brackish waters but, to date, has not brought in sufficient sediment to overcome the sediment deficit incurred over the decades of freshwater management. The refuge continues to assess the biological, chemical, and geological impacts of these changes, specifically exploring whether the underlying peat layers, which were not increasing during the decades of freshwater management, have recently experienced increased subsidence or other biochemical changes. Therefore, while the environmental baseline for these habitats is difficult to fully assess, for this analysis we assume that the baseline is the condition of the refuge as of mid-2012. Thus, alternative A assumes little or few future proactive efforts and assumes that future habitats will evolve on the template of past natural events and earlier human manipulations of the marshes. Alternative B assumes that the service will undertake future proactive measures, geared to restoration of a more natural system than existed in 1988, or even decades before, with the goal of limiting its actions to ones which will result in more naturally sustainable future conditions, i.e. “fix it, and then let it be.” Alternative C assumes a return to former management conditions and recognizes that extensive engineering actions to construct a robust barrier island capable of sustaining freshwater marshes in light of sea level rise and climate change will require construction of a substantial sand barrier with perpetual renourishment actions. Similarly, for upland management, since the refuge has not been engaged in active farming for 6 years, Alternative A assumes that incremental vegetation changes will result in the gradual development of bushes, thickets, and ultimately woodlands, which the Service will not actively manage other than to remove invasives. Alternative B will bring these areas into a forested condition more rapidly by planting certain desired trees and other species. Alternative C anticipates a return to active farming.

This chapter does not separately evaluate the consequences of certain types of conservation actions described in chapter 4. These actions often have impacts too trivial to matter, and would be categorically excluded if independently proposed, which would exclude them from further analysis or review. Such categorically excluded actions include but are not limited to:

- Conducting environmental education and interpretation programs (unless major construction is involved, or significant increase in visitation is expected)
- Conducting research, inventorying biological resources, or otherwise collecting habitat data or other natural resource information
- Operating and maintaining infrastructure and facilities (unless major renovation or improvements are involved)
- Recurring, routine habitat management actions and improvements
- Constructing small projects (e.g., fences, berms, interpretive kiosks) or developing access for routine management
- Planting and restoring native vegetation
- Changing minor amounts or types of public use

- Issuing new or revised management or public use plans when only minor changes are planned
- Enforcing Federal laws or policies

Impacts of Refuge Management on the Socioeconomic Environment

Chapter 3, Description of the Affected Environment, describes in more detail the regional socioeconomic setting of Prime Hook NWR. It also highlights community attitudes and opinions about the refuge as reported by the U.S. Geological Survey-Fort Collins Science Center (Sexton et al. 2007). A regional economic impact analysis was also conducted by the Fort Collins Science Center to estimate how current management and proposed management activities affect the local economy. The refuge management activities of economic concern in the analysis are:

- Refuge purchases of goods and services within the local community
- Refuge personnel salary spending
- Revenues generated from the Refuge Revenue Sharing Program
- Spending in the local community by refuge visitors
- Other management activities, e.g., cooperative farming program

The complete report of the regional economic impact of alternatives A, B, and C can be found in appendix I. The report also includes a cost analysis of administering refuge hunting programs.

We also considered the general socioeconomic consequences of managing habitat and wildlife to maintain, enhance, or restore elements of biological integrity, diversity, and environmental health on ecosystem services and how they affect humans. We also evaluated socioeconomic impacts in terms of the degree in which the proposed alternatives might affect the local economy, social structures, or quality of life of the local communities in and around the refuge and in Sussex County.

Managing for biological integrity, diversity, and environmental health on refuge lands will likely have impacts and consequences on the socioeconomic environment. However, it is difficult to accurately quantify a local monetary value on socioeconomic consequences of ecosystem services accrued when we maintain and enhance the biological integrity and diversity of refuge habitats.

Ecosystem services are the benefits to humans from a multitude of resources and processes that are supplied by nature. Services include climate regulation, waste treatment, water supply, carbon sequestration, protecting areas against storm and flood damage, nutrient cycling, habitat provision, and others that all contribute toward human comfort, security, and well-being. Saltwater wetlands, freshwater wetlands, forests, and ponds all provide different levels of environmental services.

The notion of ecosystems providing important services is not new. However, assigning ecological, socio-cultural, and economic values to ecosystem services is causing us to think differently about conservation. For example, quantifying ecosystem services as “natural capital” creates innovative financial incentives for conservation. Striking a balance between ecology and economy promises to provide practical ways to link the environment and people, and lead us toward more sustainable solutions.

Several recent reports have focused on the ecosystem services and the economic value of those services. Table 5.3 highlights some of these recent studies.

Table 5-3. Ecosystem Services

Ecosystem	Southwick Associates (2011) NWR lands (Value/acre/year)	Weber (2007) Cecil County, Maryland (Value/acre/year)	Kauffman (2011) Delaware River Basin (Value/acre/year)
Upland Forest	$1,674	$12,033	$1,978
Wetlands (nonspecific)	$10,608		
Riparian Forest		$52,765	
Freshwater Wetland		$43,685	$13,621
Salt marsh		$28,146	$7,235
Open Water			$1,946

	Southwick Associates (2011) NWR lands (Value/acre/year)	Weber (2007) Cecil County, Maryland (Value/acre/year)
Carbon Sequestration		$31 Upland Forest $65 Tidal Marsh
Clean Air		$191 Upland Forest
Soil and Peat Formation		$1,351 Tidal Marsh $17 Upland Forest
FloodProtection/ Stormwater Mgmt	$2,800/acre/year	$1,430 Tidal Marsh $679 Upland Forest
WaterSupply/ Hydrologic Regulation	$2,344/acre/year	$8,630 Upland Forest
Clean Water	$2,577/acre/year	$11,000 Tidal Marsh $1,000 Upland Forest
Erosion/Sediment Control		$12,700 Tidal Marsh
Pest Control		$50 Upland Forest
Pollination		$75 Upland Forest

In 2011, the National Fish and Wildlife Foundation released a report by Southwick Associates (2011) titled “The Economics Associated with Outdoor Recreation, Natural Resource Conservation, and Historic Preservation in the United States.” The reported value for ecosystem services was $10,608 per acre per year for wetlands and $1,014 per acre per year for forests. Weber (2007) also reported the value of ecosystem services in Cecil County, Maryland to include the following values per acre per year: $12,033 for upland forest, $43,685 to $52,765 for freshwater wetlands (non-riparian wetlands and riparian forest), and $28,146 for tidal marsh. Weber (2007) further broke these figures down based on the type of ecosystem services (e.g. carbon sequestration of upland forest valued at $31 per acre per year), which are discussed below. Kauffman (2011) discussed ecosystem services values in the Delaware River Basin and reported the following values per acre per year: $13,621 for freshwater wetlands, $7,235 for salt marsh, $1,978 for upland forest, and $1,946 for open water.

Similarly, Industrial Economics, Incorporated in 2011 prepared a report for the Division of Water Resources in the Delaware Department of Natural Resources and Environmental Control titled, "Economic Valuation of Wetland Ecosystem Services in Delaware." Industrial Economics (2011) reported a 1.2 percent decline in wetlands across the State of Delaware (3,132 acres) over a 15 year time frame (2007 to 2022), with an estimated annualized loss of approximately $2.4 million in the value of ecosystem services. This included ecosystem services such as carbon storage ($1.59 million annualized cost), water purification ($770,000 annualized cost), inland flood control, coastal storm protection, and wildlife protection.

Based on these previous studies, the value of Prime Hook's ecosystem services (not including outdoor recreation) can be estimated. Since the Refuge is approximately 80 percent wetlands and 20 percent uplands (2,026 acres), the value of Prime Hook's wetlands, if healthy, can range from $58 million to $86 million per year. The value of Prime Hook's uplands, if healthy, can range from $2 million to $24 million per year. Combining wetland and upland habitats, the total value of Prime Hook's ecosystem services can range from $60 million to $110 million per year. However, current refuge marshes are not healthy due to the impacts of ongoing saltwater intrusion from the Delaware Bay; therefore, the current value of ecosystem services is lower than previously estimated.

For purposes of the report, pest control focused on native herbivores, decomposition focused on dung burial of animal wastes, and nutrient recycling and wildlife nutrition focused on maintenance of wildlife species from insect food resources. This was a very conservative estimate, as other insect services like suppression of weeds and exotic herbivorous species, facilitation of dead plant and animal decomposition, and improvement of soils were not included. But the authors (Losey and Vaughan) felt that estimating even a minimum value for services that native insects provide to the socioeconomic environment would elevate priorities for insect conservation. Managing a large block of native habitats (10,000 acres of refuge forest, wild grassland, and other early successional habitats) will allow 40,000 acres of agricultural lands surrounding the refuge to benefit from wild insect-mediated pollination and other services.

Insect pollinators can have impacts on the socioeconomic environment but are seldom considered in economic analyses. We have considered strategies and conservation actions that incorporate insect conservation in our alternatives to locally stem pollinator population declines and reviewed the impacts and environmental consequences of doing so. Implications of habitat and mosquito integrated pest management practices on insect pollinators and impacts to humans and wildlife will also be discussed in respective alternative sections in the invertebrate section of this chapter.

Impacts of Refuge Management on Socioeconomic Environment that Would Not Vary by Alternative

We expect the three proposed alternatives to have minimal adverse impacts on the economy of the towns or county in which the refuge lies. We would expect none of the alternatives to significantly alter the demographic of economic characteristics of the local community. All refuge actions we propose would neither disproportionately affect any communities nor damage or undermine any businesses or community organizations. No adverse impacts are foreseen to be associated with changes in the community character or demographic composition by proposed alternatives.

Impacts of Refuge Management on the Socioeconomic Environment in Alternative A

Under alternative A, refuge management activities directly related to refuge operations will generate an estimated $2.7 million in local output, 25 jobs and $742 thousand in labor income in the local economy. Including direct, indirect, and induced effects, all Refuge activities would generate total economic impacts of $3.9 million in local output, 33 jobs and $1.1 million in labor income (appendix I).

Values of ecosystem services in alternative A will be lower than those reported in the other two alternatives. Passive management will let "mother nature run its course" and may likely result in the conversion of more than 5,000 acres of wetlands to open water, including both existing tidal salt marsh and impounded marshes. The loss of ecosystem services could exceed 50 percent as reported in other alternatives. Natural wetland recovery is not impossible, but could take decades or hundreds of years and will be dependent on sea level rise. With more open water, the wetland complex may only partially meet the potential for flood control, storm surge protection, erosion, and habitat value for fish and wildlife.

From 1963 to present, extensive mosquito control has occurred on the refuge to "…effect nuisance relief, to protect public health, and to avoid adverse impacts to local economies from severe mosquito infestations…" by the State of Delaware Mosquito Control Section (Section). To significantly reduce the heavy reliance on insecticides from 1989 to 2002, the Section employed its preferred method to control mosquitoes: a source reduction technique of open marsh water management. Total acres sprayed before open marsh water management averaged several thousands of acres per year (e.g., 8,010 acres were sprayed on refuge in 1985). Gradually, sprayed acres fell to 1,500 acres by 1994. Following open marsh water management construction, average annual acres sprayed was reduced to 400. Thus, public health was protected while reducing insecticide use.

The adverse impact to agriculture if the marsh is not restored is the increase of saltwater intrusion, erosion of the coast, and increased damages from storms. As salinity levels increase with continued marsh loss, the risk of storm damage to agricultural resources may increase. Many crops have very low tolerance to salinity, and as salinities increase, field productivity and quality decreases. As the coastal landscape erodes and tidal surges force higher salinity waters inland, many areas would have to counteract this effect by installing tide gates or levees. The loss of agricultural productivity associated with saltwater intrusion and an increased risk of storm damage may have an adverse economic impact to adjacent landowners.

Most of the wildlife-dependent recreational activities that occur on the refuge include hunting, fishing, wildlife observation, and general enjoyment of the marsh environment. Recreational resources would be adversely affected with the loss of wetlands and habitat diversity. Wildlife abundance is directly related to the amount of wetland present. As land loss through erosion or subsidence continues the wildlife abundance in the project area would decrease. The abundance of migratory birds and other animals directly dependent on the wetlands would also decrease as they move to more suitable habitat.

Lower quality fishery spawning, nursery, and foraging habitat may translate to a decline in sport fishing success on the refuge. Hunting opportunities would decline with the declines in game species. Wildlife observation opportunities may decline with declining migratory bird usage. In general, loss of emergent wetlands to shallow, unvegetated open water would result in decreased fishery production and therefore have adverse impacts on recreational fishing. Conversion of emergent marsh to large unvegetated open water would result in a diminished capacity of the area to support fish and wildlife populations (USACOE 2010).

Marsh wetlands reduce storm surges from tropical systems. An increase in storm surge impacts from a loss of emergent marsh can directly affect land loss, which may result in the loss of parking areas, roads, observation towers, piers, and other recreational infrastructure (USACOE 2010). The continued loss of these coastal barrier systems would result in the reduction and eventual loss of the natural protective storm buffering of these barrier systems, including the adjacent marshes.

We conclude that while social or economic impacts would be greater under alternative A than the other alternatives, these adverse effects would not be realized at a regional level for Sussex County or the state of Delaware, either directly, indirectly, or cumulatively. Therefore, there will be no significant impact on the socioeconomic environment under alternative A.

Impacts of Refuge Management on the Socioeconomic Environment in Alternative B

Under alternative B, refuge management activities directly related to refuge operations will generate an estimated $3.3 million in local output, 30 jobs and $892.9 thousand in labor income in the local economy. Including direct, indirect, and induced effects, refuge activities will generate total economic impacts of $4.7 million in local output, 41 jobs and $1.29 million in labor income. In 2007, total labor income was estimated at $2.996 billion and total employment was estimated at 87,113 jobs for Sussex County (IMPLAN 2007 data). Total economic impacts associated with refuge operations under alternative B represent less than one percent of total income (0.04%) and total employment (0.05%) in the overall Sussex County economy. Total economic effects of refuge operations play a larger role in the Prime Hook communities near the refuge such as Milton and Lewes where most of the refuge public use related economic activity occurs. (This information is summarized from the more detailed analysis presented in appendix I).

Alternative B proposes to restore over 4,000 acres of impounded marshes to tidal salt marsh and to reforest nearly 900 acres, which will enhance the value of ecosystem services through better storm surge and flood protection, carbon sequestration, fish and wildlife habitat, and better air and water quality. Ecosystem services values will be slightly greater than those estimated in alternative A.

Habitat management objectives and strategies for refuge wetland and upland habitats in this alternative maximize biological diversity and enhance and restore biological integrity and environmental health. These management actions enhance insect conservation. For example, the elimination of several hundred acres of non-native crop cultivation and subsequent restorations of this acreage to native plant communities increase insect densities and biodiversity, which in turn support greater avian diversity and abundance.

Alternative B management and conservation actions that increase avian diversity and abundance can potentially increase the capacity for human disease prevention. Managing wildlife habitats to maintain or enhance biological integrity, diversity, and environmental health (BIDEH) may lead to the reduction in risk of mosquito-borne disease transmission to humans. Functional wetlands and other natural habitats can decrease mosquito vector populations and mosquito-borne disease. Providing a greater diversity of habitat types with increased biological integrity and environmental health enhances populations of natural mosquito predators such as birds, frogs, insects, and other invertebrates that live in wetlands and feed on mosquito larvae and adults.

Recent infectious disease models illustrate a suite of mechanisms that can result in lower incidence of disease in areas of higher disease host diversity (defined as the dilution effect). These models are particularly applicable to human zoonoses, i.e., infectious disease of wildlife or domestic animals that enter human populations (Keesing et al. 2006, Krasnov et al 2007, Ostfeld and Kessing 2000). Examples of zoonoses include avian influenza, anthrax, Lyme disease, and West Nile virus.

Research conducted in the eastern U.S. during the West Nile virus epidemic in 2002, found fewer incidences of West Nile virus in humans in areas with a diverse array of bird species (Swaddle and Calos 2008). This link between higher bird diversity and reduced human West Nile virus infection is attributed to the fact that crows, jays, thrushes, and sparrows are competent (amplifying) hosts of the West Nile virus, making them able to contract the disease and pass it on through a vector more efficiently. When bird diversity is low, the competent host species tend to represent a higher proportion of the bird population, increasing the likelihood that a mosquito will encounter an infected bird and transmit the virus during its next bite. A diverse suite of bird species, including a large number of incompetent hosts in the population, tends to reduce the transmission rate to other birds, or mammals, including humans. Similar studies have shown how increased mammalian diversity decreased Lyme disease risk to humans (LoGiudice et al. 2003).

It should be understood, however, that increased BIDEH will not necessarily equate with reduced nuisance mosquito complaints. The ability of natural predation pressure to reduce certain species of mosquitoes substantially, if environmental conditions are appropriate, is perhaps limited. Likewise, the ability of chemical mosquito treatment alone to substantially reduce the threat of periodic pulses of mosquitoes is limited. Mosquitoes have evolved successfully to overcome mass mortality, regardless of the source. Neither BIDEH nor mosquito management is a panacea upon which the public can depend to eliminate the nuisance of mosquitoes if one is near marshes and wetlands.

The human threshold for mosquito tolerance is largely cultural in origin, and varies considerably across the landscape, largely upon one's frame of reference. Humans raised in a relatively urban or suburban landscape have generally little experience with persistent mosquito annoyance. Individuals born into or having lived a substantial period of time in mosquito country are more likely to take the natural pulses in mosquito (or no-see-um, deer fly, blackfly) numbers in stride. Regardless of where one resides, actual mosquito-borne disease outbreaks are spotty and rare.

It should be noted that it has been the policy of other refuges on the Delmarva Peninsula not to allow mosquito control except during public health emergencies. Blackwater (approximately 25,000 acres), Martin (4,528 acres), Eastern Neck (2,285 acres), Chincoteague (approximately 14,000 acres), Wallops Island (373 acres), Eastern Shore of Virginia (1,393 acres), and Fisherman's Island (1,850 acres) NWRs, totaling over 49,400 acres, of which some smaller proportion is actually mosquito breeding habitat, do not allow either larval or adult mosquito control. Assateague National Seashore, (8,200 acres), managed by the National Park Service, does not permit mosquito control. Additionally, the State of Maryland limits mosquito control in some of its State parks and sensitive natural areas (Jim McCann, personal communication). The refuge does not expect an increased incidence of mosquito-borne disease in the human population.

The sociological aspects of forest habitat management programs are complex, and vary widely across geographic boundaries. In many cases, members of the public see and hear only the negative aspects of forest management and associate forest management programs on refuges, especially the cutting of trees, with wildlife destruction and commercialization of the resource rather than with the objectives of wildlife habitat improvement, improved forest health, and other benefits to the environment. These concerns and issues would be addressed in environmental education and interpretation programs about the refuge's forest management program. Furthermore, forest management activities proposed in alternative

B would likely require the contracted services of private timber companies or equipment companies in the region.

Wetlands in many locations play an important role in flood protection. Nowhere is this function more important than along the coast. Preserving and restoring coastal marshes can help reduce storm damage because coastal wetlands serve as storm surge protectors when storms come ashore. Wetlands can prove a significant and potentially sustainable buffer for wind wave action and storm surges generated by storms. A 1-acre wetland can typically store about 3-acre feet of water, or 1 million gallons. Trees and other wetland vegetation help slow the speed of floodwaters. This action, combined with water storage, can actually lower flood heights (*http://www.epa.gov*; accessed February 2012). Wetlands that occur along the shorelines help protect the shoreline soils from the erosive forces of waves and currents. The wetland plants act as a buffer zone, dissipating the water's energy and providing stability by binding the soils with their extensive root systems. Morgan, et al. (2009) noted more than a 60 percent reduction in non-storm wave heights within seven meters into a vegetated salt marsh compared to 33 percent within a marsh area with no vegetation. Similarly, Knutson et al. (1982) found wave heights reduced by57% 5 m into a *S. alterniflora* marsh, and 65% at 10 m. Leonard and Luther (1995) found a 65% reduction in the turbulent energy of water coming onto the marsh after it had traveled just 3 m in from the marsh edge. Wetlands that occur along the shorelines help protect the shoreline soils from the erosive forces of waves and currents. The wetland plants act as a buffer zone, dissipating the water's energy and providing stability by binding the soils with their extensive root systems.

Wetlands protect water quality by trapping sediments and retaining excess nutrients and other pollutants such as heavy metals. These functions are especially important when a wetland is connected to groundwater or surface water sources that are used by humans for drinking, swimming, fishing, or other activities. These same functions are also critical for the fish and other wildlife inhabiting the waters.

Sediments, which are particles of soil, settle into the gravel of streambeds and disrupt or prevent fish from spawning, and smothering fish eggs. Other pollutants -- notably heavy metals -- are often attached to sediments and present the potential for further water contamination. Wetlands remove these pollutants by trapping the sediments and holding them. The slow velocity of water in wetlands allows the sediments to settle to the bottom where wetland plants hold the accumulated sediments in place.

Failure to restore and maintain coastal wetlands may result in significant increases in damages from storm surges that are currently reduced by coastal wetlands. Local long-term minor to moderate beneficial impacts to the socioeconomic environment would be realized from the deposition of dredged spoil into the marsh or open water areas of the refuge. Restoration of these marshes to historic salt marsh conditions would once again provide natural storm buffering, limit storm surge heights, and provide protection for the interior wetlands and uplands (USACOE 2010). Emergent or submergent vegetation may become established, complementing the existing fish and wildlife-dependent recreation. Recreation fishing may increase due to increased fisheries habitat on the refuge.

Other local direct short-term adverse impacts would result to recreational resources during construction or placement of spoil onto the former impoundments to restore these areas as viable salt marshes. During and immediately after construction, there would be a decrease in the quality of habitat, and wildlife and fisheries species associated with recreational opportunities would be displaced; however, the area would reestablish emergent wetland vegetation. These adverse impacts would be temporary and localized. Adverse impacts would be offset by the restoration of the salt marsh that could contribute to restoring base organisms used for recreational activities such as fishing, birding, and hunting (USACOE 2010). Restoring wetlands and reducing the land loss rates may protect nearby recreational infrastructure such as parking areas, roads, piers, and observation towers. Recreation activities dependent upon wetland habitat may be maintained or possibly increased (USACOE 2010).

We conclude that while there may be some apparent changes in social or economic conditions in nearby communities as described above, these localized effects would not be realized at a regional level for Sussex County or the state of Delaware, either directly, indirectly, or cumulatively. Therefore, there will be no significant impact on the socioeconomic environment under alternative B.

Impacts of Refuge Management on the Socioeconomic Environment in Alternative C

Alternative C is dependent upon the capability of maintaining the freshwater impoundments from saltwater intrusion. Currently, the refuge is losing water management control at the water control structures, the marsh is not accreting at a level to keep up with sea level rise, and extensive beach replenishment is required in the midst of increased storm frequency and intensity. If the 4,000 acres of impounded marsh revert to open water, and if additional impacts to upland buffer habitats from salt water intrusion or future storm events are not considered, then the value of Prime Hook's ecosystem services for wetlands could decrease by as much as 50 percent.

Under alternative C, refuge management activities directly related to all refuge operations generate an estimated $2.9 million in local output, 26 jobs and $768.4 thousand in labor income in the local economy. Including direct, indirect, and induced effects, all Refuge activities would generate total economic impacts of $4.03 million in local output, 34 jobs and $1.1 million in labor income. Total economic impacts associated with refuge operations under alternative C represent less than one percent of total income (0.04%) and total employment (0.04%) in the overall Sussex County economy (appendix I). Similar to alternative B, total economic effects of refuge operations play a larger role in the Prime Hook communities near the refuge such as Milton and Lewes where most of the refuge public use related economic activity occurs.

In order to achieve water management control over the impoundments which will not likely result in another breach, construction and maintenance of a barrier island adequate to withstand a 100-year storm may be required. The design, costs, specifics, and impacts of a detailed plan for construction of a dike sufficient to withstand a 100-year storm would entail subsequent NEPA analysis, as well as engineering and economic evaluations. While the costs of such an endeavor would be substantial, the magnitude of change for the regional economy is far less, as refuge visitation and public recreational opportunities benefits have not changed substantially despite the dramatic habitat changes. In terms of local viewpoints, some members of the adjacent Prime Hook community have expressed concerns about increased flooding of their bayside properties since the breaches have occurred. Tidal levels are being monitored to examine this, and alternative C would also address this concern to a degree. However, actions within the alternative would not alter the inherent risks associated with construction on a very low-lying barrier from high or intense storms directly impacting the community from Delaware Bay side.

Similar to alternative B, we conclude that while there may be some apparent changes in social or economic conditions in the nearby communities as described above, these effects would not be realized at the Sussex County or state of Delaware regional level, either directly, indirectly, or cumulatively. Therefore, there will be no significant impact on the socioeconomic environment under alternative C.

Impacts on Cultural and Historical Resources

Chapter 3, Description of the Affected Environment, describes in more detail the refuge's 14 prehistoric sites and 31 historic sites, which were identified in archaeological, historical, and geomorphological surveys conducted in 1982, 1984, and 2004 (USFWS 1982, USFWS 1983, Tetra Tech FW, Inc. 2004).

Impacts on Cultural and Historical Resources That Would Not Vary by Alternative

We expect all of the alternatives to have local long-term minor beneficial impacts and local negligible adverse impacts on cultural and historical resources on the refuge. Refuge lands are protected from development or destructive land uses that may result in substantial impacts on cultural and historic resources. Regardless of which alternative we select, we would protect known cultural and historic resources.

For compliance with section 106 of the National Historic Preservation Act, the refuge staff will, during the early planning stages of proposed new actions, provide the regional historic preservation officer with a description and location of all projects, activities, routine maintenance, and operations that affect ground and structures, details on requests for compatible uses, and the range of alternatives considered. That office will analyze those undertakings for their potential to affect historic and prehistoric sites, and consult with the State historic preservation officer and other parties as appropriate. We will notify the State and local government officials to identify concerns about the impacts of those undertakings.

Refuge lands are vulnerable to looting, despite our best efforts at outreach, education, and law enforcement; however impacts are expected to be negligible based on our observations of past visitor impacts from public uses. Upland areas adjacent to wetland areas have been identified for high potential for cultural resources. In addition, refuge visitors may inadvertently or even intentionally damage or disturb known or undiscovered cultural artifacts or historic properties. We would continue our vigilance in looking for this problem, use law enforcement where necessary, and continue our outreach and education efforts.

For each of these alternatives, we have concluded that the impacts will not be significant.

Impacts on Cultural and Historic Resources in Alternative A

Impacts on cultural and historical resources under Alternative A ("No Action") serve as a baseline for comparing and contrasting alternatives B and C to the refuge's existing management activities.

Refuge activities under alternative A have the potential to impact cultural resources either by direct disturbance during the construction of facilities related to public use or administration and operations, or indirectly by exposing artifacts during actions such as limited prescribed burning. The passive habitat management approach in alternative A would result in less manipulation of refuge habitats, particularly in managing for early successional habitats, conducting reforestation projects, and prescribed burning. Although the presence of cultural resources, including historic properties, cannot stop a federal undertaking, the undertakings are subject to section 106 of the National Historic Preservation Act and, at times, other laws. As projects are underway, we would remain watchful for potential sites or artifacts, and take all necessary precautions should we locate them.

Conclusion for Management Actions in Alternative A
Management action in alternative A would result in local long-term minor beneficial impacts and local negligible adverse impacts on cultural and historic resources. Subject to section 106 of the National Historic Preservation Act and other relevant policies and laws, there would be no impairment of refuge cultural and historic resources.

Impacts on Cultural and Historic Resources in Alternative B

The benefits for cultural and historic resources would increase under alternative B due to a proposed increase in interpretation and environmental education capability and programs that would foster a greater public appreciation of their value.

Adverse impacts to cultural and historic resources under alternative B may increase as more acreage is actively managed through reforestation or wetland restoration. Negligible impacts are expected and are avoided by following section 106 of the National Historic Preservation Act as described under alternative A.

Conclusion for Management Actions in Alternative B
Management action in alternative B would result in local long-term minor beneficial impacts and local negligible to minor adverse impacts on cultural and historic resources. Subject to section 106 of the National Historic Preservation Act and other relevant policies and laws, there would be no impairment of refuge cultural and historic resources.

Impacts on Cultural and Historic Resources in Alternative C

The benefits to cultural and historic resources would be enhanced from both alternatives A and B because more staff will be devoted to environmental education and interpretive programs to foster a greater public appreciation of their value. Refuge management activities under alternative C have the potential to impact cultural resources by indirectly by exposing artifacts during actions such as cooperative farming, managing for early successional habitats, conducting reforestation projects, and prescribed burning. Although the presence of cultural resources, including historic properties, cannot stop a federal undertaking, the undertakings are subject to section 106 of the National Historic Preservation Act and, at times, other laws. As projects are underway, we would remain watchful for potential sites or artifacts, and take all necessary precautions should we locate them.

Conclusion for Management Actions in Alternative C
Management action in alternative C would result in local long-term minor beneficial impacts and local negligible adverse impacts on cultural and historic resources. Subject to section 106 of the National Historic Preservation Act and other relevant policies and laws, there would be no impairment of refuge cultural and historic resources.

Impacts on Air Quality

Chapter 3, Affected Environment, discusses the status of air quality in the landscape around the refuge. We evaluated the management actions each alternative proposes for their impacts on air quality.

Impacts on Air Quality That Would Not Vary by Alternative

There are no major stationary or mobile sources of air pollution present on the refuge, nor would any be created under any of the alternatives. We expect refuge land management to help reduce any future direct and cumulative impacts by maintaining natural vegetative cover on the 10,000 plus acres where suitable, requiring that all upgrades to existing facilities or all new facilities be energy efficient, and limiting public uses to those that are appropriate, compatible, and wildlife-oriented activities. Collectively, these management actions would help reduce the potential for additional synthetic sources of emissions in the surrounding landscape.

Localized increases in emissions from visitor vehicles or boat motors would be negligible compared to current off-refuge contributions to pollutant levels and likely increases in air emissions in the Sussex County airshed from land development over the next 15 years. Impacts are mitigated by prohibiting gasoline motors on Turkle and Fleetwood Ponds. We will continue to encourage the non-motorized use of trails, particularly the Canoe Trail, for wildlife observation and other compatible recreation. Any adverse air quality effects from refuge activities would be more than offset by the benefits of maintaining the refuge in natural vegetation.

The two management actions that may most affect air quality the most are prescribed fires and planting or perpetuating trees. Although both of these will occur no matter which alternative is selected, the degree to which we practice them, and their impacts, will vary. The major pollutants from prescribed burning are particulates (small particles of ash, partly consumed fuel, and liquid droplets) and gases (carbon monoxide, carbon dioxide, hydrocarbons, and small quantities of nitrogen oxides). Those will increase or decrease based on the alternative we select.

Low intensity prescribed burning would release inconsequential amounts of gases (USDA 1989). Particulates can reduce visibility or cause negative effects on the health of people with respiratory illnesses. Appropriate smoke management can minimize or nearly eliminate both negative effects. The consideration of the wind speed, direction, and mixing heights is all-important in managing smoke. In planning our prescribed burns, we consider all those factors and other environmental and geographical factors. Based on our experience, we expect prescribed burning to produce no major, long-term adverse impacts.

Tree planting or letting old fields grow naturally into forest cover will improve air quality. Trees store carbon and release oxygen. Because air quality in the region is generally good, we do not expect our management to result in measurably improved air quality, but it may contribute to improved local, ambient conditions. However, we recognize that Sussex County is an EPA non-attainment area for air quality with State burning bans in place during summer months.

The area of the refuge has a history of wildfire, which was mostly caused by humans. We would seek to minimize the possibility of serious fires and their associated health and safety concerns. We would assess the hazards associated with the wildland urban interface along the refuge boundaries with privately owned land to ensure that our management practices are not creating excessive fuel loading that would lead to severe fires.

In summary, our management activities would not significantly adversely affect regional air quality; none of the alternatives would violate EPA standards, and all three would comply with the Clean Air Act.

Impacts on Air Quality in Alternative A

Air quality is generally good in Sussex County, with certain periods of non-attainment of State air quality standards during the late summer and early fall. Eliminating smoke impacts resulting from any refuge prescribed fire during non-attainment periods will ensure that no negative impacts to public health and safety will be a consequence of the refuge using prescribed burning during these times.

Air quality would benefit from the filtering effects of the 10,132 acres of the refuge. The sequestering effects of presently owned forested acres would produce a negligible reduction in atmospheric carbon.

We expect very short-term, negligible localized adverse impacts on air quality from the emissions of motor vehicles used by staff and refuge visitors, from refuge equipment, and from prescribed burning. However, no foreseeable long term or cumulative impacts on local or regional air quality will result from any proposed refuge activities, nor will these activities contribute to any substantial increase in regional ozone levels, particulate matter, or other negative air quality parameters.

Conclusion for Management Actions in Alternative A
Management actions in alternative A would result in negligible short-term and long-term cumulative impacts on air quality. With the use of best management practices, there would be no impairment of refuge's air quality. However, changes in wetland vegetation caused by failing impoundment infrastructure and more frequent and severe annual coast storms may have uncertain impacts on local and regional air quality.

Impacts on Air Quality in Alternative B

This alternative increases wetland vegetation on the refuge through restoration of freshwater wetlands to salt marsh and increases forests by planting or allowing lands to regenerate naturally, which may result in local long-term minor beneficial impacts on air quality. Forests contribute positively to air quality in two ways: by precluding development and sequestering carbon. Under this alternative, we would convert at least 450additional forested acres from managed croplands. We would manage our forests with longer rotation ages, which would result in increased carbon sequestration. The predominance of more mature stands would improve forest health, diversity, and resilience to disturbance. Impacts on the physical environment (water, soil, geology and hydrology, and air quality) would be negligible as long as forestry best management practices are employed. A list of all possible best management practices, developed by Delaware Forest Service, is provided in the habitat management plan. Carbon sequestration will also be increased by restoring about 3,000 acres of salt marsh.

Given our emphasis on maintaining about 200 acres of early successional habitat, annual prescribed burning may increase, resulting in local, temporary increases of particulate matter and various combustion gases. By adhering to the established standards of smoke management, we can minimize the potentially negative effect of particulates.

Under alternative B, construction of the expanded facilities would cause negligible local impacts on air quality. Short-term, localized effects from construction vehicles and equipment exhausts would occur. Operations of these facilities would result in emissions from heating and cooling systems, and visitor and employee travel would add sources of air pollution; however, these are partially offset by energy-efficient heating and cooling systems and our replacement of our fleet with more energy efficient models.

Public use of the refuge is expected to increase under this alternative, resulting in additional emissions from visitor vehicles and boats (e.g., in hunting waterfowl). Impacts are mitigated by prohibiting gasoline motors on the proposed fishing areas of Goose and Flaxhole Ponds. Impacts to air quality are expected to be negligible.

Conclusion for Management Actions in Alternative B

Management actions in alternative B would result in negligible to local long-term minor beneficial impacts and local negligible adverse impacts on air quality. Alternative B would contribute an imperceptible beneficial impact and an imperceptible adverse impact to the total cumulative long-term impact to air quality. With the use of best management practices, there would be no impairment of refuge's air quality.

Impacts on Air Quality in Alternative C

Same as alternative B..

Conclusion for Management Actions in Alternative C

Same as alternative B.

Impacts on Soils

Soils play key roles in regulating elements and nutrient cycles, and serve as a fundamental basis of the physical environment of all habitats on the refuge. Soil biotic communities consume wastes and the remains of dead organisms and recycle their constituent materials that are incorporated into the soil into forms usable by plants. (Daily et al. 1997). Natural geologic processes within coastal marine environments also perform fundamental roles in sediment supply and sedimentation rates of marsh soils. The linkage between marsh elevation, sea level rise, and sedimentation rates represents important aspects of the morphodynamics of marsh soils and the impacts on wetland soil elevation changes (Komar 1988).

We evaluated the alternatives and various proposed actions and activities with respect to their potential impacts on refuge soils. We considered the impact of the following actions:

- Restoring and enhancing native plant communities
- Conducting prescribed fires, mowing, and brush-hogging
- Manipulating water levels in impounded marshes
- Controlling invasive plant species with herbicides
- Reducing mosquito pesticide use to conserve and protect insects
- Mosquito control
- Restoring salt marsh in impounded wetlands

Impacts on Soils That Would Not Vary by Alternative

The refuge has used herbicides in the past and will into the future to meet management objectives under all alternatives, for pre- (site preparation) and post-restoration to control vegetation. The mobility of an herbicide is a function of how strongly it is adsorbed to soil particles and organic matter. Whenever possible, we choose herbicides that strongly adsorbed to soil particles, relatively insoluble in water, and not environmentally persistent, which would therefore be less likely to move across the soil surface into surface waters or leach through the soil profile and contaminate groundwater. Cost will not be the primary factor in selecting an herbicide for use on refuge land and waters; the most efficacious herbicide available with the least risk to soils will be chosen for use on the refuge.

All pesticide usage would comply with the applicable federal (FIFRA) and state regulations pertaining to pesticide use, safety, storage, disposal and reporting. Before pesticides can be used to eradicate, control or contain pests on refuge lands and waters, pesticide use proposals (PUPs) would be prepared and approved in accordance with 7 RM 14. In addition, best management practices will minimize or eliminate possible effects associated with pesticide drift or surface runoff that may impact refuge soils.

Impacts on Soils in Alternative A

Impacts on soils under Alternative A ("No Action") serve as a baseline for comparing and contrasting Alternatives B and C to the refuge's existing management activities.

Managing and Protecting Habitat
Recent and ongoing afforestation of 200 acres and continuing to allow an additional 100 acres to revert to native vegetation restores the ecological services that improve soil fertility and sustain soil health. Over time, soil structure and associated microbial communities in these areas will reestablish themselves. The refuge has conducted a limited prescribed burning program over the years. The appropriate prescribed burning of wetlands and uplands habitats can improve soil conditions by releasing vital nutrients back into the soil.

Ongoing natural succession on several hundred acres of refuge upland fields to native vegetation will continue to reduce soil erosion and increase natural levels of soil fertility. As refuge soils are rehabilitated naturally, early pioneering species like sweetgums are very important for nitrogen cycling and serving as hosts for mycorrhizae that are needed by later succession plant species. These beneficial fungi pump essential elements to conifer and hardwood tree zones from below, and help restore microbial activity and channels in the soil for native soil biota.

Regular tidal flow would continue to enter Unit II through the newly formed inlets. Tidal flow would try to reestablish, reverting impounded marshes to a brackish and ultimately a saline wetland or open water environment. Marsh accretion rates are spatially and temporally variable, and dependent to a large degree on storm-dominated sediment dynamics and overwash processes to supply sediment to coastal marsh and barrier beach systems (Aubrey and Speer 1985, Leatherman and Zaremba 1986, Roman et al. 1997). Preliminary data from radiometric coring conducted by DNREC's Coastal Program indicates that Unit II marshes have not been keeping up with current sea level rise rates over the last 50 years (Scarborough and Wilson, *unpublished data*). In the end, restored tidal flow may improve the current low rate of sediment accretion, as the effects of storm sedimentation could aid in the vertical accretion of these marshes. However, in the absence of proactive restoration of the sediment and elevation, there may be a very slow or limited return of vertical, unless precluded by sea level rise altogether.

There remains a recognized lack of understanding regarding the interactions among changes in wetland elevation, sea level, and wetland flooding patterns, and changes in other sediment accretion drivers, such as nutrient supply, sulfate respiration, and soil organic matter accumulation (CCSP 2009). Human-altered drainage patterns, as exist in the refuge impoundments, appear to be limiting the vertical accretion of sediment. In such cases, rapid saltwater intrusion into the unit could potentially cause subsidence through collapse of organic soils and conversion to open water (DeLuane et al. 1994, Pearsall and Poulter 2005). Too rapid a conversion of the former marsh system may cause, or has already caused, unanticipated or unfortunate biochemical results, which has led marsh restoration experts to advise that tidal restoration programs be conducted gradually (Portnoy and Giblin 1997).

Even with greater sediment availability and tidal exchange, under some circumstances sediment building process may not overcome the combination of sediment loss and relative sea level rise (Boumans, et al. 2002). Where sedimentation rates are low, on a shallowly subsided site breached 100 years ago, insufficient sediment had accumulated for vegetation to become established (NECIA 2007). Pethick (2002) found a negative sediment budget for restored sites during the period of no vegetation. Erosion was reduced once the vegetation established. Williams, et al (2002) indicated that the time required for a 1.5 m subsided site to reach colonization by vegetation ranges from 10 to more than 30 years.

Washover and inlet formation can potentially contribute to the sediment budget of the refuge's sandy beach and marsh environments in the long term. Washover is a major process in the retreat mechanism of coastal barrier beaches in response to sea level rise (Dillon 1970, Kraft et al. 1973, Kraft et al. 1976b).

Public Use
At current levels of public use and under current regulations, the refuge expects negligible impacts to refuge soils. Hiking trails, boat launch sites, wildlife observation areas, parking areas, and other high-use areas would continue to be well maintained to keep soil impacts to a minimum. We will note any erosion problems during routine monitoring and correct them as soon as possible. Potential adverse impacts on soils can also result from compaction by visitors using trails and other areas. These trails are for pedestrian use and preclude the use of mountain bikes or ATVs. Hiking or walking can alter habitats by trampling vegetation, compacting soils, and increasing the potential of erosion. In moderate cases of soil compaction, plant cover and biomass is decreased. In highly compacted soils, plant species abundance and diversity is reduced in the long-term, as only the most resistant species survive (Liddle 1975). To minimize impacts on bank erosion, no wake zones and a maximum motor restriction of 30 horsepower on Prime Hook Creek and Slaughter Canal will be posted.

Conclusions for Management Actions in Alternative A
Management actions under alternative A would have local long-term minor impacts and local short-term and long-term significant impacts, in terms of the sediment within the impounded wetlands. Although there is the potential that the affected wetlands may receive sufficient sediments through the breaches to naturally restore sediment elevation eventually, this is unlikely over the 15-year timeframe of this plan. Impacts during that timeframe would be significant. Service policy 6 RM 4.1 states that the long-term productivity of the soil will not be jeopardized to meet wildlife objectives. In addition, the BIDEH policy (601 FW 3) states, "We favor management that restores or mimics natural ecosystem process or functions to achieve refuge purposes." Management actions under alternative C should result in no impairment of the refuge's BIDEH; however, there may be some impairment to BIDEH with the loss of salt marsh to open water. Alternative A management actions in upland areas related to public use would have negligible local impacts on upland soils.

Impacts on Soils in Alternative B

Proposed management actions in alternative B that would affect soils include five primary changes: elimination of intensive agricultural practices, an increase in acreage of native plant communities, restoration of impounded wetlands, allowing natural processes to proceed on barrier island habitats, and increased public use.

Managing and Protecting Habitat
The proposed habitat management changes in alternative B will use more natural means to meet habitat and wildlife objectives through the maintenance of natural ecosystems when the more intensive and artificial method of cropland management is discontinued and through restoration actions to return the former freshwater impoundments to salt or brackish water systems. On the basis of acreage alone, the cumulative impacts of these actions will be substantial. Nearly all of the actions will result in positive impacts on natural soil processes, as described in detail below. We anticipate minor or negligible and short-term

negative impacts as fields are burned, additional sediment is placed in the impoundments, or heavy equipment is used for afforestation.

Eliminating farming will have beneficial impacts on refuge soil resources by restoring native soil biota. Enhancing complex multi-trophic interactions in soils is critical to rehabilitating lands impoverished by intensive agricultural practices. However, restoration is a slow process and may take a century or more for native soil communities to rebound (Hendrix and Bohlen 2002). Restoring native plant communities is an essential rehabilitative action to restoring and enhancing native soil biota. Whether soils are restored or naturally revert, increases in underground soil organisms reestablish vital processes of decay and nutrient cycling restore natural soil fertility and soil structure (Lal 2003).

The rehabilitation of the refuge's soils through the restoration of native plant communities will significantly increase carbon sequestration and increase soil carbon stocks for utilization by plant resources. The amount of carbon sequestration in soils is often measured as carbon stock equilibrium of soil to vegetation. Generally, carbon stocks in soils are about four times greater than carbon stocks in vegetation (Lal et al. 2004).

Conducting low intensity and infrequent prescribed burns (2 to 5 year intervals) on the refuge in early successional habitats, and understory burns to improve Delmarva fox squirrel forested habitats can also improve soils by maintaining native vegetation and regularly returning quick pulse of nutrients to soils across the refuge landscape on a rotational basis.

Improved forest management practices on current refuge acreage and increasing forest-cover of prior converted agricultural lands using proactive reforestation techniques would also increase the coverage of native forested vegetation that conserves and protects soils for the long term. Restoration of native forests and improving existing stands will also increase and enhance microbial and invertebrate biomass in the forest soils, which in turn stimulates microbial activity and naturally restores and conserves soil fertility and reduces soil erosion. Impacts of forestry management practices on soil are possible because of the involvement of heavy equipment and possible clearing of vegetation, but are expected to be negligible as long as forestry best management practices are employed. A list of all possible best management practices, developed by Delaware Forest Service, is provided in the habitat management plan (appendix B). Because nearly all refuge lands are flat, with less than 2 percent slope, they would be more resistant to erosion, siltation, and runoff.

Cumulatively, the impacts of the Service's proposed actions under alternative B will have moderate impacts to upland soils and, as described above, these impacts will all or nearly all be positive.

Salt marsh restoration proposed within alternative B will improve the quantity and quality of soil and sediment within the impoundments. Restored tidal range leads to higher sediment transport and deposition onto the wetland surface, as sediment-carrying flood tides flood over creek banks and onto the marsh platform. Restored sedimentation will allow the wetland surface to rise through accretion. Washover and inlet formation, permitted to occur unimpeded under alternative B, can contribute to the sediment budget of the refuge's sandy beach and marsh environments in the long term. Washover is a major process in the retreat mechanism of coastal barrier beaches in response to sea level rise (Dillon 1970, Kraft et al. 1976b).

The salt marsh restoration and rehabilitation of former freshwater impounded marsh areas (4,000 acres) in Units II and III and the reestablishment and enhancement of natural geologic processes would have moderate site-specific beneficial impacts on refuge wetland soils and increase the resiliency of refuge marshes to predicted future rates of sea level rise by increasing and enhancing refuge sediment budgets.

As described in chapter 4, the alternative B objective 3.1 rationale explains that successful restoration will require the restoration and enhancement of refuge sediment budgets and the restoration or possible increase of the tidal range of refuge wetlands. Current refuge coastal marsh conditions can be categorized as micro-tidal, subsiding, and sediment-starved. The restoration of the impounded wetlands to salt marsh will reduce the wave velocity, resulting in increased sediment deposition on the marsh surface and decreased sediment erosion. Weinstein (2002) constructed berms to divide an experimental site to prevent continuous flow and wave build up to promote sediment settling. Similar sacrificial levees or berms or islets may provide a protective environment during which time a marsh can become established. As the levee or berm degrades, the restored marsh will reconnect to adjacent areas. However, even in a sand deficient barrier island setting, well-established, vegetated dunes cannot prevent the natural transgression of the shoreline in front of it and will eventually be eroded as the shoreline continues to narrow (Mendelssohn 1990).

The sustainability of the refuges' restored tidal marshes will depend upon the balance between relative sea level rise and re-establishing and enhancing sediment supply to reverse the adverse impact of restricted tidal flow. Within the next 5 to 15 years, it is anticipated that restoration management actions will generate minor to moderate beneficial impacts on the soils of the refuge's barrier island and back-barrier wetland habitats.

Improper sand sources (incorrect sediment grain size) could have adverse impacts on piping plover or horseshoe crab habitats of the refuge. The Shoreline and Waterways Management Section has successfully conducted beach nourishment projects hauling sand from off-site sources to project sites that have been found to successfully create suitable habitat for horseshoe crabs and piping plovers (DNREC 2004). Refuge staff would work with DNREC and the U.S. Army Corps of Engineers to ensure proper sand size is obtained for any sand placed on the refuge. DNREC and the U.S. Corps of Engineers have analyzed the sediment of the main channel of the Delaware River. The results can be found at *http://www.dnrec.delaware.gov/Info/Pages/US_Army_Corps_of_Engineers_2010_Dredging_Application.aspx* and at *http://www.nap.usace.army.mil/cenap-pl/drmcdp/pr.html.*

Sand will only be placed on the beach if it is needed for marsh restoration or beach nesting species or horseshoe crabs. Sand placed on the refuge's beaches must be similar in character to the sand naturally occurring on the beach. When using sand from off-site sources, it is important to consider the appropriate grain size for each specific project. Characterizations of sand from the project area can be achieved by conducting an analysis to determine the grain size of sand needed and avoid sand particles that are too small that tend to be transported in suspension when overwashed with water (Wanless 2009). Herrera et al. (2010) reported the similarity between sand densities, grain size, or color may have reduced negative effects of adding sand.

The conversion of some prior wetlands, which were enrolled in the cooperative farming program, to moist soil management would result in fewer impacts on the physical environment than past management practices. Removing these lands from cropland management would avoid existing problems with soil compaction and annual disturbance of native vegetation. “The restoration of disturbed wetlands would have its greatest potential in areas of marginal agricultural lands” (Frederickson et al. 1988).

Adverse impacts from establishing moist-soil vegetation and management in fields on the refuge would be short-lived and mitigated by proper timing and use of best management practices for construction. Virtually all problems with siltation, erosion, and degraded water quality would be eliminated by proper use of silt fences, grassy waterways, and proper and timely revegetation of exposed soils. Specific provisions in sediment and erosion plans and permits administered by Delaware’s Department of Natural Resources and Environmental Control and the U.S. Army Corps of Engineers would regulate any construction.

The rapid introduction of saltwater into the refuge’s freshwater impoundments has resulted in and may be continuing peat and marsh collapse. Peat or marsh collapse occurs because the geochemical character of the sediments has been altered. Seasonally flooded freshwater peat is low in porewater sulfides and slower to decompose than salt marsh peat. Rapid reintroduction of sulfate-containing seawater can lead to rapid decomposition of the fresh marsh peat through sulfate reduction. Rapid decomposition of the marsh peat, i.e. the collapse of the peat, can lead to subsidence, or sinking, as below-ground root material and turgor (rigidity of plant tissue) is lost. This will hinder the establishment of salt marsh vegetation, which cannot be established if the sediment is constantly flooded, and thus is far more likely to lead to open water.

The discharge of dredged or fill material for restoration on the refuge may, in varying degrees, change the complex physical, chemical, and biological characteristics of the substrate. Discharges that alter substrate elevation or contours can result in changes in water circulation, depth, current pattern, water fluctuation, and water temperature. Erosion, slumping, or lateral displacement of the surrounding bottom of such deposits can adversely affect areas of substrate outside the perimeters of the disposal site by changing or destroying habitat. The bulk and composition of the discharged material and the location, method, and timing of discharges may all influence the degree of impact on the substrate (40 CFR 230). The effects can be minimized by using containment levees or berms, maintaining and containing the discharged material properly to prevent point and nonpoint sources of pollution, and timing the discharge to minimize impact, for instance, during periods of unusually high water flows, wind, wave, and tidal actions. In addition, distributing the dredged material widely in a thin layer at the disposal site maintains natural substrate contours and elevation.

The discharge of dredged or fill material on the refuge may result in greatly elevated levels of suspended particulates in the water column for varying lengths of time. The new levels may temporarily reduce the primary productivity of the area. The biological and the chemical content of the suspended material may react with the dissolved oxygen in the water, which can result in oxygen depletion. The extent and persistence of these adverse impacts caused by discharges depend upon the relative increase in suspended particulates above the amount occurring naturally, the duration of the higher levels, current patterns, water level, fluctuations present when discharges occur, volume, rate, and duration of the discharge, particulate deposition, and the seasonal timing of the discharge (USACOE 2010). These actions are minimized by selecting sites or managing discharges to confine and minimize the release of suspended particulates and decrease turbidity levels.

The refuge may have adverse impacts from excessive elevations using dredge material. Overfilling (excessive elevation) should be avoided so as not to impede channel formation and encourage undesirable vegetation. This can be minimized by setting limitations on the amount of material to be discharged or volume receiving water.

Public Use
Under alternative B, an increase of public use opportunities such as deer and waterfowl hunting, fishing, wildlife observation and photography, interpretation, and environmental education, will cause additional impacts to soils. These impacts are expected to have negligible to minor and adverse impacts (short-term, long-term, or cumulative) to soils.

We predict negligible-to minor -short-term impacts from the construction of expanded facilities for environmental education and visitor services programs. Maintenance or improvement of facilities (parking areas, roads, trails, and boat ramps) will cause negligible-to- minor short-term impacts to localized soils and waters. Negligible, short-term disturbance to soils will occur during the construction of new parking areas on Fowler Beach Road and on Broadkill Beach Road to facilitate hunting and wildlife observation and photography activities. Negligible, short-term disturbance will also occur on proposed trails on existing interior roads and maintained access routes north and south of Fowler Beach Road, south of Broadkill Beach Road, south of Prime Hook Beach Road, on proposed extensions of the Blue Goose Trail, and on Deep Branch Road. New proposed trails will create minimal disturbance for the wheelchair-accessible photography blind on the south side of Fowler Beach Road. The construction of new walking trails will influence vegetation, causing some soil compaction, which ultimately reduces vegetation composition and structure. For both new construction and maintenance of facilities, we will employ silt fencing and other best management practices during construction of any facilities in proximity of wetlands to avoid runoff of sediments. As these new parking areas and trails are used, the cumulative effects of these new visitor facilities will be long-term (although readily reversible if refuge missions change.) Nonetheless, even cumulatively, the impacts to soils of these proposed actions is minor.

Several rare peat bog communities have been located near Goose Pond and Flaxhole Pond; these areas are open to deer hunting. Sensitive hydric soils that support these rare plant communities are easily destroyed by trampling. Visitation to these sites will be kept to a minimum in order to prevent damage to hydric soils and trampling of sensitive rare plants.

Soil compaction will increase in the immediate areas surrounding blind site stakes for waterfowl hunting in the Unit III waterfowl lottery area. Soil compaction will also occur along heavily traveled hunt areas in the regular waterfowl hunt areas, regular deer hunt areas, and in the lottery deer hunt area and on heavily used shoreline areas for boat access in Goose and Flaxhole Ponds. To minimize impacts on bank erosion, no wake zones and a maximum motor restriction of 30 horsepower on Prime Hook Creek and Slaughter Creek will be posted.

Conclusions for Management Actions in Alternative B
Management actions under alternative B will have local long-term significant beneficial impacts and local short-term minor adverse impacts to soils, associated with salt marsh and upland forest restoration. To accomodate increased visitor use, impacts to soils are anticipated to be negative and minor and short-term, long-term, and cumulative. Service policy 6 RM 4.1 states that the long-term productivity of the soil will not be jeopardized to meet wildlife objectives. In

addition, actions under alternative B support the BIDEH policy (601 FW 3) which states, "We favor management that restores or mimics natural ecosystem process or functions to achieve refuge purposes…We will restore lost or severely degraded elements of integrity, diversity, and environmental health at the refuge scale and other appropriate landscape scales where it is feasible and supports achievement of refuge purpose(s) and System mission." Visitor uses accommodate priority uses, and help to reduce impacts over random unplanned impacts, such as those which arise when parking occurs along berms instead of in designated parking lots. Management actions under alternative B should result in no impairment of the refuge's BIDEH.

Impacts to Soils in Alternative C

Managing and Protecting Habitat
Soil erosion, soil compaction, and reduction of soil bacteria can occur with conventional farming tillage practice. However, the refuge's cooperative farming program incorporates cover crops and other best management practices that encourage conservation tillage to reduce soil erosion. When conservation tillage is used, it can reduce soil disturbance and increase crop residue, which decreases soil erosion. Cooperative farming under alternative A utilizes, as approved, glyphosate-tolerant corn and soybeans, which increase the chance that conservation tillage can be implemented successfully (Towery and Werblow 2010).

Approximately 400 acres of cover crops, such as winter wheat that grow in late fall and provide soil cover during the winter, would be planted on the refuge annually. Cover crops on the refuge will greatly reduce winter wind and water erosion (Dabney 2001; Hartwig 2002). By reducing soil erosion, cover crops often reduce both the rate and quantity of water that drains off the field, which would normally pose environmental risks to waterways and ecosystems downstream (Dabney et al. 2001). Cover crop biomass acts as a physical barrier between rainfall and the soil surface, allowing raindrops to steadily trickle down through the soil profile. Cover crop root growth results in the formation of soil pores, which in addition to enhancing soil macrofauna habitat provides pathways for water to filter through the soil profile rather than draining off the field as surface flow. With increased water infiltration, the potential for soil water storage and recharging of aquifers can be improved (Joyce et al. 2002).

In addition, one of the primary uses of cover crops is to increase soil fertility. These types of cover crops are referred to as green manure. They are used to manage a range of soil macronutrients and micronutrients. Often, green manure crops are grown for a specific period, and then plowed under before reaching full maturity in order to improve soil fertility and quality. In the spring of each year, the cooperative farmers would till cover crops under which would improve soil fertility and quality. In addition, cover crops sequester atmospheric carbon, which is converted to organic matter and improves soil quality.

Under alternative C, alterations to the refuge's marshes, such as presence of tidal restrictions (roads), dune stabilization, creation of drainage ditches, and the creation of freshwater impoundments will have a profound impact on sedimentation rates in the impounded wetland complex. Such alterations and management regimes cut off sediment supply and have resulted in the loss of sediment accretion, contributing to the sinking of the impounded marsh platform in Units II and III. Radiometric isotope analysis of sediment core data from Unit I (tidal salt marsh) and Units II and III (impounded freshwater marsh) demonstrated that historic sedimentation rates in Units II and III fall far below local sea level rise rates of 3.20 mm/yr (Lewes Tide Gauge data), and representing the lowest such rates measured in the state (DNREC *unpub. data*). Meanwhile, the relatively intact Unit I tidal salt marsh areas are keeping pace with local sea level rise rates. These soil impacts will be increased under alternative C, because the longer a site is diked, the greater the difference in surface elevations between diked and natural marshes (Weinstein et al. 2002).

Public Use
Under alternative C, impacts to soils would be similar to alternative A, except slightly higher during the hunting season due to increased deer and waterfowl hunting opportunities from current management.

Conclusions for Management Actions in Alternative C
Upland management actions would have short-term minor benefits with the use of cover crops and other conservation tillage practices on soils. Service policy 6 RM 4.1 states that the long-term productivity of the soil will not be jeopardized to meet wildlife objectives. In addition, the BIDEH policy (601 FW 3) states, "We favor management that restores or mimics natural ecosystem process or functions to achieve refuge purposes…We will restore lost or severely degraded elements of integrity, diversity, and environmental health at the refuge scale and other appropriate landscape scales where it is feasible and supports achievement of refuge purpose(s) and System mission." Although these policies recognize farming and impoundment management as appropriate management tools, we must consider the sustainability and contribution to biological integrity, diversity and environmental health. Both farming and impoundment management will have short- and long-term minor-to-moderate adverse impacts on soils, which may adversely affect the biological integrity, diversity, and environmental health of the refuge.

Impacts on Hydrology and Water Quality

None of our proposed refuge management activities in any alternative should adversely affect local or regional hydrology and water quality. None would violate Federal or State standards for contributing pollutants to water sources, and all three alternatives would comply with the Clean Water Act.

Impacts on Hydrology and Water Quality That Would Not Vary by Alternative

Managing and Protecting Habitat
For all three alternatives climate change and sea level rise will have direct impacts on the hydrology and water quality of refuge habitats with considerable uncertainty as to exactly when and how quickly potential changes to hydrology will occur. SLAMM (Sea Level Rise Affecting Marsh Model) analysis using high resolution data at the refuge suggest that within the next 100 years significant marsh loss with subsequent gains in open water is very likely to occur.

For example, a modeled scenario of one meter sea level rise and a marsh accretion rate of 3.1 mm/year can result in a projected 20 percent loss of upland habitats, 14 percent loss in forested wetlands and scrub-shrub habitats with an increase from current open water component of 15 percent to 88 percent of the entire refuge will be very likely in the next 100 years. These sea level rise related changes and large increases in open water acreage throughout the refuge will have significant management implications and major impacts on refuge hydrology, water quality, marsh and water management and will be considered in all three alternatives.

Recent refuge water quality condition of aquatic environments have been evaluated in 2011 and compared to criteria based on EPA National Coastal Condition Assessment Guidelines for the Northeast coast. These guidelines are based on indicators of anthropogenic enrichment. Measured water quality parameters included nitrogen, phosphorus, silica and chlorophyll a concentrations. These parameters are all directly related to phytoplankton biomass and on algal loading in the water column. EPA water quality standardized concentrations for these parameters categorize good, fair and poor water quality conditions. High nutrient concentration levels imply that excessive nitrogen, phosphours and organic inputs from human activities lead to eutrophication.

The refuge's location along the Delaware Bay is at the receiving end of the Broadkill watershed for any run-off that results from rain or storm events. Known point-sources for nitrogen and phosphorus loading occur at the headwaters of Slaughter Creek that enters Unit II and then is dispersed into Units III and IV following the current hydrological flow of water through the refuge ecosystem. Non-point sources come from land uses adjacent to the refuge that includes agricultural and septic-system run-offs into the refuge during heavy rain and storms. Specific monitoring data shows that heavy nutrient loading into the refuge results in poor water quality conditions long after rain and storm events occur where chlorophyll a, nitrogen and phosphorus concentrations have exceeded 100-fold the over "poor water quality" concentration levels set by the EPA.

These data indicate that for much of the year refuge aquatic systems are highly eutrophic. There is little the refuge can do to mitigate heavy nutrient loadings from run-off from upstream actions within the Broadkill watershed. Under all three alternatives the refuge will work to expand public awareness and knowledge about how and when heavy nutrient loading processes occur and impacts on refuge wetland vegetation and aquatic environments.

Herbicides use for pre- (site preparation) and post-restoration to control non-native vegetation will be conducted using appropriate equipment and best management practices to reduce or eliminate potential exposure of non-target habitats and species associated with drift, surface runoff, and leaching to groundwater. The most efficacious herbicide available with the least potential risk to groundwater and surface water quality would be chosen for use on the refuge.

Public Use

Recreational uses on the refuge, especially those in wetlands and open water, may affect water quality negatively by increasing erosion, stirring up bottom sediments, or introducing pollutants into waterways. We do not expect emissions from vehicles or boat motors to substantially affect the water quality of the region. Most hunters are now using air-cooled mud-motors instead of water-cooled two-cycle outboard motors. Localized increases in emissions from boat motors would be negligible compared to current off-refuge contributions of boaters to pollutant levels in the nearby Broadkill River and the Delaware Bay. Impacts are minimized by prohibiting gasoline motors on Turkle and Fleetwood Ponds. Anglers in boats with paddles or electric motors could disturb the bottoms of ponds. No wake zones and maximum horsepower restrictions of 30 horsepower on Prime Hook Creek and Slaughter Canal will help to minimize bank erosion. We do not expect the other water-related recreational uses to have significant adverse impacts on hydrology or water quality.

Non-toxic shot is required for all hunting except lead slugs for deer and fox hunting. Fishing may impact water quality and create bank erosion, for example if vegetation is trampled and erosion occurs along Petersfield Ditch and Slaughter Canal banks. Negative impacts to water quality can result from human waste and litter associated with public use activities. Under all alternatives, we will be monitoring the condition of the banks of ditches and canals within the refuge and posting signs, closing areas, or using fencing to direct fishing activities towards the less steep slopes as needed. Public outreach and education on littering and proper waste disposal will lessen potential negative water quality impacts.

Environmental education activities that involve the sampling of wetlands and ponds could cause temporary, localized, minor impacts on water quality as the students disturb the bottom of the pond or walk on the marsh to gather specimens.

Impacts on Hydrology and Water Quality in Alternative A

Impacts on hydrology and water quality under alternative A ("No Action") serve as a baseline for comparing and contrasting alternatives B and C to the refuge's existing management activities.

Managing and Protecting Habitat
Continued management emphasis of maintaining wetland and riparian buffers, treating invasive plants especially *Phragmites* and improving and restoring water flows and circulation in impounded systems by periodically cleaning existing ditches all result in beneficial impacts to water quality of freshwater ecosystems on the refuge. There are some risks to water quality from prescribed fire and herbicide use in conjunction with invasive plant control.

There will be direct impacts on hydrology and water quality as upland field acres continue to revert to natural succession characteristic of the Delmarva coastal plain ecosystem, without proactive management actions to sustain early successional seral stages (grassland and shrublands) or conduct farming.

In salt marsh habitats, the return of tidal flow to Units I will have several beneficial impacts on the natural hydrology and water quality of existing salt marshes by allowing nature to take its course. However, Units II and III would completely revert to open water and tidal mudflat habitats, interspersed with salt marsh vegetation. It would be very likely that little emergent wetland plant production would be able to occur in these areas because of significant marsh platform elevational deficiencies.

This alternative will make no effort to control saltwater intrusion into Unit III, which has had poor sediment accretion, as described described in Chapter 3 and demonstrated from refuge wetland studies. Resulting increased frequency and duration of saltwater incursion into Unit III will increase the salinity of the water in Unit III, and this rapid change could result in a conversion of emergent wetland areas in Unit III to largely permanent open water.

The low wetland surface elevation and reduced historic accretion in the impounded wetland complex leave the wetlands vulnerable to substantial changes under a scenario of natural return to tidal hydrology, without mitigation through active marsh restoration. Williams et al. (2002) found that deeply subsided areas in high wave energy conditions had not vegetated after 17 to 20 years, remaining open water and/or mud flat. Stevenson et al. (1986) stated that changes in marsh acreage to open water could in turn lead to reconfiguration of prevailing currents, which influence sediment transport patterns. Orr et al. (2003) states although salt marshes can adjust their levels in response to sea level rise, they may not be able to keep up beyond a threshold rate. If that rate is surpassed, intertidal marshes may convert to open water, a process that could dramatically affect the rest of the system.

Public Use
The impacts of public use on hydrology and water quality for alternative A are discussed in Impacts on Hydrology and Water Quality That Would Not Vary by Alternative.

Conclusions for Management Actions in Alternative A

Most of the impacts on water quality and hydrology associated with managing and protecting uplands are negligible, local, and short term, provided best management practices are followed. The use of best management practices for herbicide use, prescribed fire and other upland habitat management actions described in alternative A would not impair water quality or the environmental health of aquatic environments.

Continuing to allow nature to take its course will create greater hydrological instability and flooding to occur on refuge impounded marsh areas that have substantial marsh accretion deficiencies. Alternative A management actions will exacerbate inadequate marsh accretion and lead to more rapid flooding that stresses plants and eventually causes open water to replace emergent marsh in degraded impounded area areas. Thus management actions under alternative A would continue have local short-term and long-term moderate impacts to water quality and hydrology.

Impacts on Hydrology and Water Quality in Alternative B

Managing and Protecting Habitat

Direct and indirect impacts on hydrology and water quality result from habitat restoration to native vegetative communities and converting agricultural ecosystems to natural ecosystems, as planned in alternative B. Compared to Alternative A, we would extend and enhance forested upland buffers parallel to all refuge waterways and protect wetland habitats with greater than 100-foot forested buffer zones through proactive reforestation actions in zone areas. Buffer zone creation would help mitigate heavy nutrient loading from run-off into refuge aquatic environments.

Impacts from forest management on hydrology would be minimal as long as forestry best management practices are employed. A list of all possible best management practices, developed by Delaware Forest Service, is provided in the habitat management plan included in this CCP (Appendix B). Because nearly all refuge lands are flat, with less than 2 percent slope, they would be more resistant to erosion, siltation, and runoff that could otherwise impact refuge hydrology.

Proposed salt marsh restoration in Unit II will permit natural tidal flows and natural hydrologic patterns that create mini-inlets. Proper hydrology must be attainable and channels to drain the marsh are essential for successful restoration (Teal et al. 2002). Despite salt marsh restoration efforts, the wetlands in Unit II and Unit III will still be impounded due to the roads that stretch across them, which requires some consideration with regard to management. and restoration strategies. Water management strategies used for brackish (mesohaline 5 to 18 ppt) and saline (polyhaline 18 to 30 ppt) wetlands, with limited rainfall inputs, emphasize an active drawdown and reflooding scheduling regimes to maximum water circulation within impounded wetlands, which is required to control salinity management and maintain soil aeration. Periodic ditch cleaning of an extensive network of refuge marsh ditches and tidal channels, where appropriate for natural marsh functioning, will maintain and enhance water circulation, improve water quality, and avoid stagnant water conditions.

As described in Chapter 4, prior to any wetland restoration actions proposed in alternative B, the refuge will conduct hydrology and water quality modeling and analysis several specific restoration scenarios. Salt marsh restoration actions proposed in alternative B would have numerous impacts to water quality and hydrology on the refuge.

Adherence to requirements in the Clean Water Act ensures that the use of dredged material for salt marsh restoration will ensure that we do not have adverse impacts on water quality and hydrology in the impounded wetlands. As mandated by section 404 (b)(1) of the Clean Water Act, the use of dredged material would require that the reintroduction of sediments into a project area "will not have an unacceptable adverse impact either individually or in combination with known and /or probable impacts of other activities affecting the ecosystems of concern." The section 404 (b)(1) guidelines (40 CFR 230) are the criteria for evaluating the proposed discharges for dredged or fill material into waters of the United States. Any project must demonstrate through the completion of a section 404 (b)(1) evaluation that may proposed discharge of dredged material is in compliance with the guidelines. A project using dredge spoil must satisfy four requirements as follows:

1) Section 230.10(a) – address impacts associated with loss of aquatic site functions and values at the disposal site and requires that the discharge represent the least environmental damaging practicable alternative.

2) Section 230.10(b) – requires that the discharge not violate state water quality standards.

3) Section 230.10(c) – requires that the discharge not significantly degrade the aquatic ecosystem.

4) Section 230.10(d) – requires all practicable means be used to minimize adverse environmental impacts.

Section 230.61 mandates the any proposed dredged material project use an effects-based testing protocol to determine the impacts of the discharges of dredged or fill material into the waters of the U.S. The protocols can be found in Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual (USEPA/USSACE 1998). This constitutes an approach that depends on the preponderance of evidence acquired through physical, chemical, and biological assessments required by sections 230.60 and 230.61 of the guidelines.

For example, the dredge material that will be retrieved from reach E of the Delaware River Main Channel Deepening project is one potential source for large quantities of dredge material for salt marsh restoration on the refuge. These sediments have been found to contain negligible and environmentally acceptable levels of contaminants that could impair water quality at the restoration site (ACOE 1997). In addition, as the restoration project develops, an application for a water quality certificate would be made in accordance to the Clean Water Act.

The discharge of dredged or fill material for restoration may change chemistry and the physical characteristics of the water at a restoration site within the impoundment, through the introduction of chemical constituents in suspended or dissolved form. The introduction of nutrients or organic material to the water column because of the discharge can lead to a high biological oxygen demand, which in turn can lead to reduced dissolved oxygen. Turbidity associated with the disposal of dredged material would increase locally; however, this would be temporary. With the increase in sediments may come increased trace metals associated with bed sediments and agrichemicals in the water may increase (USACOE 2010).

In addition, dredged material used in refuge wetland restoration may modify current patterns and water circulation by obstructing flow, changing the direction or velocity of water flow, changing the direction or velocity of circulation, or otherwise changing the dimensions of the wetland water body.

As a result, changes could occur in refuge shoreline and substrate erosion and deposition rates, the deposition of suspended particulates throughout the impoundment complex, the rate and extent of mixing dissolved and suspended components of the wetland water body, and water stratifications. Consequently, this material can alter the normal water level fluctuations pattern of the impounded wetland restoration site, resulting in prolonged periods of inundation, exaggerated extremes of high and low water or a static non-fluctuating water level. Such water level modifications may change salinity patterns, alter erosion or sedimentation rates aggravate water temperature extremes, and upset the nutrient and dissolved oxygen balance of the aquatic ecosystem. Obstructions that divert or restrict flow of salt water may change existing salinity gradients. The dredged or fill material can cause changes in water circulation that may permanently flood or dewater refuge wetlands or mudflats, or disrupt periodic inundation, resulting in an increase in the rate of erosion or accretion. These actions will be minimized by selecting specific restoration sites or managing discharges to confine and minimize the release of suspended particulates decreasing turbidity levels. The effects will be further minimized by using containment levees or berms as needed, maintaining and containing the discharged material properly to prevent point and nonpoint sources of pollution, and timing the discharge to minimize impact, for instance, during periods of unusual high water flows, wind, wave, and tidal actions. In addition, distributing the dredged material widely in a thin layer at the disposal site will maintain natural substrate contours (40 CFR 230). These undesired impacts will be minimized through careful restoration planning and implementation.

During marsh restoration in the impounded wetland complex, tidal channels will be incorporated into the restoration design to minimize erosional losses and maximize deposition on the marsh surface. The ebb flow needs to be low as to not carry sediments off the marsh (Teal et al. 1998). Construction of channels will assist restoration success by enhancing tidal flooding, increased sedimentation rates, improved drainage, enhanced plant colonization rates, and species diversity and distribution range (Wolters et al. 2005). Hypersalinity can be a common problem in restoration sites (Burdick et al. 1997). Restoration of proper hydrologic regimes in the impoundment complex will promote rapid recovery of salt marsh functions that, in turn, will minimize any adverse impacts.

Restoration of salt marsh will also impact hydrology through reduction of wave heights. Morgan et al. (2009) found marshes reduced the height of waves coming onto the marsh surface by 63 percent only 7 meters into the marsh; where no marsh was present, wave heights were reduced by only 33 percent. Wamsley et al. (2011) found barrier islands, even if degraded, reduce wave heights and can reduce wave energy in wetland areas, protecting them from erosion. Restoration resulted in further decreases in storm surges and waves. Levees or berms constructed for the restoration of salt marsh in the impounded wetland complex will provide a sheltered environment to protect the developing site from externally generated waves (NECIA 2007). Designing water control structures, culverts, tidal channels, and diversions that will pass both low and high water levels and maintain circulation are important for the long-term sustainability of the hydrology of the restored marsh. The removal of a portion of Fowler Beach Road or increases in culvert size may improve tidal flushing and the overall hydrology of the area.

The low wetland surface elevation and reduced historic accretion in the impounded wetland complex pose a challenge for restoration of tidal hydrology. Williams et al. (2002) found that deeply subsided areas in high wave energy conditions had not vegetated after 17 to 20 years, remaining open water and/or mud flat. Stevenson et al. (1986) stated that changes in marsh acreage to open water could lead to reconfiguration of prevailing currents, which influence sediment transport patterns. Orr et al. (2003) states that although salt marshes can adjust their levels in response to sea level rise, they may not be able to keep up beyond a threshold rate. If that rate is surpassed, intertidal marshes may convert to open water, a process that could dramatically affect hydrology of the entire impounded wetland system.

Restoration of prior converted wetlands used for intensive agriculture will restore and improve altered hydrology in these areas and improve water quality. Ceasing farming activities in wet areas will also improve the water quality and hydrology of surrounding wetlands.

The use of a cookie cutter or rotary ditcher to maintain numerous existing ditches in refuge impoundments will increase water circulation, provide drainage flow for water level management capabilities, and avoid stagnant water conditions. Ditches periodically become clogged with silt and decaying vegetation exacerbated by extensive snow goose herbivory sustained during the fall and winter months. The use of a cookie cutter or rotary ditcher to maintain numerous existing ditches in refuge impoundments will maintain water circulation and water quality and provide drainage flow for water level management capabilities. However, the operation of the machine leaves large amounts of dead and decaying vegetation in its wake resulting in an immediate increase in the biological oxygen demand in the system, which may last several months. The magnitude of the biological oxygen demand increase depends upon the rate of decay that is dictated by water temperatures. The aerating action of the cutter blades may offset this impact somewhat, but the increased oxygen supply in the water is a short-lived benefit. Since the operation of the cookie cutter includes sediment redistribution, dead vegetation contained in the suspension of bottom materials will further aggravate the available oxygen demand. Turbidity around the machine will be extremely high during operation but should return to normal shortly after completion of the work. Monitoring around the operation will assure that the turbidity does not significantly increase beyond the work area.

The impacts of the cookie cutter/rotary ditcher operations can be partially mitigated by consideration of anticipated biological oxygen demand, dissolved oxygen, water temperature, and water levels. The oxidation and decay of cut vegetation and disturbed bottom material from maintained sites is expected to require three months to a year to return to normal, depending on temperature and available oxygen. Associated with this will be mats of decaying matter. In order to reduce these impacts, a seasonally conducted and routine channel rehabilitation process will be used. Ditches requiring both vegetation removal and sediment redistribution will be worked only during cooler water temperature periods (less than 60 °F) between February 1 and March 15 to limit the impact on biological oxygen demand. Depressed water temperatures during a drawdown will prolong the decay process and should allow vegetative mats to flow out of the system. A monitoring effort will also be implemented in conjunction with the cookie cutter to determine the magnitude of the impact on the ditches and impoundments. Refuge staff will 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.

Extensive ditching for drainage and mosquito control has altered the natural hydrological cycles on refuge salt marshes. Several refuge Open Marsh and Water Management (OWMW) studies have shown that OMWM ditching can have negative impacts on salt marsh areas when water tables drop below six inches from the marsh surface. Lowered water tables, excessively dry out the marsh surface and allows undesirable vegetation to take over salt marsh cordgrass stands. High ditch densities excavated for OMWM purposes have negative impacts on salt marsh hydrology and should be avoided.

Public Use
Potential impacts on hydrology and water quality from increased recreational use would slightly increase over those described for alternative A due to expansions in public use activities. Impacts are expected to be negligible.

Expanded hunting opportunities for deer and waterfowl will cause negligible, yet increased, impacts on the water quality in refuge impoundments, Prime Hook Creek, and Slaughter Canal.

Anglers using Goose and Flaxhole Ponds are restricted to boats only and are not permitted to fish from shore, thereby minimizing vegetation trampling and soil erosion along the banks. Boat motor restrictions in these water bodies will prevent unwanted pollution and sediment suspension.

Conclusions for Management Actions in Alternative B
Alternative B management actions that propose proactive re-forestation, the creation and expansion of vegetated buffer zones around aquatic environments, and restoration of farmed fields to native vegetative communities will generally improve water quality.

Salt marsh and natural hydrological restoration actions proposed in alternative B will repair hydrological and coastal geomorphological functioning to Units II and III by restoring severely degraded wetland integrity and health within impounded areas, consistent with our BIDEH policy.

Impacts on Hydrology and Water Quality in Alternative C

Managing and Protecting Habitat
Exclusion of salt water intrusion into freshwater impoundments, and maintenance of water flows and circulation in impounded systems by periodically cleaning existing ditches, will maintain the freshwater quality of freshwater ecosystems on the refuge. There are some risks to water quality from prescribed fire and herbicide use in conjunction with invasive plant and upland habitat management programs, including farming. Agricultural practices also greatly affect hydrologic patterns. Clearing the early successional environments generally decreases interception of rainfall that would occur with natural plant cover year round and reduces soil infiltration, resulting in increased overland flows.

Cooperative farming practices under alternative A involve the use, as approved, of glyphosate-tolerant soybean and corn, which are sprayed with glyphosate herbicides to control pest plants. Glyphosate herbicides are associated with less surface run-off than are other common herbicides (Shipitalo et al. 2008). Drainage ditches for farming that currently exist in refuge wet areas directs water flows more quickly downstream, increasing size and frequency of run-off and accelerating water delivery to wetlands and waterways.

Intensive ongoing farming of marginal soils on the refuge can impact the hydrology of freshwater ecosystems and moist-soil management of impoundments, because maintain lower water levels may be necessary to maximize crop yields for farmers during summer months, which in turn lowers water tables in the marsh in order to keep upland areas drier.

In the absence of artificial dune restoration in Unit I, natural dynamic hydrologic patterns of highly dynamic coastal environments, like barrier beach island ecosystems, are not be impeded. This action will renew tidal flows in Unit I salt marshes, and restoration of natural hydrologic patterns that create mini-inlets, expanding overwash habitats. This increased circulation of salt water into Unit I will continue to have implications for Units II and III. Even if Unit II is managed as a freshwater impoundment, periodic saltwater intrusion into Unit II will be likely, which will increase the salinity of water in both Units II and III freshwater impoundments. Overall, the hydrology of refuge salt marshes will continue to be affected by the long-term effects on hydrology of coastal structures present, e.g., roads, levees, etc. (Burdick et al. 1997).

The impacts of the use of a rotary ditch under alternative B are the same as those discussed under alternative B.

As described in Chapter 3, radionuclide studies of refuge marsh accretion rates conducted in 2010 and 2011 indicate that for the past 50 years refuge salt marshes are keeping up with the local sea level rise rate of 3.20 $\pm$ 0.28 mm/yr as measured at the Lewes tide gauge. However, refuge impounded marsh areas are found to have significant elevational deficiencies in relation to local sea level rise that can cause the total conversion of impounded marsh areas to open water, drastically altering hydrology. The rapid intrusion of salt water through several breaches formed in Unit II in 2009, coupled with upgrading of culvert pipes connecting Unit II to Unit III, has already significantly altered the hydrology of these units, with the rapid reintroduction of salt water. Immediate and cumulative impacts on hydrology of rapid introductions of saline waters into these areas have been rapid emergent marsh loss, prolonged flooding and impaired hydrological function and drainage capability, subsidence of the marsh platform, and the large-scale conversion of emergent marsh to open water. These impacts will continue until all infrastructure associated with impoundment water management is repaired. Even with repairs and upgrades to impoundment infrastructure, these data suggest that impoundment management described under Alternative C, which cuts off sediment transport into impounded marsh areas, will have a substantial impact on the hydrology of the impounded wetland complex into the future.

Public Use

Proposed expansions in hunting opportunities are expected to cause more impacts to water quality in alternative C than those outlined in alternative A, but less than alternative B. Impacts for other recreation will be similar to alternative A. Impacts are expected to be negligible.

Conclusions for Management Actions in Alternative C

Management actions under alternative C would have local short-term minor beneficial impacts and local short-term and long-term moderate-to-major adverse impacts to water quality and hydrology. Most of the adverse impacts on water quality and hydrology associated with managing and protecting uplands are negligible, local, and short term, provided best management practices are followed. The use of best management practices for herbicide use, prescribed fire and other upland habitat management actions described in alternative C would not impair water quality or the environmental health of aquatic environments.

The manipulation associated with creating managed freshwater wetlands represents a major impact on local hydrology. Furthermore, climate change and accelerated sea level rise have already and will continue to have minor-to-moderate adverse impacts on our ability to manage salinity and water levels in our wetlands and control salinity intrusion into our upland habitats. Even once necessary infrastructure repairs and upgrades are made, impoundment management will be challenging and will contribute to marsh elevational deficiencies within the impounded marsh complex, further altering hydrology.

Increasing salinity intrusion across the entire refuge wetland complex will have substantial consequences that would require extensive and costly measures to repair failing impoundment infrastructure in order to offset adverse impacts. However, such costly mitigation measures would not assure success given current and future conditions associated with climate change and sea level rise.

Impacts on Vegetation

The types of activities proposed in the three alternatives that would affect vegetation and other biological resources include water level and salinity management in impoundments, prescribed burning, brush-hogging and mowing, disking, treating invasive or unwanted vegetation with herbicides; controlling erosion; thinning and other forest management practices; afforestation and restoring prior converted wetlands; constructing new trails; constructing new buildings or public use facilities such as piers, docks, trails, photo blinds, observation towers; increasing or offering new opportunities for public use such as opening new tracts to visitors or offering new areas for hunting waterfowl; ceasing dune stabilization to allow natural succession and dynamic coastal processes to proceed unimpeded along undeveloped barrier island areas of the refuge; or initiating proactive salt marsh restoration projects.

Impacts on vegetation of the refuge habitats will also be significantly influenced by climate change and sea level rise as increased weather extremes and more severe coastal storms will introduce greater frequency and duration of salt water intrusions in freshwater wetland and upland habitats.

Impacts on Vegetation That Would Not Vary by Alternative

Managing and Protecting Habitat

Across all alternatives, we would engage in prioritized invasive species control at the early-detection, rapid-response stage, which will result in the protection of up to 100 percent of the native cover from targeted threats. Working closely with adjacent private landowners to control invasive plants like *Phragmites* and encourage the propagation of native vegetation will assist in lowering risks of catastrophic fire. Regardless of alternative, it is hoped that, over the long term, the invasive species coverage and associated resources required to control them will decline, as native communities are restored, become established, and represent the dominant vegetation cover-type.

Restoration and proper maintenance of refuge vegetation communities associated with achieving wildlife and habitat objectives will contribute to long-term prevention, eradication, or control of pests. Herbicides used for pre- (site preparation) and post-restoration to control non-native vegetation will increase desirable plant communities by the manipulation of species composition, plant density, and growth rate. Thus, the control of invasive pests and eventual restoration of the native plant community will have moderate local impact to the native vegetation communities throughout the refuge. During ditch maintenance using the rotary ditcher, vegetative loss is expected to be negligible. There is also a potential for the spread of *Phragmites* through the relocation of rhizomes downstream of the project site; however, this potential remains negligible if the *Phragmites* in the project site area has been treated with an herbicide prior to any work activity. Staff will also monitor the soil deposition areas for an increased occurrence of *Phragmites*.

Additional habitat management activities proposed under all alternative that will have a local impact on vegetation include establishing and enhancing vegetated buffers along riparian and wetland borders, and establishing connecting corridors between isolated forested patches either through proactive plantings or natural succession. Buffer zones created either through proactive reforestation or allowing natural succession to occur will enhance areas that serve as native seed dispersal corridors by establishing connective networks and reducing fragmentation across the refuge landscape, which will expand natural native plant seed colonization of new areas. This, in turn, has the local impact of enhancing biological integrity and restoring environmental health (Lars et al. 2009).

Regardless of the alternative, the refuge will continue to conserve, manage, and maintain healthy and diverse forest habitats as funding and resources permit, although the means of achieving this may vary by alternative.

Canada goose herbivory during the growing season is a relatively new impact upon wetlands. In 2002, a research study conducted at neighboring refuges, Bombay Hook and Chincoteague NWRs, suggested that higher levels of use by geese may cause a long-term change in wetland community structure (Laskowski et al. 2002). Biomass of several species of vegetation was significantly adversely impacted by feeding resident Canada geese at both refuges. Resident geese directly damage agricultural resources by eating grain crops and trampling spring seedlings. Heavy grazing by geese can result in reduced yields and in some instances a total loss of the grain crop (Allen et al. 1985, Flegler et al. 1987). While migratory Canada goose are an indigenous North American species, the behavior, genetics, and behavior of the non-migratory flocks have been influenced by human actions; the Service recently issued a national EIS addressing Canada goose control. Lethal and nonlethal Canada goose control activities outlined under all strategies common to all alternatives would be expected to significantly decrease the number of injurious resident Canada geese in specific areas, thus reducing local impacts on vegetation. The long-term viability of migrant Canada goose populations would not be affected, however. Similarly, because mute swans are highly invasive of wetland habitats, and can consume large quantities of submerged aquatic vegetation, control of mute swans on the refuge will have a local beneficial impact on wetland vegetation communities.

Various light goose (snow goose) populations in North America have reached such high levels that they are damaging habitats on their Arctic and subarctic breeding areas (Abraham and Jefferies 1997, Alisauskas 1998, Jano et al. 1998, Didiuk et al. 2001) as well as in some migration and wintering areas (Giroux and Bedard 1987, Giroux et al. 1998, Widjeskog 1977, Smith and Odum 1981, Young 1985). The increasing numbers of light-geese are viewed as a continental problem, but with real local adverse impacts on vegetation. Grubbing for rhizomes, especially in salt marshes, results in areas denuded of vegetation, typically referred to as eat-outs. Vegetation density at these eat-outs may return to previous normal levels after several years, if left alone. However, where eat-outs occur within salt marsh habitats, snow geese often return each winter to the same areas to feed. Such impacts have been observed at the refuge. It is also speculated that during the time snow geese are feeding in a salt marsh, much of the soil and sediment may be loosened and placed into suspension. In fact, recently analyzed water quality samples from the refuge impoundments have found extremely high sediment concentration in the water during times of extensive snow goose browsing on the refuge. This material may then be washed away during high or flood tide periods. After several years of successive erosive eat-outs at the same location, the lower ground elevation may further prevent the return of vegetation, causing a more long-term impact to vegetation community on the site. Reducing snow goose numbers on the refuge will reduce adverse minor-to-moderate impacts of snow goose herbivory on salt marsh habitats.

Deer overabundance can affect native vegetation and natural ecosystems and has been well-studied (Tilghman 1989, Nudds 1980, Hunter 1990; Behrend et al. 1970). White-tailed deer selectively forage on vegetation (Strole and Anderson 1992), and thus can have substantial impacts on certain herbaceous and woody species and on overall plant community structure (Waller and Alverson 1997). Over-browsing by deer can decrease tree reproduction, understory vegetation cover, plant density, and plant diversity (Warren 1991). High densities of deer have also been recognized as vectors for spreading invasive species like Japanese stiltgrass. Historically (pre-European contact and during the colonial times) there was more extensive forest/fewer open fields and more human and natural predation, therefore deer numbers were in greater balance than at present. Thus, control of the white-tailed deer population on the refuge will have a moderate beneficial impact on the vegetation communities.

Public Use

Under all alternatives, repeated visitation to any particular locale at the refuge would continue to cause minor site-specific damage to vegetation. However, overall impacts to vegetation are expected to be negligible because visitors are expected to remain on existing trail routes and interior access roads. Repeated use of an aquatic area by boats equipped with go-devils can damage to emergent and submergent vegetation beds. Portions of or whole plants can be torn, sometimes by roots, and boat wakes contribute to erosion. Accidental introduction of invasive plants, pathogens, or exotic invertebrates attached to boats or trailers, or on shoes or clothing, is another source of direct minor impacts on vegetation. Maintenance activities may involve the occasional trimming or felling of trees to maintain or improve infrastructure such as roads or trails. In places where unmarked paths are created by hunters and anglers, little used pathways will retain their dominant vegetation species, but on medium-use pathways some plant species will be replaced and heavily-used paths will often contain invasive species (Liddle and Scorgie 1980). Such unmarked paths have been observed on the refuge in areas where anglers access the water along its edge, but overall this impact is negligible.

Impacts to vegetation communities resulting from hunter access are expected to be negligible, as most species will have already undergone senescence or become dormant. Additional impacts to vegetation are minimized by not permitting hunters to cut vegetation for shooting lanes or for use as camouflage. Impacts to vegetation are further minimized because hunting from a stand that has been attached with nails, wire, screws, or permanently attached to a tree in any other way is prohibited. As a result of research activities, the removal of vegetation core samples can cause increased negligible site-specific impacts on vegetation communities, and sampling activities can cause site-specific trampling of vegetation.

Impacts to Vegetation Common to Alternatives A and B

Managing and Protecting Habitats

Salinity increases and intrusion into impounded marsh areas will have significant impacts on historic freshwater perennial and annual plant communities. Allowing passive conversion to salt marsh and open water in refuge coastal wetland habitats as proposed in alternative A or proactive salt marsh restoration as proposed in alternative B will both result in drastic changes in emergent wetland vegetation communities as freshwater plants are replaced by halophytic marsh plants. As relatively few plant species are halophytes (less than 2 percent of all plant species) the transition from freshwater to brackish and salt water salinity regimes across the refuge's wetlands will also result in a decrease of wetland plant diversity. On the brackish end of salinity ranges, vegetation such as saltmarsh bulrush in low marsh areas and saltmeadow cordgrass in high marsh areas may increase temporarily during growing seasons with abundant rainfall and accompanying lower salinities. Species such as dwarf spikerush, widgeongrass, and sea purslane may predominate in higher salinity marshes (Williams et al 2002, Whitman 1987). Letting brackish or saline water impoundments dry out will encourage saltmeadow cordgrass to become established, while more stable water level regimes will allow cattails to establish if salinities stay low. Algal mats, primarily *Cladophora*, will cover more saline open water areas, especially if a strong flow of water is not maintained (Daiber 1986). These changes and potential impacts will be similar under either alternatives A or B, and may differ only in degree and specific distribution, depending on rainfall, salinity, and hydrologic conditions.

During spring and summer of 2010, an outbreak of an algal species (Genus *Cladophora*) occurred in the impounded wetland complex; this form of algae is common in both freshwater and marine water systems. Although it is not clear exactly why the bloom occurred, it is believed to have been a combination of several factors, including warm weather conditions, excess nutrient levels from dying freshwater vegetation, run-off from high waters flushing nutrients from adjacent farmlands and septic systems, and the vulnerability of a stressed system in transition. Negative impacts of the bloom were aesthetic, not ecological. A bloom could recur if freshwater vegetation is killed by saltwater influxes and salt marsh vegetation is not sufficiently established.

Public Use
The phasing out and elimination of more than 130 deer hunting stands and waterfowl hunting blinds will remove disturbance to impacted vegetation and soils and alter the aesthetic view of the landscape for refuge visitors.

Impacts to Vegetation in Alternative A

Impacts on vegetation under Alternative A ("No Action") serve as a baseline for comparing and contrasting Alternatives B and C to the refuge's existing management activities.

Managing and Protecting Habitats
Reforestation in portions of Unit III will continue to create early successional communities, which are rare and declining in the state and along the East Coast. Native herbaceous and grass species will reappear in Unit IV, in fields currently being maintained as grasslands, ultimately to a level where they become self-sustaining population sources. The direct impacts of habitat management associated with alternative A would be the recurring temporary removal of vegetation through brush-hogging, mowing, burning, or applying herbicides. Some non-target species like milkweeds, goldenrods, and other native wildflower plants would experience short-term direct impacts, but would recover as vegetation grows quickly during the growing season. Broad-spectrum herbicides, such as glyphosate products, when applied aerially or on the ground, also kill non-target desirable plant species. We reserve these methods for areas that are infested with high densities of invasive plants, making selective application impossible. In other areas, localized spot spraying or physical removal of invasive plants may be required to protect rare plants. Other direct impacts to vegetation result from prescribed fire, including the return of nutrients to soils by combustion of dead plant biomass, reduction of litter, and creation of openings where grasses and fire-adapted herbaceous vegetation can become established.

Under Alternative A, tidal flows established from inlets formed in fall 2009 would continue to introduce new sediments to Unit II that could aid in the natural return of the unit to salt marsh. The higher saline conditions would result in halophytic vegetation re-colonizing back-barrier wetlands and washover habitats. However, relying on a passive reversion of 1,500 acres in Unit II into salt marsh, without any alteration of road and water management infrastructure, will increase salt water intrusion from Unit II into Unit III. Saltwater intrusion in Unit III is likely to have long-term adverse impacts on the globally rare seaside alder (*Alnus maritima*, S1, G1), Atlantic white-cedar, and other hardwood swamp communities adjacent to the upper reaches of Prime Hook Creek. Depending on rate and frequency of salt water incursions into Unit III, most of the forested wetlands (1,300 acres) would become highly stressed and not likely recover and elements of freshwater wetland plant diversity would be lost.

In the absence of any proactive marsh restoration efforts, it is likely that additional portions of the Unit II and Unit III impoundments will convert to open water due to subsidence, peat collapse, and low accretion rates, resulting in open water where there had previously been dense stands of freshwater wetland vegetation (Smith et al. 2009, Pearsall and Poulter 2005, Weinstein et al. 2000, Portnoy and Giblin 1997, DeLuane et al. 1994). While salt marsh may be re-established in the former fresh water impoundments, there is a strong likelihood that much of the former freshwater marshes would convert to open water unless sufficient sediment erodes from the surrounding uplands or is washes into the interior from the bay. Conversion to open water would be a major and adverse impact, as this habitat supports less vegetation than either freshwater or salt water marshes. Larger expanses of open water would also make existing salt marsh stands more susceptible to the adverse impact of erosion (Weinstein et al. 2000) and hinder the establishment of new stands of salt marsh vegetation (Williams and Orr 2002, Weinstein et al. 1996).

If forests are permitted to return to open fields solely through natural regeneration, invasive species and other factors are likely to result in less desirable forest conditions. This would have an overall minor-to-moderate impact on the health and composition of upland forest vegetation communities.

Public Use
The impacts on vegetation under this alternative would be the same as those discussed in the section Impacts on Vegetation That Would Not Vary by Alternative.

<u>Conclusion for Management Actions in Alternative A</u>
Management actions under alternative A would have long-term minor-to-moderate impacts as well as opposing short-term and long-term moderate-to-major impacts. No impairment of the refuge's BIDEH is expected. However, if large areas convert to open water, diversity, and the refuge's integrity may be impaired at the local level.

Under Alternative A, permitting natural succession in upland fields would restore and conserve native vegetation and create contiguous forest blocks by connecting currently fragmented forested parcels throughout much of the refuge with long-term beneficial impacts on natural upland vegetation communities, primarily forests. However, the absence of active reforestation efforts would result in more forest area in an undesirable condition. Given the dynamic nature of the coastal system encompassing the refuge, there will be continued passive conversion of wetland vegetation communities from artificially managed freshwater vegetation to a mix of natural salt marsh, open water, and mudflats. However, if no actions are taken to encourage salt marsh development through restoration, larger portions of the refuge may convert to open water than would otherwise, which could further hinder wetland vegetation development. Thus, adverse impacts to vegetation are greater under alternative A than under alternative B.

Changes in public use are expected to cause more adverse impacts to vegetation in alternative C than those outlined in alternative A, but less than alternative B.

Impacts to Vegetation in Alternative B

Managing and Protecting Habitat
This alternative would focus on increasing the acreage of upland forested habitats from the current level of 775 acres to approximately 1,645 acres. We

would increase the numbers of transitional habitats (grasslands, shrublands, and young trees) by restoring and maintaining a greater number of acres of early successional areas that were previously farmed. Such restoration will promote habitat connectivity and reduce habitat fragmentation. These improvements to the vegetation communities on the refuge will also protect and restore key ecological processes, such as pollination, seed dispersal of native plants, and nutrient cycling.

Selective forestry techniques involving partial removal of trees (not clear-cutting), usually in uneven-aged stands of hardwoods, will promote the growth of desired shade-tolerant or intermediate tolerant tree species. The remaining desirable trees will be able to better receive sufficient light, moisture, and nutrients to grow to optimal size. Selection system harvesting would allow a timber stand to retain its forest appearance in the years immediately following harvest. Active forest management will result in the temporary removal of vegetation, but such impacts are of short-term duration, as vegetation grows quickly during the growing season. Potential minor adverse impacts of selective cutting on forest vegetation would be slower long-term growth, allowing undesirable species to predominate in the stand, holding back valuable sun-loving species, and being an easily and frequently abused method. Establishment of weedy or undesirable vegetation would also be a possible adverse impact in regenerating managed forest stands, whether natural or planted, and would require control through mechanical or chemical means.

Relying on natural regeneration whenever possible for stand replacement following prescribed management operations would enhance early root development and would ensure a local origin of the seed, which can reduce the chance of tip moth damage. In most cases, the resulting natural forest regeneration on the refuge will likely be dominated by pine, red maple, and sweet gum. Due to the many complications related to the germination of oak seeds, such as parasitism, predation, and other various site conditions, it is likely that natural oak regeneration in refuge forests will be minimal. The planting of oak or other hard mast producing species will ensure their replacement and continued occupancy of the stand. Additional future silvicultural treatments, as needed, will ensure survival and optimum growth of new trees, thus increasing their chances of achieving dominance in the stand. The overall benefits regarding regeneration and stand replacement, species composition diversity, forest health, and long-term sustainability of refuge forest habitats would far outweigh any temporary negative impacts of executing these prescriptions. Reforestation through tree planting will have a moderate direct impact on the composition of forest communities, through the use of desirable species suitable for that site. Whether natural or planted, the result of active forest management would be a long-term increase of desired forest vegetation communities.

Management of problem or undesirable vegetation prescribed under alternative B will help ensure optimum growth and survival of desired forest regeneration, whether natural or planted. Only approved chemicals that are labeled for these specific uses and have been shown to be most effective would be considered. Those substances, when used in accordance with their labeling, would have little to no impact on non-target fauna and flora. Extreme care would be taken to prevent drift to non-target areas as well as non-federal lands. All applications would be performed in accordance with current labeling and Federal, State, and local regulations.

Prescribed fire treatments prescribed under alternative B will have a moderate beneficial impact on forested communities on the refuge because burning as a timber stand improvement technique can improve natural regeneration, especially of oak species, through several means (Baker and Langdon 1990; Snyder 1992; Van Lear 1992). Fire removes excessive litter buildup from the forest floor, thereby preparing a favorable seedbed forseedlings from freshly germinated acorns, which are unable to emerge through a heavy litter cover. Fire also helps control infestations of insect consumers of acorns and new seedlings because many of these insects spend all or part of their lives on the forest floor. Impacts from prescribed burning to the understory vegetation, such as woody plants, will vary with frequency and season of burning conducted on the refuge (Baker and Langdon 1990; Wade and Lunsford 1989). The chance of fire escaping is always a factor, which could have an adverse impact on non-target vegetation on and adjacent to the refuge. Overall, the use of fire as a management tool will have negligible adverse impacts on upland vegetation.

Proposed salt marsh restoration in refuge impoundments would have a moderate-to-major long-term impact on wetland vegetation communities, as freshwater plant species are replaced by native high marsh and low marsh dominated, by halophytes such as glasswort, saltmeadow cordgrass, and smooth cordgrass. Refuge salt marsh wetland restoration efforts will allow for better sediment delivery, and higher sediment concentrations in the water column, which will allow refuge coastal wetlands to build more elevation and grow thicker stands of saltmeadow and smooth cordgrass (Williams and Orr 2002, Boumans et al. 2002, Burdick et al. 1997). Coastal wetland and sea level rise modelers (Kirwan et al. 2010) have suggested that under conservative sea level rise projections of 3 to 5 mm/yr, coastal marshes with small tidal ranges (less than 3 meters) and low sediment concentrations (less than 20 mg/l) will likely submerge in the next 30 to 40 years. Under scenarios of rapid ice-sheet melting (10 to 20 mm/yr sea level rates), only marshes with a tidal range of greater than 3 meters and sediment concentrations above 30 mg/l can survive (Kirwan et al. 2010). Refuge salt marsh restoration actions developed as part of Alternative B will focus on increasing the tidal range and sediment concentrations entering refuge coastal wetlands that will be needed to achieve these desired tidal range and sediment concentration thresholds. Salt marsh vegetation communities resulting from restoration strategies in alternative B will be more resilient to sea level rise and self-sustaining for the long-term (NOAA 2010, Kirwan et al. 2010, Cahoon et al. 2009, Reed et al. 2008).

The active restoration effort proposed in alternative B is more likely to have a long-term impact on the recovery of refuge's coastal wetlands than a passive return to salt marsh would (NOAA 2010, Smith et al. 2009, Teal and Weinstein 2002). Strategies such as the use of living shoreline techniques would reduce wind fetch across expanses of open water in the impounded wetlands, which subjects adjacent salt marsh vegetation to erosion (Morgan et al. 2009, Williams and Orr 2002, Weinstein et al 2000). In degraded marshes, salt marsh vegetation responds favorably to the placement of dredge material for restoration (La Peyre et al. 2009; Ray 2007; DeLaune 1990), and ecological functioning of salt marshes can be restored (Stagg and Mendelssohn 2010). Thus, the placement of dredged sediment throughout large portions of the impoundment complex to restore elevation would have a moderate-to-major impact on the establishment of salt marsh vegetation, as elevation is a primary limiting factor for growth of *Spartina* species (Weinstein et al. 2002, Morris et al. 2002, McKee et al 1989, Baca and Kana 1986). Planting of sprigs or seedlings will expedite salt marsh establishment once appropriate conditions are achieved through other techniques (Allen and Hardy 1980). If strategies to raise marsh elevations are not successful, some additional portions of the impounded wetland complex may convert to open water due to subsidence, peat collapse, and low accretion rates, resulting in open water where there had previously been stands of freshwater wetland vegetation

(Smith et al. 2009, Pearsall and Poulter 2005, Weinstein et al. 2000, Portnoy and Giblin 1997, DeLuane et al. 1994).

The active salt marsh restoration strategies proposed in alternative B involve manipulations that may have short-term adverse impacts on vegetation. For example, the application of supplemental sediment within the impounded wetlands may temporarily cover emerging vegetation. If living shoreline structures are placed in the wetlands, or if internal or temporary dikes are necessary to create restoration cells, construction equipment may disturb beach grass or wetland vegetation and the dikes themselves may temporarily displace some existing vegetation. These adverse impacts would be very site-specific, relative to the size of the entire impounded wetland complex (ACOE 1996). In addition, an increase in wetland salinity through salt marsh restoration could stress forested wetlands adjacent to the impounded wetland complex, which are not adapted for saline conditions.

Through monitoring soil and water salinities and practicing intensive water level manipulations during the growing season, management of brackish impounded wetlands proposed in alternative B can produce stands of salt marsh bulrush (*Schoenoplectus robustus*) in some areas of the wetland complex. Maintaining salinity ranges at 10 to 20 ppt within impounded marshes and conducting appropriate drawdowns can encourage the production of dwarf spikegrass (*Eleocharis parvula*), widgeongrass (*Ruppia maritima*), and sea purslane (*Sesivium maritima*). Periods of maximum drawdown and re-flood can also be coordinated with spring and neap tide cycles to maximize saltmeadow cordgrass in salt marsh restoration areas. Salinity management can also enhance habitat conditions used to control undesirable vegetation, i.e., invasive plants, but trade-offs may exist between controlling undesirable vegetation and promoting desirable waterfowl food plants. Such management must be carefully implemented to avoid developing hypersaline (greater than 50 ppt) conditions in marsh soils. Hypersaline soil conditions that persist during the summer will have moderate and potentially long-term adverse impacts on vegetation. Vegetative growth will be curtailed or not occur at all, or no annual recruitment of desirable wetland plants will be possible. This adverse impact can be mitigated through careful water level management strategies.

Public Use

The indirect beneficial impact on vegetation from expanded public use opportunities include staff and visitors' increased and enhanced awareness, appreciation, and protection of native plant communities, particularly those that contain high value for habitat, cover, or food resources. Another indirect benefit to vegetation from the refuge hunt programs is the increased potential to partner with hunting organizations that would assist in wildlife habitat enhancements projects such as seeking grants or donations for planting native trees, assisting in herbicide applications for controlling invasive plants, and restoring moist-soil impoundments.

We expect trampling of vegetation to increase due to proposed expansions in public use activities, including fishing, hunting, wildlife observation, wildlife photography, and environmental education and interpretation. However, impacts are expected to be negligible because visitor access is limited to designated areas and for reasons previously highlighted under actions that would not vary by alternative. Expanded hunting opportunities for deer, waterfowl, turkey, and upland game will cause a negligible level of increased trampling and disturbance of terrestrial and aquatic vegetation as previously discussed in alternative A. Free roam areas for deer and waterfowl hunting opportunities will provide hunters greater access and increase the potential for vegetation trampling, particularly around blind sites in the Unit III impoundment. The possibility for new trails to be developed from repeated hunter entry will likely occur, especially in marshes where hunters will seek paths providing easiest access. Expanded fishing opportunities, particularly to Goose and Flaxhole Ponds, will create only negligible disturbance to vegetation because visitors will be required to remain on designated trail routes and established interior roads.

We expect negligible impacts from the construction of expanded facilities for environmental education and other visitor services programs. We will employ silt fencing and other best management practices during construction of any facilities in proximity of wetlands to avoid runoff of sediments. Only negligible disturbance to vegetation will occur during the construction of new parking areas on Fowler Beach Road and on Broadkill Beach Road to facilitate hunting and wildlife observation/photography activities because existing interior roads and access routes will be used. These will occur in areas north and south of Fowler Beach Road, south of Broadkill Beach Road, on proposed extensions of the Blue Goose Trail, and Deep Branch Road. New proposed trails will create minimal disturbance to vegetation for the wheelchair-accessible photography blind.

The direct, site-specific impact of new trails has the potential for increasing edge effects on adjacent vegetation communities, which provides inroads for invasive species to colonize. These effects depend upon the type of habitat, the type and placement of trail, and the amount of canopy. A narrow earthen or woodchip path through a closed-canopy forest is not likely to fragment or produce edge effects in such an upland forest environment. But a wide path mowed through a managed early successional area could fragment the habitat. Placing trails with care, such as utilizing existing interior roads, can avoid most adverse impacts. Quantifying the impacts on vegetation from trails depends exactly on their location, length, width, and type (gravel, dirt, wood chip, and boardwalk).

Beach public use will also impact beach and dune vegetation. Vaske et al. (1992) reported that results from vegetation studies on beaches revealed that human traffic and off-road vehicle use were having adverse impacts on dunes and sandy beach habitats. Where people accessed dunes, vegetation cover and dune height were significantly lower than areas not used by visitors. Vegetation cover averaged 45 percent lower at disturbed sites than undisturbed sites. Dune damage was reported greatest when caused by off-road vehicles, next by human foot traffic (20 percent more cover), and least by deer (40 percent more plant cover) (Vaske et al. 1992). To minimize some of these adverse impacts, off-road vehicle traffic is not allowed on refuge beach strand areas.

Conclusion for Management Actions in Alternative B

Management actions under alternative B would have long-term moderate-to-major impacts and short-term negligible-to-minor impacts on refuge vegetation. No impairments of the refuge's BIDEH are expected. Through the restoration of freshwater impounded wetlands to salt marsh, the refuge may be giving up diversity at the local scale but providing diversity and biological integrity at the landscape and regional levels, and enabling coastal vegetation communities to naturally adapt to climate change and sea level rise.

This restoration will result in moderate-to-major long-term wetland vegetation changes, causing only negligible or minor short-term impacts in the process. Given the dynamic nature of the coastal system encompassing the refuge, the conversion prescribed by alternative B of vegetation communities from artificially managed freshwater vegetation to restored natural salt marsh is the most responsible and self-sustaining strategy for the refuge.

Upland management actions would restore and conserve native vegetation and create contiguous forest blocks by connecting currently fragmented forested parcels throughout much of the refuge with long-term impacts on upland vegetation communities, primarily forests.

Public use management actions would have negligible to minor adverse impacts on ecological processes and biological productivity would not be affected.

Impacts on Vegetation in Alternative C

Cooperative farming under alternative A involves the use, as approved, of glyphosate-tolerant corn and soybeans. The repeated use of glyphosate can be associated with the development of glyphosate resistance in weeds. This was first documented in horseweed in Delaware (VanGessel 2001). Overall, this poses only a negligible impact to native vegetation communities. Implementation of cooperative farming displaces native herbaceous, shrubby, or forested vegetation communities that would otherwise grow in the farmed fields.

Management of freshwater impoundments as described under alternative A would perpetuate freshwater vegetation wetland communities, provided the prescribed water levels can be reasonably achieved. Water level management impacts the production of annual and perennial vegetation within an impoundment based on the timing and frequency of drawdowns and reflooding schedules during the growing and non-growing seasons. However, if the prescribed salinity range (0 to 10 ppt) of impounded soils and water regimes cannot be maintained from April through the end of August, then freshwater moist-soil plant communities will not thrive. If the freshwater vegetation communities are impacted in a recurring manner, the impact could be a major long-term hindrance of freshwater vegetation in refuge impoundments, in spite of any impoundment management efforts. This moderate-to-major impact on freshwater vegetation in the long-term is likely, given the increasing rates of overwash and breaching along the Delaware Bay along Unit II. It is unclear whether an intact barrier island can be achieved,or how frequently it may be overwashed or breached in the future, given the long-standing history of shoreline migration at the refuge and the projections for increased storm intensity and climate change. Since a single breach or large overwash event could introduce sufficient salt water to kill much of the freshwater vegetation, the long-term sustainability of the fresh water marshes is uncertain, at best. Absent a very substantial and robust artificial barrier island and dune system north of the Prime Hook Community, and a low incidence of coastal storms washing saltwater through the low-lying community itself, it is unlikely that measures to maintain freshwater marshes in Units II and III will be fully successful over time.

Water level management and the timing of drawdowns in moist-soil management, when used, would have specific impacts on the composition and production of freshwater vegetation and moist-soil plants. For example, an early drawdown has been shown to produce more red-root flat sedge in highly organic soils, whereas later drawdowns produce more Walter's millet. In mineral soils, early drawdowns would result in more smartweed species, whereas later drawdowns would result in more barnyard millet. The preferred method of a slow drawdown regime would create conditions favorable for moist-soil plant germination and establishment. For example, slow drawdowns on experimental plots result in seed yields of 700 pounds per acre, whereas fast drawdowns on similar units resulted in yields of only 50 pounds per acre (Fredrickson 1991). Other factors besides management technique, such as seed banks, soil types, soil temperatures, soil moisture levels, soil and water salinities, day length, and residual herbicides would also influence the composition and abundance of developing vegetation.

Proposed expansions in hunting opportunities are expected to cause more impacts to vegetation in alternative C than those outlined in alternative A, but less than alternative B. All other types of recreation will have fewer impacts than those in alternative A. Impacts are expected to be negligible as discussed under alternatives A & B. Prime Hook Creek will not be open to deer and waterfowl hunting; however boating for fishing and wildlife observation/photography will be permitted year-round on the westernmost 4 miles, and from March 16 through August 31 on the easternmost 3 miles along with waterfowl hunting. Refuge salt marshes in Unit IV will not be open to waterfowl hunting, which will prevent any disturbance to vegetation.

Conclusions for Management Actions in Alternative C

Most management actions in alternative C will continue to have a baseline level of local short-term moderate impacts and local long-term minor-to-major impacts on vegetation communities. In upland habitats, current management actions will continue to promote native vegetation communities, except in fields enrolled in cooperative farming. Most direct impacts resulting from vegetation control and management actions will be temporary. Impacts on native vegetation in managed agricultural fields will be long-term, adverse, and moderate. In the impoundments, while retention of productive freshwater marshes with low amounts of invasive *phragmites* would be considered of positive benefit on freshwater vegetation species, moist-soil management techniques are premised on maintaining freshwater conditions (0 to 0.5 ppt) or very low brackish conditions (5 to 10 ppt) that are needed to annually produce freshwater vegetation communities dominated by wild millet, sprangletop, panicgrasses, and smartweeds. Thus, failing impoundment infrastructure and more frequent and severe annual coastal storms are having and will continue to have moderate impacts on refuge vegetation with changes in the abundance, distribution, and composition of wetland vegetation, as freshwater wetlands remain difficult to consistently manage and sustain. Thus, a more likely outcome under Alternative C is that there will be continued and increasing incidents of salt water intrusion, resulting in partial or total loss of freshwater vegetation. Without effective restoration of conditions suitable for salt marsh survival, the impoundments are most likely to convert to open water which is why it is predicted that the long term impacts on vegetation in the impoundments would be major and adverse.

Impacts on Federal and State Endangered Species

We evaluated the proposed habitat management actions and strategies of all alternatives for their potential to affect, beneficially or adversely, the habitats required for population of Delmarva fox squirrel, where breeding, wintering, or migrating bald eagles concentrate, and for restoring numbers of state-listed endangered species. Our proposed management actions include conservation actions targeting Federal and State endangered species, such as reducing forest fragmentation and managing of beach habitats to reduce predation and disturbance to beach nesting birds. Habitat management actions focus on minimizing impacts and maintaining or enhancing barrier island habitats and sandy beach areas to aid in recovery of the federally threatened piping plover, benefit migrating red knots, and promote the recovery of other State endangered shorebird species.

Impacts on Endangered Species That Would Not Vary by alternative

Managing and Protecting Habitat and Public Use

The geographic distribution of treatments and quantities of pesticides used during invasive plant and mosquito control varies from year to year. This requires that the refuge identify potential impacts to federally endangered species in a section 7 interagency endangered species consultation as an integral part of the Service's annual pesticide use proposal program.

Disturbance factors resulting from public use are always considered for all listed species. The Delmarva fox squirrel and piping plover are listed as endangered and threatened by the Service and the red knot was designated as a candidate species in 2006 for possible listing. Several other species listed as endangered by the Delaware Division of Fish and Wildlife include American oystercatcher, common tern, Forster's tern, least tern, and bald eagle. Of these, the piping plover, red knot, American oystercatcher, common tern, Forster's tern, and least tern will not be impacted by hunting because they would be unlikely to use the refuge's forested habitats and their occurrence on the refuge is outside of the hunting season for deer, upland game, and waterfowl. Impacts on piping plover, red knots, American oystercatcher, common tern, Forster's tern, and least tern will be minimized through the seasonal closure of designated beach dunes and overwash areas from March 1 through September 1 to all visitors. A section 7 evaluation has been conducted as part of this review, and it was determined that proposed activities in any alternative would not likely affect Delmarva fox squirrel or piping plover. Furthermore, the hunting of any squirrel species is prohibited on the refuge to further minimize impacts to this endangered species.

While the bald eagle is no longer a federally listed species, the refuge uses the national bald eagle management guidelines for bald eagle management to implement time-of-year restrictions for nesting eagles. The guidelines do not permit any activity within 330 feet of an active nest during the breeding season, particularly where eagles are unaccustomed to such activity (U.S. Fish and Wildlife Service 2007c).

Fishing, hunting, and wildlife observation and photography on or near Turkle Pond were existing activities prior to nesting by bald eagles on adjacent Horse Island. When bald eagles were listed as endangered, the section 7 evaluation conducted on the refuge concluded that these activities in Turkle Pond would not likely affect this species and the uses were permitted. We will monitor use in Turkle Pond to determine if there is an impact on the eagle nest on Horse Island.

We have consolidated the placement of the majority of trails to one area (headquarters area) and tried to incorporate the edges of forest, grasslands, and wetlands to reduce fragmentation of large blocks of habitat. This maintains less-disturbed areas for species sensitive to fragmentation. Establishing permanent trails helps to reduce disturbance by pedestrians to wildlife on the refuge, including the Delmarva fox squirrel. Because animals show greater flight response to humans moving unpredictably than humans following a distinct path permanent trail establishment helps to mitigate some of the adverse effects of human disturbance (Gabrielsen and Smith 1995).

Impacts on Endangered Species in Alternative A

Impacts on threatened and endangered under Alternative A ("No Action") serve as a baseline for comparing and contrasting Alternatives B and C to the refuge's existing management activities.

The primary feature of alternative A is passive habitat management in both refuge upland and wetland habitats. The passive conversion of open areas and old fields to revert to forest will have considerable benefits for Delmarva fox squirrels, bald eagles, and other State-listed species dependent on the same forest habitat requirements, although desired forest conditions may not be achieved as readily or as quickly than with active reforestation and forest management.

The unimpeded return of tidal flow throughout the wetland complex, will permit natural overwash processes which has the potential to create new suitable habitat for the piping plover and red knots. In the absence of proactive restoration, more of the refuge's impounded wetland complex will convert to open water, possibly limiting habitat for state or federally listed shorebird species.

Under projected climate change scenarios the Delaware Bay is predicted to lose 60 percent or more of intertidal feeding habitats used by both breeding and migrating shorebirds by 2100 (Galbraith et al. 2002), and the refuge specifically is predicted to experience substantial loss (Scarborough 2009). Shorebird species of state or federal concern, such as piping plovers and red knots, that are dependent on coastal dunes, sandy beach and intertidal flats may experience additional adverse impacts and threats to survival and reproductive success.

Conclusions for Management Actions in Alternative A

Management actions in alternative A would result in short-term local minor beneficial impacts and would also have local minor-to-moderate adverse impacts. No impairment of the refuge's BIDEH is expected unless the impounded areas revert to open water. The loss of marsh to open water would have a negative effect on diversity and biological integrity.

Impacts on Endangered Species in Alternative B

Managing and Protecting Habitat and Public Use

With more intensive forest management than in alternative A (mechanical thinning, prescribed fire, and other stand improvement techniques) and the conversion of open fields to mixed hardwood forest through proactive reforestation projects, there will be considerable benefits for Delmarva fox squirrels, bald eagles, and other State-listed species dependent on the same forest habitat requirements. Performing forest management on refuge complex lands would be instrumental in addressing the following Delmarva fox squirrel recovery tasks, identified in the recovery plan (Moncrief et al. 1993): (4.1) determine effects of timber management and other land use practices on the DFS; (4.2) develop and refine guidelines for prescriptive habitat management for the DFS; (4.3) develop and implement guidelines for habitat management on public lands occupied by the DFS; and (4.4) monitor the outcome of prescriptive habitat management.

Whiteman and Onken (1994) suggest that the enhancement of Delmarva fox squirrel habitat can be accomplished primarily through silviculture. Because a combination of forest management techniques would be implemented as determined to be necessary for forest health, a combination of the associated impacts would result. Hardwood mast production will be maximized in refuge forests and a sparse understory will be maintained by promoting large crown development of mast producers in the overstory. The rate at which immature stands reach the desired conditions for Delmarva fox squirrel will be expedited by identifying potential hard and soft mast crop trees and performing a light thinning around these trees to encourage crown development. Performing regeneration harvests in some of the mature and over-mature stands throughout the refuge will reduce the potential for forested habitats to become stagnant. The selective removal of dominant and co-dominant canopy trees that are nearing the end of their life will allow necessary light to reach the forest floor to facilitate seed germination and free up additional resources to enhance the growth of new regeneration. The planting of oak or other hard mast producing species may be required in openings created through forest management in order to ensure their replacement and continued occupancy of the stand, which might otherwise be dominated by pine, red maple, and sweetgum.

Small clearcuts surrounded by forest are not likely to cause problems for Delmarva fox squirrel. Paglione (1996) and Bocetti and Pattee (2003) noted that Delmarva fox squirrel shifted their home ranges away from the timber harvested sites and into adjacent forest with no observable negative effects. It appears that

Delmarva fox squirrel respond to 30 to 40 acre timber harvests by shifting into adjacent habitat if it is available. Larger clearcuts may cause problems when they are more isolated and cause Delmarva fox squirrel to move greater distances to find new habitat. Commercial thinning of timber stands that are 25 years old or less are not likely to cause problems for Delmarva fox squirrel because timber stands of this age are not considered their habitat. Even though Delmarva fox squirrel may move through these stands at times, the removal of understory or portions of the stand are not considered to reduce its suitability as corridor or area occasionally used.

Tree selection techniques would focus on healthy trees with well-formed crowns and should include species from both the red and white oak groups along with beech and pine. The crop tree species diversity would promote a more consistent mast crop. Creating openings in the canopy will not only enhance natural regeneration but will also enhance growth and mast production of remaining trees, much like a crop tree release. The perpetuation of the stand through promoting regeneration and the associated improvements in mast production will have significant long-term benefits for Delmarva fox squirrel. Future implementation of timber stand improvement techniques will ensure the species composition of these stands is not significantly altered.

In summary, performing simple forest management practices will enhance the quality and quantity of the existing Delmarva fox squirrel habitat.

Prescribed burning, which would be used throughout all forest cover types and age classes as a form of timber stand improvement, would aid in creating and maintaining open understory conditions favored by Delmarva fox squirrel, and promoting habitat diversity and food availability (Weigl et al. 1989). Carefully performed prescribed burning on the refuge will benefit the endangered Delmarva fox squirrel by enhancing habitat and reducing hazardous fuel buildup. Prescribed burning in woodlands would aid in creating and maintaining open understory conditions favored by Delmarva fox squirrel, and promoting habitat diversity and food availability. In contrast to the gray squirrel (*Sciurus carolinensis*), the Delmarva fox squirrel often travels on the ground (Moncrief et al. 1993) and has been shown to prefer mature forests with a minimum of underbrush (Moncrief et al. 1993), closed canopies, open understories, and a high proportion of forest edge (Dueser et al. 1988). Authors have suggested that habitat for Delmarva fox squirrel in general may be improved by leaving mature and large-crowned trees in managed forests, encouraging nut-bearing trees, and opening up the forest understory by burning or light grazing (Chapman, et al. 1982). Fox squirrels have been found to prefer sites where understory closure is 30 percent or less (Allen 1982).

Protecting, retaining, and enhancing super canopy trees and not removing large standing and downed snags and dead wood, or any tree used by nesting bald eagles, will also benefit many State and federally listed species. Protecting all active and historic nest sites and areas and also partially constructed nest trees with 330-foot no buffer zones during critical life cycle stages will also be highly beneficial for endangered species. Improving stand condition of roosting and breeding forested areas on the upland islands (Oak Island, First Hill, Second Hill, Negro Island, and Horse Island), which serves as the core bald eagle management area will also benefit other State-listed bird species.

Conservation and enhancement of washover and ephemeral inlet areas, mudflats, sandflats, wrack lines, and shorelines of coastal ponds, lagoons, or salt marshes will maximize annual survival and production for breeding and migrating piping plovers and migrating red knots. Loss and degradation of barrier island habitats due to extensive development on the East Coast and shoreline stabilization have been major contributors to both species declines. Refuge management strategies aimed at the restoration of natural processes on the barrier island ecosystem are likely to have the greatest long-term benefits for piping plovers, red knots and other rare shorebird species by correcting and mitigating for past adverse habitat practices (USFWS 1996, USGS 2005, USFWS 2007).

If not prevented or minimnized through management, human disturbance can be a notable factor in plover nesting success. Seasonal beach closures on the refuge will minimize impacts from disturbance. Dogs also are a disturbance factor for piping plovers, because they may chase adults, kill chicks, and eat eggs. Prohibiting dog use on the refuge reduces or eliminates the adverse impact from dogs.

With the restoration of salt marsh in Unit II, natural overwash processes will be permitted to occur unimpeded. This has the potential to create new suitable habitat for the piping plover and red knots. Melvin 1991 stated that natural beach and overwash processes should be encouraged. The deposition of dredged material on beaches can substantially improve quality and availability of plover habitat (USFWS 1996, Melvin 1991). This type of beach nourishment is considered beneficial in the short-term when the beach is severely eroded (USFWS 1996). It is unlikely that the restoration of the salt marsh would have a significant adverse impact to piping plover or red knots.

However, the placement of dredge material on beaches may adversely affect plover habitat if the substrate is not suitable and the timing of disposal is inappropriate. If sediment quality standards and time of year restrictions (mid-August to mid-March) are utilized, they can minimize any adverse impacts. Direct impacts associated with salt marsh restoration would include short-term, local disruption of individuals during construction activities. Construction activities would be scheduled at times to avoid impacts as much as possible.

Additional impacts on Federal and State-listed species would be the same as described above in Impacts on Federal and State-Listed Species That Would Not Vary by Alternative.

Conclusions for Management Actions in Alternative B

Management actions in alternative B would result in short-term local moderate beneficial impacts and it would also have local short-term minor-to-moderate adverse impacts. No impairment of the refuge’s BIDEH is expected.

Impacts on Endangered Species in Alternative C

Managing and Protecting Habitat

The impacts on federal and state listed species would be the same as described above in impacts on Federal and State-listed Species That Would Not Vary by Alternative.

Public Use

The impacts on Federal and State-listed species would be the same as described above in Impacts on Federal and State Listed Species That Would Not Vary by Alternative.

Conclusions for Management Actions in Alternative C

Management actions in alternative C would result in short-term local minor beneficial impacts and have local short-term minor-to-moderate adverse impacts. No impairment of the refuge’s BIDEH is expected.

Impacts on Waterfowl

Focal waterfowl species include:

Northern pintail
American black duck
Fall migrating and wintering dabbling ducks
Spring migrating dabbling ducks
Snow geese

Wetland conservation and management is the highest priority of the refuge, consistent with the original establishment purposes for migratory birds. It is our utmost conservation priority because wetlands constitute close to 80 percent of our refuge land base and support Service trust species, such as migratory birds that include waterfowl, shorebirds, secretive marsh birds, waterbirds, and passerines species, as well as anadromous and interjurisdictional fish and the habitats on which these trust species depend.

We evaluated the management actions for each of the CCP alternatives for their potential to benefit or adversely impact all of the various wetland communities on the refuge that provide habitat for waterfowl:

- Restoring impounded wetland areas to a tidal salt marsh community
- Restoring prior-converted wetlands that were farmed to moist-soil units
- Reducing numbers of snow geese to meet Service population goals across state and flyway landscapes and mitigate negative impacts of heavy herbivory on refuge marshes
- Establishing or increasing the width and extent of vegetated buffers (preferably trees) around wetlands
- Managing to prevent the expansion or proliferation of invasive plant species
- Maximizing annual native plant production, conserving and protecting insect and other invertebrate food resources for waterfowl
- Regulating hunting pressure on waterfowl
- Access by visitors and other users that might impact wetland habitats or disturb migrating waterfowl
- Mitigating mosquito control treatments that might reduce food resources for waterfowl

Impacts on Waterfowl That Would Not Vary by Alternative

Managing and Protecting Habitat
Across all of the alternatives, controlling invasive plant species, particularly *Phragmites*, is an important management activity conducted in refuge wetland habitats. Migrating and wintering dabbling ducks and Canada geese would experience direct benefits from the reclamation of *Phragmites* areas that quickly revert to native plant foods (spikerushes, millet, smartweeds, and grasses). Since these native plants are also associated with specific native insect community assemblages that do not exist in *Phragmites*' stands, invertebrates would provide additional food sources that supplement waterfowl plant foods. Because we spray *Phragmites* from mid-August to the end of September, fall migrating and wintering waterfowl would mostly avoid any impacts from disturbance. By that time, blue-winged teal, the earliest fall migrant waterfowl species, are just starting to arrive. The herbicides and surfactants approved for wetland use are not toxic to birds, fish, or invertebrates. Therefore, even if birds do get wet, it would only be a temporary impact.

Forested buffers surrounding refuge wetlands also provide indirect benefits by preventing the marshlands from receiving elevated levels of pesticides and pesticide residuals, nutrients, or solids from run-off from off-refuge sources that negatively impact the quality of feeding habitats for waterfowl.

Adverse short-term, long-term, and indirect impacts to waterfowl results from gradual or rapid acreage losses of freshwater wetland communities, especially emergent and swamp cover types, resulting from salt water intrusion that is very likely to occur under all alternatives because of changing coastal conditions, increased storm activity and sea level rise.

Mosquito Management
Across all alternatives, chemical mosquito control will be conducted on refuge wetland and beach strand habitats. With the exception of chironomids, which may suffer direct mortality, Bti or methoprene larvicides may have negligible to minor indirect adverse impacts on non-target wildlife, including waterfowl.

Insects are an important component in the diet of migrating and wintering waterfowl. Forty-three percent of all ducks and geese are primary insectivores and 54 percent are partially insectivorous (Losey and Vaughan 2006). During the breeding season, insectivory can be especially important to adult ducks as well as ducklings (Reinecke 1979; Reinecke and Owen 1980). Waterfowl species breeding in refuge wetland habitats, such as black ducks and mallards, consume insect species, such as dragonfly and chironomid larvae, which may be directly or indirectly impacted by pesticides use to control mosquitoes at that time of the year.

To the extent that refuge waterfowl consume non-target aquatic and terrestrial invertebrates, waterfowl may be adversely impacted by mosquito control under all three alternatives. The degree to which adulticides and larvicides will impact waterfowl food resources will likely vary by time, location, chemical used, concentration, treatment interval and number of treatments. The ability of waterfowl to move to alternate feeding sites or shift their diet within the treatment site to alternative food resources is unknown. Site-specific direct and indirect adverse impacts from mosquito control to the local waterfowl populations are unknown. To the extent that refuge waterfowl feed on or are dependent on target species, such as mosquitoes and mosquito larvae as a food resource, is likely to be more pronounced unless the birds are able to shift food preferences within a treatment site, or move to alternative feeding sites (Krapu 1974, Reinecke and Owen 1980, Reinecke 1979, Swanson et al. 1974, WMH 1995, Kaminski and Prince 1981).

Administration and Public Use
Since the refuge consists of 80 percent wetlands, all recreational activity has the potential of impacting waterfowl feeding or resting near the refuge's hunting area(s). Conflicts arise when migratory birds and humans are present in the same areas (Boyle and Samson 1985). Response of wildlife to human activities includes departure from site (Owen 1973, Burger 1981, Korschgen et al. 1985, Henson and Grant 1991, Kahl 1991, Klein 1993), use of suboptimal habitat (Erwin 1980, Williams and Forbes 1980), altered behavior (Burger 1981, Korschen et al. 1985, Morton et al. 1989, Ward and Stehn 1989, Havera et al. 1992, Klein 1993), and increased in energy expenditure (Morton et al. 1989, Belanger and Bedard 1990). McNeil et al. (1992) found that many waterfowl species avoid disturbance by feeding at night instead of during the day.

During the period of September 1 to March 15, which is when most wintering and migrating waterfowl are on the refuge, adverse impacts to these birds could result from unregulated human disturbance in optimum waterfowl habitats at the refuge. This conclusion is based on the role of disturbance as it relates to waterfowl life history requirements and behaviors such as feeding, flight, metabolic processes, molting, preening, and resting. These daily waterfowl maintenance activities are costly from an energetic standpoint and require that waterfowl have undisturbed access to quality habitats with diverse food resources to meet their daily and seasonal energy requirements. Since these activities are critical to the survival of waterfowl, a discussion of their behaviors and metabolic processes is appropriate.

Feeding: Waterfowl have complex feeding strategies, which are conducted at optimum levels only in an environment void of disturbance. Feeding is the only activity that provides energy to birds, and the amount of time allocated to feeding is dependent upon relationships between energy-nutrient requirements and foraging strategies used in meeting these needs (King 1974). Feeding on readily available and easily consumed foods requires less time than feeding on dispersed resources or foods that require searching, e.g., mobile invertebrates or complex foraging behavior, e.g., underground tubers (Rapport 1980).

Generally, feeding periods for wintering waterfowl are early morning and late evening. Morton et al. (1989) found that American black ducks (*Anas rubripes*) spent an average of 4.49 hours per day feeding, with the majority of feeding activity occurring either during the first three hours after daylight, or the last three hours of the day, the remainder of the day was spent engaging in resting (4.54 hours), swimming (1.83 hours), or several other maintenance activities (balance of the day). This suggests that waterfowl, when undisturbed, prefer to feed early and late, while spending the remainder of the day in maintenance activities such as resting, preening, or courtship.

Mallards (*Anas platyrhynchos*) generally do not feed in water deeper than 40 cm (Thomas 1976) but prefer to feed in water depths of 10 cm or less (Fredrickson and Taylor 1982), which is indicative of the habitat provided in the refuge's managed impoundment complex. Unregulated access in these provided habitats could adversely impact the feeding strategies of waterfowl using the refuge.

Flight: Many research projects have been conducted on the basic energy requirements of waterfowl, and these projects emphasize the importance of readily available food resources. As birds arrive in Delaware during fall migration, they need areas to rest and feed to replenish energy reserves. It is important to recognize that approximately 90 percent of the migration period is spent in a stationary mode at successive stopover sites (Hedenstrom and Alerstam 1998). Birds at stopover sites spend their time resting and foraging as they rebuild protein and energy stores in preparation for their next migratory flight (McWilliams et al. 2004). It is also important to recognize that flight is a very expensive activity from a metabolic perspective and forcing birds into flight creates the need to replace lost energy reserves that could have been used for other activities. Protection is needed to allow waterfowl the opportunity to forage and replenish energy reserves depleted during migration and avoid the energetic costs associated with being forced into unnecessary flight.

Metabolic processes: Along with rebuilding protein and energy stores, and in addition to flight, there exist basic energy maintenance requirements of birds. These daily requirements, which include the energy costs of thermoregulation, maintenance of basal metabolic rate, and other activities, combine to account for 40 to 60 percent of a bird's annual energy budget (Walsberg 1983). Without reliable access to high quality food resources, waterfowl must either migrate to better habitats or suffer reduced fat reserves, which can result in below-optimum body condition. As an illustration of the food resources required to maintain body condition, Magee (1996) found that, in waterfowl, the energetic cost of flight for one hour would require enough foraging effort to consume 19.6 grams of corn (75 kernels) or 117.8 grams of amphipods (6,250 individuals) to replace lost energy reserves. From the standpoint of how fat deposition relates to reproductive potential, Heitmeyer (1985) discovered that hen mallards in the Mingo Basin of Missouri needed to reach a minimum weight threshold of 1360 grams (greater than 3 pounds) when they left the wintering grounds to ensure there would be adequate fat reserves to initiate nesting activities upon arrival at the breeding grounds. At Chincoteague NWR, Morton et al. (1989) found that wintering black ducks experienced reduced energy intake while doubling energy expenditure by increasing the time spent in locomotion in response to disturbance. Black ducks consumed 10.4 times more energy in flight than at rest, and 1.8 times more energy in alert behavior or swimming than at rest, suggesting that human disturbance of wintering black ducks impaired their physiological condition, thereby reducing winter survival and/or nutrient reserves carried to the breeding grounds. During migration stopovers, waterfowl must be afforded the time and opportunity to forage in high quality habitat to attain the desired body mass and fat deposits, and replace lost energy reserves. To meet these metabolic demands, waterfowl rely on many Federal, State, and private wetlands, including Prime Hook NWR, to rest, feed, and reacquire lost fatty deposits.

Molting: Feather molts are very costly from a metabolic standpoint waterfowl convert from the alternate (summer) plumage to their basic (breeding) plumage and most feathers are replaced during this period when birds are preparing for courtship rituals and pair bonding. Heitmeyer (1985) describes the prebasic molt of female mallards as extensive and intense, requiring a substantial amount of energy reserves to complete, as these birds replace approximately 50 grams of feathers in a 6 to 7 week period. This increase in nutrient demand translates to the need for individual mallards to be afforded the opportunity for undisturbed foraging. Excess disturbance may negatively impact the ability of waterfowl to secure nutrients, thus disrupting molting processes and associated reproductive strategies.

Preening: Maintenance of feathers by preening has been previously correlated to molt activity and is undoubtedly influenced by molt chronology. Male mallards preen most often during autumn; preening declines throughout early winter, which corresponds with declining molt activity (Combs 1987). Adverse impacts to preening activities would be similar to those associated with the molting process.

Resting: Resting appears to be a complementary activity to feeding, molting, and preening. As feeding declines from morning to afternoon, resting increases, which is necessary to allow birds to digest food consumed during previous periods of feeding (Paulus 1984b, Clark et al. 1986), and rejuvenate muscle fibers that may have been damaged during periods of flight (McWilliams et al. 2004). The inability of waterfowl to rest may have a direct negative impact on the ability of waterfowl to digest foods and repair muscle fibers, thus impacting other necessary life history behaviors.

As discussed in the previous section, wintering waterfowl need access to areas that are free from human interruption to complete seasonal and annual life cycle events. These interruptions can be characterized as disturbance, which causes an animal to deviate from behavior patterns that normally transpire without human influence. To explain further, a disturbance stimulus is produced when a human-related presence or object, e.g., birdwatcher, motorized vehicle, or sound, e.g., seismic blast or gunshot, occurs that causes changes to the natural behavioral patterns of animals (Frid and Dill, 2002). Activities such as hiking, photography, jogging, hunting, fishing, boating, research and management activities, bicycling, and driving are among many types of disturbance that can and do occur on any national wildlife refuge. Because a disturbance-free sanctuary is critical to waterfowl during the period of September 1 to March 15, it is important to understand that if unimpeded access is allowed, the ability of the Prime Hook NWR sanctuary to meet the needs of waterfowl may be reduced. The following sections discuss the values and functions of waterfowl sanctuaries and illustrate the impacts of disturbance on the ability of waterfowl to utilize habitat.

Disturbance is a primary factor influencing avoidance behaviors in waterfowl (Paulus 1984b, Heitmeyer 1985, Austin 1987) as ducks and geese are highly sensitive to motor traffic and human disturbance (walking, bird viewing, vehicular traffic) along roads during fall and winter (Bartelt 1987, Belanger and Bedard 1989 and 1990, Bowles 1995, Dalhgren and Korschgen 1992, Gabrielson and Smith 1995, Heitmeyer 1985, Klein 1989, Knight and Cole 1991 and 1995, Madsen 1985, Van Der Zande et al. 1980, Raasch 1996). When waterfowl are in areas adjacent to roads, they reduce time spent foraging and spend more time alert and vigilant to disturbance. For instance, a research study examining disturbance effects conducted on Mingo NWR in southeastern Missouri showed that mallards became alert at a mean distance of 213 m (698 ft) and flew from the site at a mean distance of 173 m (568 ft) in response to vehicle disturbance (Raasch 1996). In another study in Virginia, Pease et al. (2005) described the responses of seven species of dabbling ducks to six different forms of disturbance and recorded whether the birds had no response, alert, swam, and flew. Analysis of the data from Virginia showed that 74.2 percent of birds responded (alert, swam, or flew) when birds were within 200 meters (656 feet) of a human caused disturbance. As a result, when birds exhibit avoidance behaviors, swimming and flying activities increase while resting and feeding activities decrease (Combs 1987), which creates the need for additional foraging effort, which in turn influences seasonal movements and habitat selection. Areas void of regulations can cause increased human-wildlife interactions that can negatively impact the life history behaviors and metabolic processes of migratory waterfowl.

Laskowski et al. (1993) studied behavior of snowy egrets, female mallards, and greater yellowlegs on Back Bay National Wildlife Refuge in Virginia within 91.4 meters of impoundment dikes used by the general public. Behavior of snowy egrets was recorded during August and September. Mallards were monitored during migration in November and January. Greater yellowlegs behavior was observed during the northward shorebird migration. Behavior was monitored during the typical public activities of walking, bicycling, and driving a vehicle past the sample sites.

The study found that snowy egret resting behavior decreased and alert behavior increased in the presence of humans. Preening decreased when humans were present, but this change was not significant. Feeding, walk/swim, and flight behaviors were not related to human presence. Female mallards in November decreased feeding, preening and alert behaviors in the presence of humans. Resting, walk/swim, and flight behavior were not influenced by human presence. In January, female mallard resting and preening behaviors were not influenced by the presence of humans. However, feeding, alert, walk/swim, and flight behaviors were related to human presence. Greater yellowlegs increased alert behavior in the presence of humans. No other behaviors were affected. Maintenance behavior (combined feeding, resting, and preening) decreased when humans were present for all study species. In addition, this decrease was accompanied by an increase in escape behavior by each species. Maintenance behavior of mallards in January decreased in the presence of vehicles and combined disturbance. Escape behavior increased when vehicles or bicycles were present. Maintenance behavior of greater yellowlegs declined when bicycles and vehicles were present but was not influenced by pedestrian presence. Snowy egrets and female mallards increased movement between subplots and to areas within the study area away from the disturbance.

Speed of approach by vehicles has also been identified as having detrimental effects to waterfowl, as objects that approach quickly tend to frighten birds more often than objects that approach at lower speeds (Frid and Dill 2002). Pease (2005), found that vehicles traveling more than 13 miles per hour but less than 30 miles per hour created the least amount of disturbance. As a contrast to speed, Pease noted that humans approaching waterfowl on foot had a greater disturbance impact than passing vehicles. Thus, research suggests that waterfowl are disturbed less by vehicles that pass at a moderate rate of speed and more distressed by vehicles going very fast, very slowly, or by humans on foot.

Non-motorized boating can affect refuge resources in a number of ways. Studies show that canoes and kayaks disturb wildlife (Bouffard 1982, Kaiser and Fritzell 1984, Knight 1984, Kahl 1991). They may affect waterfowl broods, wintering waterfowl, shorebirds, raptors, and wading-birds, but their low speed and their use primarily during the warmer months would mitigate those impacts, especially on wintering waterfowl and raptors. Air thrust boats and jet skis are not permitted.

When birds leave the refuge because of human disturbance, high quality habitat is left unexploited for the duration of time that the birds are displaced. The length of time that a bird is displaced from a feeding site determines how much additional foraging effort will be required to replace lost food resources, which impacts other maintenance activities such as molting, resting, and preening. There have been several research studies that examined how long it took waterfowl to return to habitats after being disturbed. For example, the return rate of mallards and Canada geese (*Branta canadensis*) at Mingo NWR following vehicular disturbance indicated that two-thirds of the birds were still displaced after 25 minutes. At the Russell Lakes State Wildlife Area in Colorado, mallards flew from a pond during disturbances and did not return within 1 hour (George et al. 1991). In Wisconsin, only 15 to 56 percent of canvasbacks (*Aythya valisineria*) returned to foraging sites following disturbances (Kahl 1991), and staging snow geese (*Chen caerulescens*) populations in Quebec were found to be lower the day after they had been disturbed at a rate of less than two disturbances per hour, and that vehicular disturbance and unobstructed visual sight planes of approximately 400 to 500 m (1312 to 1640 ft) are detrimental to waterfowl use and subsequent rates of return (Belanger and Bedard 1989). Repeated disturbances (more than 2 per hour), which could occur if unregulated access is permitted, can have serious detrimental impacts on the utilization of seasonal wetlands, which may ultimately cause birds to completely abandon a site, disperse to poorer quality habitat, or change feeding strategies.

As wildlife professionals, we recognize that public use and access is important, but this use must be managed so that disturbance to wildlife is minimized and habitat utilization is not compromised. With these objectives in mind, it becomes necessary to recognize that disturbance to waterfowl early and late in the day can negatively impact biological processes such as feeding, flight, metabolic processes, molting, preening, and resting. For example, birds are feeding early in the morning to obtain food resources, but are beginning to come to roost at sunset to begin a period of rest after returning from evening feeding forays. This period of rest is just as important as feeding, it permits the digestion of food ingested prior to roosting and allows the repair of muscle fibers damaged during flight. If measures to minimize or eliminate the cause of disturbance are not considered, the impacts from these activities can negatively affect the potential for wildlife to acquire the necessary resources needed to meet nutritional life history requirements throughout their annual life cycle (Raasch 1996, Fredrickson and Reid 1988).

Providing waterfowl sanctuaries will minimize some of these impacts and allow waterfowl to have undisturbed access to these areas during biologically critical periods of the day. Havera et al. (1992) and Dahlgren (1988) in comprehensive literature reviews of human disturbances to migrating and wintering waterfowl have noted that the use of sanctuaries (non-hunted areas) was the most common and effective solution to mitigating adverse disturbance impacts. Across all alternatives, a waterfowl sanctuary in Unit II (1,300 acres under alternative A; 1,800 acres under alternatives B and C) provides seasonal protection to wildlife from hunting and other recreational uses.

The use of sanctuaries as a management tool is an old concept. Bellrose (1954) wrote of the early 1900s when owners of duck lands found that providing non-hunted areas on their properties was of value in building and holding concentrations of waterfowl. The principal factor governing duck use of areas that were all hunted, half hunted/half unhunted, or not hunted was a sense of security. Waterfowl numbers averaged 16 times more abundant per acre on half hunted/half unhunted areas than on areas that were completely hunted.

Other hunting measures that serve to mitigate adverse impacts to waterfowl:

- Provide adequate buffer areas and large enough sanctuaries to ensure full use by waterfowl

- Provide temporal respite for ducks by limiting hunts to half days or use an intermittent hunt program (3 to 4 hunts/week)

- Regulate hunter access limiting boat access and traffic to specific areas

Hunting is a priority, wildlife-dependent, consumptive activity with additional direct effects on waterfowl. General adverse impacts of waterfowl hunting are mortality, crippling, and disturbance. Belanger and Bedard (1995) concluded that disturbance caused by waterfowl hunting to waterfowl resources can:

- modify the distribution and use of habitats by waterfowl;

- affect their activity budget and decrease their foraging time; and

- disrupt pair and family bonds and contribute to increased hunting mortality.

The Service annually prescribes frameworks, or outer limits, for dates and times when hunting may occur and the number of birds that may be taken and possessed. These frameworks are necessary to allow State selections of season and limits for recreation and sustenance, aid Federal, State, and Tribal governments in the management of migratory game birds, and permit harvests at levels compatible with population status and habitat conditions. Because the Migratory Bird Treaty Act stipulates that all hunting seasons for migratory game birds are closed unless specifically opened by the Secretary of the Interior, the Service annually promulgates regulations (50 CFR Part 20) establishing the frameworks from which States may select season dates, bag limits, shooting hours, and other options for each migratory bird hunting season. The frameworks are essentially permissive, in that hunting of migratory birds would not be permitted without them; in effect, Federal annual regulations both allow and limit the hunting of migratory birds.

Migratory game birds are those bird species so designated in conventions between the United States and several foreign nations for the protection and management of these birds. Under the Migratory Bird Treaty Act (16 U.S.C. 703-712), the Secretary of the Interior is authorized to determine when "hunting, taking, capture, killing, possession, sale, purchase, shipment, transportation, carriage, or export of any bird, or any part, nest, or egg" of migratory game birds can take place, and to adopt regulations for this purpose. These regulations are written after giving due regard to "the zones of temperature and to the distribution, abundance, economic value, breeding habits, and times and lines of migratory flight of such birds," and are updated annually (16 U.S.C. 704(a)). This responsibility has been delegated to the Service as the lead Federal agency for managing and conserving migratory birds in the United States. Acknowledging regional differences in hunting conditions, the Service has administratively divided the nation into four flyways for the primary purpose of managing migratory game birds. Each flyway (Atlantic, Mississippi, Central, and Pacific) has a Flyway Council, a formal organization generally composed of one member from each state and province in that flyway. Prime Hook NWR is in the Atlantic Flyway.

The process for adopting migratory game bird hunting regulations, located in 50 CFR part 20, is constrained by three primary factors. Legal and administrative considerations dictate how long the rule-making process will last. Most importantly, the biological cycle of migratory game birds controls the timing of data-gathering activities and thus the dates on which these results are available for consideration and deliberation. The process of adopting migratory game bird hunting regulations includes two separate schedules for the development of regulations, based on early and late hunting season regulations. Early hunting seasons pertain to all migratory game bird species in Alaska, Hawaii, Puerto Rico, and the Virgin Islands, migratory game birds other than waterfowl (e.g., dove, woodcock, etc.) and special early waterfowl seasons, such as for teal or resident Canada geese. Early hunting seasons generally begin prior to October 1. Late hunting seasons generally start on or after October 1 and include most waterfowl seasons not already established. There are basically no differences in the processes for establishing either early or late hunting seasons. For each cycle, Service biologists and others gather, analyze, and interpret biological survey data and provide this information to all those involved in the process through a series of published status reports and presentations to Flyway Councils and other interested parties. Though not as detailed as that for waterfowl, relevant data are collected and summarized for migratory bird species such as dove, woodcock, etc. Bird monitoring data are available through the Service's Division of Migratory Bird Management Website (*http://www.fws.gov/migratorybirds/*; accessed February 2012).

Because the Service is required to take abundance of migratory birds and other factors into consideration, the Service undertakes a number of surveys throughout the year in conjunction with the Canadian Wildlife Service, State and Provincial wildlife management agencies, and others. To determine the appropriate frameworks for each species, we consider factors such as population size and trend, geographical distribution, annual breeding effort, the condition of breeding and wintering habitat, the number of hunters, and the anticipated harvest. After frameworks are established for season lengths, bag limits, and areas for migratory game bird hunting, migratory game bird management becomes a cooperative effort of State and Federal governments. After Service establishment of final frameworks for hunting seasons, the States may select season dates, bag limits, and other regulatory options for the hunting seasons. States may always be more conservative in their selections than the Federal frameworks but never more liberal. Season dates and bag limits for national wildlife refuges open to hunting are never longer or larger than the State regulations. In fact, based upon the findings of an environmental assessment developed when a national wildlife refuge opens a new hunting activity, season dates and bag limits may be more restrictive than the State allows.

National Environmental Policy Act (NEPA) considerations by the Service for hunted migratory game bird species are addressed by the programmatic document, Final Supplemental Environmental Impact Statement: Issuance of Annual Regulations Permitting the Sport Hunting of Migratory Birds (FSES 88-14) filed with the Environmental Protection Agency on June 9, 1988. We published the Notice of Availability in the *Federal Register* on June 16, 1988 (53 FR 22582), and our Record of Decision on August 18, 1988 (53 FR 31341). Annual NEPA considerations for waterfowl hunting frameworks are covered under a separate environmental assessment, in which the FONSI is published generally in August of that hunt year. Further, in a notice published in the September 8, 2005, *Federal Register* (70 FR 53376), the Service announced its intent to develop a new supplemental environmental impact statement for the migratory bird hunting program. Public scoping meetings were held in the spring of 2006, as announced in a March 9. 2006, *Federal Register* notice (71 FR 12216). More information may be obtained from the Chief, Division of Migratory Bird Management., US Fish and Wildlife Service, Department of the Interior, MS MBSP-4107-ARLSQ, 1849 C Street, NW, Washington, DC 20240.

At Prime Hook NWR, the impacts of hunting of waterfowl are negligible when compared to the State's total waterfowl harvest. For example, from 1987 to 2009, the average annual waterfowl harvest at the refuge is 2.6 percent of Delaware's total waterfowl harvest (Table 5-4). Furthermore, in 2009, the refuge's harvest of ducks was only 3.4 percent of Delaware's total duck harvest, 0.10 percent of the Atlantic Flyway's duck harvest, and 0.01 percent of the entire United States' duck harvest (Table 5.5; Raftovich et al. 2011). Also in 2009, the refuge's harvest of geese (Canada and snow geese combined) was only 0.82 percent of Delaware's total goose harvest, 0.04 percent of the Atlantic Flyway's goose harvest, and 0.01 percent of the entire United States' goose harvest (Table 5.5; Raftovich et al. 2011).

The impacts of waterfowl hunting at the refuge are also negligible when compared to long-term trends in duck and goose populations at the refuge and across the State. Through monthly aerial surveys from October through November, the Delaware Division of Fish and Wildlife is able to evaluate long-term trends in duck and goose populations. The surveys give fairly accurate information about geese, but duck populations such as wood ducks and sea ducks are almost impossible to count. Furthermore, these surveys do not cover the entire state, but only the primary waterfowl habitat in Delaware, which is approximately the eastern half of the State. These figures represent the numbers of ducks and geese at the time of the survey, but do not reflect an actual annual estimate for the waterfowl population in Delaware due to the transitory nature of birds migrating through the State during the fall and winter months.

Based on the findings of these monthly surveys from 1987 to 2009, the average annual waterfowl harvest at the refuge is only 1.8 percent of the estimated peak waterfowl survey findings on the refuge (Table 5.6). During an individual season, the percent of the refuge's harvest on statewide and refuge populations may range greatly depending on the timing of refuge hunting activity and peak waterfowl migration. For example, during the 2009-2010 hunting season, the refuge harvested between 0.19 percent and 1.5 percent of the State's estimated monthly duck population and between 0.02 percent and 0.11 percent of the State's estimated monthly goose population (Table 5.6). Refuge hunters harvested between 0.31 percent and 6.15 percent of the refuge's estimated monthly duck population and between 0.09 percent and 1.48 percent of the refuge's estimated monthly goose population (Table 5.6).

Impacts of refuge hunting on snow geese and resident Canada geese are negligible. For resident Canada geese, hunters averaged 8.8 birds per year from 2001 to 2006 (Table 5.7). For snow geese in the late season (late January into March), hunters averaged 16.0 birds per year from 2001 to 2006 (Table 5.8). From 2000 to 2009, refuge hunters harvested between 0.04 percent and 0.43 percent of the refuge's estimated monthly snow goose population (Table 5.8).

Table 5-4. Waterfowl Harvest and Aerial Survey Estimates on Prime Hook NWR Compared to Statewide Harvest (waterfowl includes geese and ducks)

Year	Statewide Waterfowl Harvest*	Refuge Waterfowl Harvest	Refuge Waterfowl Survey**	Refuge Hunter Visits
1987	63,360	1,202	21,243	1,206
1988	62,160	771	21,814	826
1989	61,480	578	64,822	333
1990	59,510	1,241	49,611	1,065
1991	63,410	1,625	55,792	1,178
1992	46,600	1,155	55,238	1,291
1993	46,850	1,421	86,087	962
1994	53,290	2,053	155,096	1,604
1995	45,540	1,572	71,131	1,024
1996	44,170	1,980	104,447	1,630
1997	71,070	3,116	191,446	1,904
1998	118,560	2,964	193,617	1,530
1999	96,410	1,987	224,693	1,403
2000	94,610	2,047	134,156	1,250
2001	76,210	2,679	107,919	1,683
2002	95,170	1,936	102,690	1,330
2003	88,800	2,546	203,615	1,486
2004	73,190	1,573	69,737	1,422
2005	71,740	1,624	111,544	1,301
2006	64,630	2,389	132,088	1,750
2007	81,620	2,989	44,086	1,850
2008	107,120	1,634	90,875	1,253
2009	86,600	1,934	79,263	1,453

**Statewide waterfowl harvest data from: http://www.flyways.us/regulations-and-harvest/harvest-trends; accessed February 2012.*

*** Waterfowl estimates were derived from peak numbers found during aerial surveys. Zone 7 was used to estimate waterfowl numbers for the refuge, which covers the area from Big Stone Beach to the Broadkill River and east of Route 1. Only one survey was conducted in 2007 (October 2007), which may not have reflected the peak (http://www.fw.delaware.gov/Hunting/Pages/Waterfowl%20Surveys.aspx; accessed February 2012).*

Table 5-5. Comparison of Waterfowl Harvest at Prime Hook NWR to State, Flyway, and United States Harvest in the 2009 Hunting Season

Waterfowl Harvest Area	Ducks	Geese
Prime Hook NWR	1,609	325
Delaware*	46,800	39,800
Atlantic Flyway*	1,680,100	922,200
United States*	13,139,800	3,327,000

**Harvest estimates from (Raftovich et al. 2011)*

Table 5-6. Comparison of Duck and Goose (Canada and Snow Geese) Harvest at Prime Hook NWR to State Waterfowl Surveys During the 2009 to 2010 Hunting Season

Month	Refuge Duck Harvest	Refuge Duck Population Estimates*	Statewide Duck Survey Results*	Refuge Goose Harvest	Refuge Goose Population Estimates*	Statewide Goose Survey Results*
October 2009	67	21,457	36,042	9	10,512	44,372
November 2009	406	30,548	63,516	104	18,734	92,604
December 2009	697	46,675	76,100	115	32,588	247,922
January 2010	439	7,141	28,688	97	6,565	102,229

** Waterfowl estimates were derived from peak numbers found during aerial surveys. Zone 7 was used to estimate waterfowl numbers for the refuge, which covers the area from Big Stone Beach to the Broadkill River and east of Route 1 (http://www.fw.delaware.gov/Hunting/Pages/Waterfowl%20Surveys.aspx; accessed February 2012).*

Table 5-7. Resident Canada Goose Harvest in Prime Hook NWR

Year	Resident Canada Goose Harvest	Refuge Hunter Visits
2001	14	33
2002	6	15
2003	10	13
2004	14	10
2005	0	0
2006	9	2

Table 5-8. Snow Goose Harvest and Aerial Survey Estimates at Prime Hook NWR

Year	Total Snow Goose Harvest*	Hunted in Late Season**	Snow Goose Harvested in Late Season**	Refuge Hunter Visits in Late Season**	Refuge Snow Goose Survey***
2000	174	No	n/a	n/a	96,112
2001	242	Yes	37	42	67,840
2002	48	Yes	7	9	72,200

Year	Total Snow Goose Harvest*	Hunted in Late Season**	Snow Goose Harvested in Late Season**	Refuge Hunter Visits in Late Season**	Refuge Snow Goose Survey***
2003	118	Yes	33	24	124,500
2004	121	Yes	3	5	55,330
2005	36	Yes	4	8	86,627
2006	73	Yes	12	12	132,088
2007	130	No	n/a	n/a	30,500
2008	56	No	n/a	n/a	84,520
2009	43	No	n/a	n/a	27,000

** Includes snow geese harvested in February/March when applicable*
*** Late season includes late January to mid-March*
**** Snow goose estimates were derived from peak numbers found during aerial. Zone 7 was used to estimate snow goose numbers for the refuge, which covers the area from Big Stone Beach to the Broadkill River and east of Route 1. Only one survey was conducted in 2007 (October 2007) which may not have reflected the peak (http://www.fw.delaware.gov/Hunting/Pages/Waterfowl%20Surveys.aspx; accessed February 2012).*

Migratory bird hunters may also disturb migratory birds and other wildlife as they travel to and from their hunting sites or when retrieving downed birds. Depending on the location and the number or species of migratory birds in the area, a disturbance can be temporary, with displaced birds moving to nearby backwaters, or more substantial, as in the case of motoring through a large flock of snow geese. For some species like bald eagles and other predators, migratory bird hunting creates a readily available food source due to birds lost or wounded.

Other measures to minimize disturbance to waterfowl are through seasonal closures of designated areas. Under all alternatives, the eastern portion of Prime Hook Creek and associated ditches are closed until March 15 to all users after the hunting season.

Direct disturbance to waterfowl occurs during white-tailed deer hunting seasons as hunters flush deer through wetlands, creeks, and open water habitats. Dogs running at large during upland game hunting seasons will also flush wintering waterfowl resting and feeding in both wetland and upland areas. Fishing activities also pose potential direct adverse impacts to waterfowl, specifically from hooks, lures, and litter. The ingestion of lead sinkers or lead shot is another concern; however, the impacts are lessened from refuge regulations requiring the use of non-toxic shot for upland hunting, except for slugs for deer hunting.

Federal Aviation Administration have permission to access the VORTAC tower located on the refuge as needed. Onsite visits by these personnel may disturb feeding geese during the period from October to March and may disturb nesting osprey from March to July. The birds are expected to habituate or return to feeding or nesting once the vehicle has passed (Klein 1993).

Research activities may disturb fish and wildlife and their habitats. For example, the presence of researchers can cause waterfowl to flush from resting and feeding areas, cause disruption of birds on nests or breeding territories, or increase predation on nests and individual animals as predators follow human scent or trails. Efforts to capture animals can cause disturbance, injury, or death to groups of wildlife or to individuals. To wildlife, the energy cost of disturbance may be appreciable in terms of disruption of feeding, displacement from preferred habitat, and the added energy expended to avoid disturbance.

Impacts to Waterfowl in Alternative A

There are minor-to-moderate adverse impacts to waterfowl under alternative A associated with the loss of freshwater impoundments. Freshwater moist soil vegetation has already been lost in Units II and III over recent years. This vegetation will be replaced by native salt marsh vegetation in some areas, and by open water in areas where the peat collapses and elevation is lost. It is difficult to predict the impacts on waterfowl as nature takes its course and reshapes impounded wetland areas connected to barrier island habitats. Waterfowl use may change when more open water and less emergent marsh areas are in a transitional phase. A reduction in floral food resources may be substituted with increases in faunal (invertebrate) food resources altering the species. Although salt marsh vegetation still provides quality waterfowl habitat, some species, such as northern pintails, will likely not utilize the newly developed salt marsh areas as extensively as they had utilized the freshwater impoundment that have been lost. This tidal conversion eventually will permanently alter the current habitat conditions for some of waterfowl species and, where it is possible; cause them gradually to shift to appropriate habitats. It is not likely that salt marsh plants would be able to naturally re-colonize impounded wetland areas, without active restoration, due to known marsh platform accretion deficiencies. The amount of open water is likely to be greater under alternative A than under alternative B, and while open water habitats are not without value for waterfowl, they do not meet the same life history needs that are met by wetlands, including salt marsh.

Impacts on waterfowl from public use proposed under alternative A would also be the same as those listed in Impacts on Waterfowl That Would Not Vary by Alternative and in alternative B. Additional impacts would be the same as those listed in Impacts on Waterfowl That Would Not Vary by Alternative.

Conclusion for Management Actions in Alternative A

Management actions under alternative A will result in local moderate-to-major impacts on waterfowl due to the greater degree of open water conversion and loss of freshwater emergent wetland vegetation in impounded marsh areas. Based on the latest information we have about impounded marsh elevations, rapid saltwater re-introductions killing most of the non-halophytic vegetation and subsequent peat collapse in Units II and III, it is very likely that salt marsh vegetation cannot return naturally to impounded wetland areas without active restoration or a major infusion of sediments which, under natural conditions, can occur from hurricanes and major coastal storms. Wetland habitat stability is not possible when impounded marsh surfaces have sunk below the point where saltmarsh cordgrass and other halophytic plants could naturally re-colonize through tidal flows of saltwater. Current open water areas are most likely to remain open.

It is difficult to predict impacts on waterfowl use given the higher ratios of open water to emergent marsh but it is very likely that transitioning to more marine aquatic environments introduces greater diversity and quantity of invertebrate food resources. We would expect fall migrating and wintering ducks may not stay long once they arrive on the refuge due to a significant reduction in plant resources. It is very likely we would see a shift in more black duck use and less pintail use and little change in green winged teal use. However there is a high degree of uncertainty as to how waterfowl use will change under alternative A management actions.

Impacts to Waterfowl in Alternative B

Managing and Protecting Habitat

Reducing the use of adulticides and preferentially restricting larvicide use to Bti products and methoprene, under appropriate conditions, may have direct beneficial impacts on insect populations with indirect beneficial impacts on waterfowl by providing high-quality protein food resources during spring migration, increasing waterfowl body condition and reproductive potential when arriving on the breeding grounds (Devries et al. 2008).

Additional salt marsh created through restoration within impounded wetland areas will provide valuable habitat of a different kind for many waterfowl species. In particular, American black ducks utilize salt marsh communities heavily during the winter, and will benefit from added salt marsh acreage. Furthermore, salt marsh will be more self-sustaining than freshwater impoundments. Freshwater wetland communities would be subject to periodic die-back from saltwater intrusion resulting from increasing storm activity, and the tidal restriction associated with impoundment management would continue to deprive the wetlands on which the waterfowl depend of the sediment accretion necessary to help keep pace with sea level rise into the future. Under alternative B, waterfowl will have the minor to moderate benefit of stable wetland communities for feeding, resting, and other activities.

Restoration of salt marsh within impounded wetland areas will reduce the annual moist soil vegetation available to waterfowl, relative to historic managed impoundment conditions. This vegetation shift will be replaced by native salt marsh vegetation, which will result in a minor to moderate local adverse impact on waterfowl use of the refuge. Although salt marsh vegetation still provides quality waterfowl habitat, some species, such as northern pintails, will likely not utilize the newly restored salt marsh areas as extensively as they had utilized the freshwater impoundments. Tidal restoration eventually will permanently alter the current habitat conditions for some waterfowl species and, where it is possible; cause them gradually to shift to appropriate habitats. It is likely that waterfowl species composition will shift somewhat, and that waterfowl abundance will be lower than the historically high concentrations of waterfowl that used the freshwater impoundments when they were fully functioning. Potential adverse impacts at the regional scale from the restoration of freshwater impoundments back to salt marsh are unknown.

Large expanses of open water will attract more snow goose use of these marsh areas. Coupled with more mild winter weather and no ice formation, large numbers of snow geese will stay on the refuge for six months or more, resulting in major negative impacts in already stressed marsh areas.

Heavy snow goose herbivory has negative impacts on marsh health as their grubbing and rooting for marsh plant tubers and roots destroy marsh soil structure and integrity. Their feeding methods can also cause significant loss of sediments as unconsolidated soil particles are loaded into the water column and flushed out of the marsh in heavily grazed areas. This further complicates the problems for impounded areas that are already highly degraded due to accretion deficiencies and intensifies the degree of subsidence of the marsh platform. The refuge will offset this impact by controlling snow goose populations locally through hunting and full participation in the state's snow goose conservation order, which provides modified hunting regulations to maximize snow goose harvest. This will have a minor-to-moderate impact on local snow goose population levels.

During restoration phases of marsh rehabilitation when new wetland plants are re-established, this new plant growth will be highly attractive to both migrating and wintering snow geese and resident Canada geese that will quickly destroy all young shoots and roots of desired vegetation. This will pose significant challenges to deal with an over-abundance of certain goose species. The refuge will need to implement resident goose control strategies including lethal methods to reduce the impact to the marsh.

Public Use
In alternative B, increasing designated waterfowl sanctuaries from 1,300 acres (Unit II) to 3,000 acres (portions of Units II, III, and IV) will benefit migrating and wintering waterfowl on the refuge by providing significantly large, areas for undisturbed resting, feeding, and loafing. These designated approximately 3,000 acres of waterfowl sanctuaries will be closed to hunting and other recreational uses on a seasonal or annual basis. Given the dominant role of the refuge in the Atlantic Flyway migration corridor, this closed area system will provide waterfowl with a better network of resting and feeding areas and also disperse waterfowl hunting opportunities on the refuge. These sanctuaries lie in Unit II (approximately 1,800 acres) and the southern half of Unit III (approximately 970 acres). The northern portion of Unit IV (approximately 230 acres), which contains a proposed trail and observation platform, will be closed from the Monday before Thanksgiving to March 15 to minimize disturbance to wildlife in this area. Waterfowl hunting will stop at noon in all hunting areas (and limited hunting days) to reduce disturbance to waterfowl feeding patterns, which in turn will result in high quality hunting experiences. Literature reviews of visitor use and its relationship to disturbance to waterbirds support the time restriction and are reflected in the hunting regulations of other refuges, particularly in the Southeast Region of the Service (DeLong 2002).

These waterfowl sanctuaries have a beneficial impact on waterfowl by aligning closed areas over existing preferred food sources and minimizing disturbance to feeding and resting waterfowl. Other seasonal closures associated with alternative B help to minimize public use disturbance to waterfowl and other wildlife.

In addition, we expect impacts to waterfowl to increase due to proposed expansions in public use activities including fishing, hunting, wildlife observation, wildlife photography, and environmental education and interpretation. These increased impacts are expected to be negligible because public activities will also be restricted to the areas outside of the 3000 acres of designated waterfowl sanctuaries.

Expanded hunting opportunities for deer and waterfowl will cause disturbance to waterfowl in refuge impoundments, Prime Hook Creek, and refuge salt marshes. On Prime Hook Creek, deer hunting will occur on Tuesday, Thursday, and Friday during the hunting seasons. On refuge impoundments in Unit III and Prime Hook Creek, waterfowl hunting will occur on Monday, Wednesday, and Saturday during the hunting season. If a duck hunting season opens on a Friday, waterfowl hunting will be open and deer hunting will close. Impacts to waterfowl will be decreased from current management by changing the end of shooting time from 3:00 pm to noon. Participating in the early teal, resident Canada goose, and snow goose conservation order will cause direct impacts to increase but will be minimal based on current refuge harvest contributions to Statewide and national harvests. Free roam areas for deer and waterfowl hunting (jump shooting) will provide hunters with greater access and also increase the potential for waterfowl disturbance. These disturbances are mitigated by creating sanctuary areas where no waterfowl hunting occurs.

Proposed waterfowl hunting in Units I and IV salt marshes have the potential to increase adverse impacts and disturbance on refuge wintering American black ducks. Zoned hunting areas have been established in Unit IV to limit hunter numbers, thereby minimizing wildlife disturbance. Since black ducks are a focal species of conservation concern, monitoring and evaluation of impacts of increased recreational use of salt marsh habitats will be required to identify and respond to unacceptable impacts.

Conclusion for Management Actions in Alternative B

Habitat management under alternative B has local minor-to-moderate beneficial impacts whenever moist-soil and salinity management is possible to achieve and local minor-to-moderate adverse impacts where impounded marsh degradation and subsidence is rapidly occurring. The benefit of restoring degraded marsh areas and future sustainability of coastal marsh platforms in relation to local sea level rise rates offsets the minor to moderate adverse impact associated with the loss of the freshwater impoundments. It is very likely we would see a shift in more black duck use and less pintail use and little change in green winged teal use.

In terms of the refuge's BIDEH and the restoration of the impoundments to salt marsh, the refuge will be sacrificing diversity at a local scale for biological integrity at the regional or landscape scale, but increasing the integrity and environmental health of all our degraded impounded areas at the local level. Waterfowl will benefit from the long term stability and sustainability of a restored salt marsh relative to a vulnerable managed impoundment. However, heavy snow goose use and resident Canada use will have negative implications for the maintenance or enhancement of BIDEH of any restoration. Heavy snow goose use will also continue to have major negative impacts on marsh elevations in areas that are heavily browsed, requiring that snow goose control strategies be implemented, which will have a negligible-to-minor impact on local snow goose population numbers.

Public use proposed under alternative B results in negligible to minor adverse impacts associated with disturbance, but also minor-to-moderate beneficial impacts resulting from a redistribution of waterfowl hunting and designation of additional sanctuary areas.

Impacts to Waterfowl in Alternative C

Managing and Protecting Habitat

Intensive moist-soil management, as practiced from 1992 to 2008 is not currently possible due to significant changes in barrier island and impounded wetland habitats because of severe coastal storm forcing processes and sea level rise. To return the refuge to its pre-2008 freshwater impoundment management capabilities, Alternative C proposes to re-engineer an intact barrier dike system separating the freshwater impoundments from bay waters and to upgrade and repair water management infrastructure. Annual moist-soil production can be an important factor that attracts and holds waterfowl during the fall and winter. Waterfowl undergo processes each year (molt, migration, reproduction) that elevate their energy requirements and other nutritional needs. Moist-soil management units support those needs by increasing the annual seed production of native wetland plants that offer excellent nutrition (Frederickson et al. 1988). In addition, moist-soil ecosystems are endowed with an invertebrate food base that supplements plant food resources. Compared to agricultural cover crops, moist-soil crops attract and support more waterfowl species year-round, are easier and more cost-efficient to produce, and increase the capacity of wetland habitats to provide the most nutritious foods to meet annual life cycle requirements of waterfowl and other species (Fredrickson and Taylor 1982). A key to successful moist-soil management is maintaining soil and water salinities below 10 ppt. Moist-soil management cannot be practiced where salinity management is no longer viable.

The use of approved glyphosate tolerant corn and soybeans on the refuge is considered by most experts to be more environmentally friendly than other herbicide technologies employed by farmers (Cerdeira and Duke 2006). Browse and cover crops planted as part of the refuge's cooperative farming program provide a limited supplemental source of food for certain waterfowl species, primarily geese. The cooperative farming program in alternative A involves the use, as approved, of glyphosate-tolerant corn and soybeans.

Even under an impoundment management regime, periodic salt water intrusion into impounded marsh areas, likely due to the unstable and dynamic shoreline along Unit II, makes the practice of moist-soil management unachievable at times. When such intrusion occurs, freshwater plants that provide food for waterfowl die, with no other vegetation species taking its place quickly enough to meet the needs of the waterfowl as they arrive. The inherent instability of the freshwater impoundments could lead to minor adverse impacts to waterfowl, which may use open water areas for loafing but would need to seek food resources elsewhere during such times.

Public Use
Proposed expansions in hunting opportunities have the potential to cause more adverse impacts to waterfowl in alternative C than those outlined in alternative A, but less than alternative B because hunting areas and opportunities are reduced in alternative C from those proposed on alternative B. All other types of recreation will have similar impacts to those in alternative A. Adverse impacts are expected to be negligible.

Prime Hook Creek will not be open to deer and waterfowl hunting; however, boating for fishing and wildlife observation/photography will be permitted year-round on the westernmost 4 miles and from March 16 through August 31 on the easternmost 3 miles, along with waterfowl hunting. Refuge salt marshes in Unit IV will not be open to waterfowl hunting, which will prevent disturbance to waterfowl and other waterbirds.

Conclusion for Management Actions in Alternative C
There would likely be local short-term moderate beneficial impacts on waterfowl resulting from freshwater impoundment management proposed under alternative C. If fully successful, impacts on waterfowl use of the refuge impounded wetlands could be major. However, the obstacles associated with such management are substantial, rendering such benefits unreliable, and adverse impacts resulting from the inherent instability of the freshwater impoundments could offset the beneficial impacts considerably. Lost elements of coastal wetland integrity and environmental health of impounded marsh areas due to significant accretion deficiencies indicate that impounding refuge coastal areas cut off sediment supplies needed for marsh platforms to keep up with local sea level rise rates.

Maintaining an equilibrium position within the Delaware Bay coastal landscape requires that marshes accrete vertically as the sea level rises and the marsh surface sinks because of subsidence. The current degraded physical conditions of these impounded areas imply that impoundment management may no longer be impossible and detracts from maintaining the BIDEH of these areas in the near future in the face of sea level rise and climate change. There is a great deal of uncertainty in predicting how waterfowl use will change as our impounded marsh areas transition from one state to another.

Public use under alternative C is likely to have adverse impacts that are either comparable to those in alternative A, or are more than alternative A, but less than alternative B. Alternative C provides more hunting opportunities than alternative A but less opportunities for other public uses.

Impacts on Shorebirds

The conservation and protection of barrier beach island, coastal North Atlantic salt marsh, and impounded wetland habitats for shorebirds are high management priorities for the refuge (see inset).

> ***Focal shorebird species:***
>
> **Barrier beach island and salt marsh habitats:**
> - American oystercatcher
> - Sanderling
> - Whimbrel
> - Willet
>
> **Impounded wetland habitats:**
> - Dunlin
> - Short-billed dowitcher
> - American avocet
> - Greater/Lesser yellowlegs

Impacts on Shorebirds that would not vary by Alternative

Under all three alternatives, varying degrees of mudflats are likely to occur within refuge wetlands, which will benefit shorebirds foraging at all times of the year, but especially during spring and fall migrations. Indirect benefits to shorebirds are gained by educating the public about special beach closures with news releases and other outreach mechanisms to engage the public understand the needs of nesting shorebirds.

Public awareness and appreciation of the refuge's efforts to conserve and protect shorebirds would possibly inspire some to volunteer or in other ways support refuge needs in the conservation and protection of critical habitats required to protect continental and hemispheric shorebird resources in perpetuity. See Impacts on Waterfowl That Would Not Vary by Alternative in the Impacts to Waterfowl Section for information on benefits to shorebirds.

Mosquito Management

The aerial and ground applications of insecticides on the refuge may have local adverse impacts on breeding and migrating shorebirds in the form of disturbance, reduction of critical insect food resources used by shorebirds, and disruptions of natural aquatic food web function. Disturbance associated with mosquito monitoring and spraying activities may cause a range of behavioral changes, including nest abandonment, or changes in food habits and foraging, to physiological changes such as elevated heart rates due to fright and flight, or even death. Recurring disturbance is a potential factor in long-term declines of shorebird populations (Pfister et al. 1992, Burger 1995).

Insecticide treatments for mosquito larvae may also kill other closely related dipteran insect species, like chironomids, that make up a large portion of food resources in salt marsh and impounded wetland habitats on the refuge and are very important food resources for migrating and breeding shorebirds. Application of insecticides, both larvicides and adulticides, may have adverse site-specific impacts on wetland and aquatic food-webs and adverse impacts on non-target insect species (Brown 1998, Cook and Hill 2000 and 2001).

The application of Bti and methoprene on the refuge are non-toxic to birds at EPA approved application rates. The extent to which the use of Bti and methoprene will limit the food resources for individual birds or local avian populations is unknown. Integrated pest management strategies will be designed to limit impacts to local invertebrate populations when the mosquito-borne disease risk to humans is low.

As horseshoe crab populations decline in the Delaware Bay, food resources provided by refuge impounded wetland and salt marsh habitats may become more critical in providing food resources for spring and fall migrating shorebirds, including species of concern such as the piping plover and red knot. Mosquito larvae are a component of the diets of other aquatic invertebrates such as dragonfly, damselfly, and beetle larvae and back swimmers, which are consumed by shorebirds (Skagen and Oman 1996). Thus protecting and conserving insect and other invertebrate food resources directly benefits shorebirds.

Public Use

All of the alternatives predict some increase in annual visitation. However, adverse impacts from increased visitation will vary with the type of habitat management and visitor use each alternative proposes. Public use activities are expected to have negligible adverse short-term, long-term, or cumulative impacts on shorebirds.

Seasonal closures of designated beach dunes and overwash areas from March 1 through September 1 are in place to minimize disturbance to nesting shorebirds such as American oystercatchers and potentially piping plovers. See Impacts on Waterfowl That Would Not Vary by Alternative in the Impacts to Waterfowl Section for additional information on impacts to shorebirds.

Pfister et al. (1992) investigated human disturbance as a factor that might limit the capacity of appropriate staging areas to support migrating shorebirds. Results indicate that adverse impacts from human disturbance will be greater on shorebird species using the front side of beach habitats and that the local abundance of impacted species may be reduced by 50 percent. Such disturbance is implicated as a potential factor in long-term declines in shorebird abundance during migration periods at disturbed sites. Disturbance to shorebirds on the refuge beaches will be minimized through seasonal beach closures to public use.

Disturbance by refuge hunters to shorebirds is expected to be negligible since most shorebird species have completely passed through Delaware by peak hunting season in November through January. Some hunting occurs when these species may be migrating before and after this peak hunting time. Shorebirds using refuge marsh habitats that are also open to hunting may be disturbed by hunters traveling in these areas or by their gunshots; however, established sanctuaries provide disturbance-free areas for migrating birds during the hunting season.

Disturbance of shorebirds becomes a very crucial issue during incubation or nesting periods. Direct adverse impacts of displacement caused by human disturbance during nesting periods include egg exposure to temperature extremes, predation of eggs when the nest is vacated by the adult, and predation at a later time due to predators following human trail or scent (Korschgen and Dahlgren 1992). Protection of nesting colonial shorebirds is easier than protection of solitary nesters, like the American oystercatcher and piping plover, because much larger beach areas must be protected, managed, and patrolled. Public education, active protection methods (small fences around nests, signs, wardens), legal measures (beach use regulations, active enforcement patrols), and well-advertised closures of portions of the beach are management actions that often successfully reduce the adverse impacts of human disturbance when shorebirds are most vulnerable. Protection of nesting colonies using fences and wardens has markedly decreased reproductive losses of least tern colonies in New Jersey (Burger 1995).

Impacts on Shorebirds in Alternative A

Managing and Protecting Habitat

The absence of active restoration, such as is proposed in alternative B, has already resulted in a higher ratio of open water in impounded wetland areas under alternative A. Due to rapid saltwater re-introductions, Unit III has started to converted to open water with some mudflat areas. This could result in minor-to-moderate local adverse impacts to shorebirds. Galbraith (2002) outlined one scenario for the Delaware Bay that predicts losing 60 percent or more of intertidal shorebird feeding habitats by 2100 due to coastal changes and sea level rise.

Public Use
Requiring a leash on all dogs in designated areas of the beach will help to minimize impacts to feeding and nesting shorebirds.

Conclusion for Management Actions in Alternative A
Management actions under alternative A would have local short-term minor-to-moderate benefits and local long-term minor-to-moderate adverse impacts. Mosquito management associated with alternative A could lead to a negligible-to-minor local adverse impact on shorebirds, primarily through disruption of the invertebrate food supply. The conversion of the impounded wetlands to open water will reduce the mudflat habitat, resulting in a minor-to-moderate adverse impact to shorebird use of the refuge. This may be partly offset by the local minor-to-moderate benefit of sandy overwash areas created along the shoreline, as coastal processes are permitted to proceed unimpeded. The most notable potential adverse impact from public use under alternative A would result from the continuing lack of proactive public use management to protect shorebirds from disturbance.

Impacts to Shorebirds in Alternative B

Managing and Protecting Habitat
Reducing insecticide use through the reduction of the use of adulticides associated with mosquito control efforts will likely have minor-to-moderate beneficial impacts to local breeding shorebirds by reducing disturbance, especially along beach strand habitats, and reducing adverse impacts on non-target insect food resources and aquatic food webs.

Conserving and protecting insect and other invertebrates on refuge habitats provides direct beneficial impacts to migrating and wintering shorebirds that can exploit quality habitats during non-breeding periods of their life cycle. Insect nutrition is essential to the life cycle requirements of shorebirds. Forty-seven percent of all shorebird species are primary insectivores and 20 percent are partially insectivorous, with the dietary requirements dependent on other invertebrate species for the remaining shorebird species (Skagen and Oman 1996).

Under alternative B, the refuge proposes to implement a limited predator control program. Red fox, raccoon, gull, crow, rice rat, feral cat, and other species have been documented as effective predators upon nesting shorebirds, eggs, and chicks. Control will result in a minor-to-moderate beneficial impact on shorebirds that nest on the refuge. Some shorebirds, such as the federally threatened piping plover and colonial beach nesting bird populations, are especially vulnerable to loss of suitable nesting habitat due to high sensitivity to human disturbance. Given the plight of migratory birds, especially those requiring the limited beach or island nesting habitats, the refuge may utilize a predator management program to benefit these species. Predator management programs have proven effective elsewhere for sustaining or increasing avian productivity (Greenwood et al. 1990, Guillemette and Brousseau 2001, Lokemoen and Woodward 1993, Sanz-Aguilar 2009, USDA 2011, USFWS 1996, USFWS 2007e). Not permitting dog walking in the refuge will also minimize impacts to feeding and nesting shorebirds.

In conjunction with restoration of salt marsh in the refuge's impounded wetlands, natural coastal processes, such as the creation of overwash fans, will be permitted to occur unimpeded. This will eventually create valuable bayfront shorebird habitat, particularly in Unit II, suitable for foraging for many species of interest, such as red knots. Restoration efforts that promote more rapid sediment accretion, or involve the deposition of supplementary sediment such as from dredging, will create mudflats by increasing wetland elevation in areas where it has been lost through peat collapse. Such mudflats may mostly become vegetated with salt marsh plants, but some open areas would likely remain and would provide the minor local benefit of more suitable foraging habitat for shorebirds (ACOE 1996). Salt marsh restoration programs attempt to be timed to reduce impacts to wildlife, so much of this activity may be conducted outside of the breeding season.

The current salt water intrusion in Units II and III and the proposed restoration of salt marsh within refuge impounded wetlands, would likely increase open water habitats and decrease mudflat acreage relative to the freshwater impoundment management regime in alternative A, with minor local adverse impacts on shorebirds as mudflat habitats disappear. Restoration, such as the placement of supplementary sediment to restore elevation, may have site-specific and short-term adverse impacts. Where such activities occur, the presence of humans, equipment, and noise may displace birds from very discrete areas, and only temporarily (ACOE 1996). Galbraith (2002) stated the reductions in foraging habitat may lead to declines in shorebird numbers and summarized Evans and Pienkowski, which reported large reductions in shorebirds with the loss of mudflats. Eertman (2002) observed a decline in dunlins and oystercatchers as vegetation succession progressed where mudflats were reduced from 75 percent to 10 percent of the area.

Public Use
We expect impacts to shorebirds to increase due to proposed expansions in public use activities, including fishing, hunting, wildlife observation, wildlife photography, and environmental education and interpretation. Impacts are expected to be negligible and are mitigated by not allowing dog walking on the refuge. See the Waterfowl Section for more information on adverse impacts to shorebirds.

Conclusion for Management Actions in Alternative B
Management actions under alternative B would have a local short-term and long-term moderate impacts and opposing local short-term and long-term minor impacts. As with the other alternatives, mosquito management associated with alternative B could lead to a negligible-to-minor local adverse impact on shorebirds, primarily through disruption of the invertebrate food supply. The salt marsh restoration proposed under alternative B may also reduce the mudflat habitat that is made available to shorebirds through water level management in freshwater impoundments, resulting in a minor adverse impact to shorebird use of the refuge. This may be offset by the local moderate benefit of sandy overwash areas created along the shoreline as coastal processes are permitted to proceed unimpeded, and by the creation of new mudflat areas as restoration efforts attempt to increase elevation in areas that have converted to open water. Ultimately, shorebirds will benefit from the restoration of stable and healthy salt marsh habitats. Negligible adverse impacts may result from proposed public use but are mitigated by prohibited dog walking on the refuge. No impairment of the refuge's BIDEH is expected. The decline in shorebird numbers may result in a loss of diversity at the local level but the restoration of the impoundments provides biological integrity and diversity at the landscape level.

Impacts to Shorebirds in Alternative C

Managing and Protecting Habitat
Under alternative C, the management of freshwater impoundments and moist-soil management units would promote invertebrate production, which would provide critical protein-rich food resources required by shorebirds (Frederickson 1991). Shorebirds undergo processes each year (molt, migration, reproduction, etc.) that elevate their energy requirements and other nutritional needs. Moist-soil management programs help meet those needs (Frederickson et al. 1988). The percentage of protein composition of common invertebrates in moist soil impoundments, such as water boatmen, back swimmers, midges, and amphipods, ranges from 50 percent to more than 70 percent. Refuge management of moist-soil vegetation in freshwater impoundments and moist-soil areas would produce mudflat habitats with water depths ranging from 0 to 10 cm deep and invertebrate densities of greater than or equal to 4 gm/m^2. When water is discharged slowly from an impoundment or moist-soil unit, invertebrates are trapped and become readily available to birds foraging along the edge or in shallow water zones.

A potential adverse impact to shorebirds from alternative A stems from the fact that freshwater impoundment management would continue to be challenging, given changes in the coastline along the impoundment and increased storm activity, which lead to overwashes and saltwater intrusion periodically. When such intrusion occurs, peat collapse can lead to the conversion to open water of areas that previously functioned as mudflats, rendering them less suitable to shorebirds for foraging. The inherent instability of the freshwater impoundments could lead to minor adverse impacts to shorebirds, which would need to seek food resources elsewhere during such times.

Public Use
Proposed expansions in hunting opportunities are expected to cause more impacts to shorebirds in alternative C than those outlined in alternative A, but less than alternative B. All other types of recreation will have similar impacts to those in alternative A. Impacts are expected to be negligible.

Conclusion for Management Actions in Alternative C
Management actions under alternative C would have local minor-to-moderate impacts and opposing local short-term and long-term minor impacts. Freshwater impoundment management under alternative C would have a minor-to-moderate beneficial local impact on shorebirds through promotion of mudflats and invertebrate food resources. However, minor adverse impacts could also result from impoundment management, as it would be less reliable and more unstable, possibly resulting in the loss of mudflats during salt water intrusion events. As with the other alternatives, mosquito management associated with alternative C could lead to a minor local adverse impact on shorebirds, primarily through disruption of the invertebrate food supply. Negligible adverse impacts may result from proposed public use.

However, the continued conversion to open water may have negative impacts on the BIDEH of the refuge's coastal impounded marsh areas. Those wetlands that are unable to accrete sufficient substrate as sea level rises will rapidly convert to deep open water, and eliminate considerable acres of habitat for shorebirds.

Impacts on Landbirds

The conservation and management of wetland, upland shrub, and forested habitats is focused on conserving and benefiting migrating and breeding landbirds. We evaluated the management actions of each of the alternative proposals for their potential to benefit or adversely affect shrub, forested wetland, and upland habitats and their contributions to conserve and protect targeted focal landbird species (see inset).

We evaluated the benefits of our actions that would conserve or restore these habitat types and enhance the numbers of breeding and migrating focal species. The key actions include:

- Phasing out agriculture
- Restoring more acreage to trees
- Improving interior forests and wetland forests
- Conserving insect food resources
- Controlling invasive species
- Increasing public awareness and appreciation of refuge habitat management to benefit focal species and other landbirds that are found on the refuge
- Restoring salt marsh communities in impounded wetlands

Focal landbird species and their associated habitats include the following:

Forested upland (breeding species):

Wood thrush
Black and white warbler
Scarlet tanager
Kentucky warbler
Great crested flycatcher
Northern flicker
Whip-poor-will

Forested wetland habitats (breeding species):

Acadian flycatcher
Prothonotary warbler
Yellow-throated vireo

Early successional habitats (breeding species):

Prairie warbler
Blue-winged warbler
Brown thrasher
Whip-poor-will
Willow flycatcher
Eastern towhee
Field sparrow
Northern bobwhite
Henslow's sparrow

North Atlantic high and low marsh (breeding species):

Seaside sparrow
Salt marsh sharp-tailed sparrow
Coastal plain swamp sparrow

We also evaluated the potential of proposed actions to cause adverse effects on these same habitat types or dependent wildlife species:

- Public use disturbing wildlife
- Placement of facilities affecting habitat quality
- Mosquito control chemical use
- Chemical spraying to treat invasive species and mechanical treatments to maintain early successional habitats or improve forest stand quality

Impacts on Landbirds That Would Not Vary by Alternative

Managing and Protecting Habitat and Public Use
Area-sensitive focal landbird species will benefit from increasing forested patch sizes of current refuge forested areas. Forested landbirds would also benefit by the expansion of the widths of forested riparian and wetland buffer zones proposed under all three alternatives, which would create more habitat for roosting, foraging, breeding, or seeking cover. The treatment of invasive species proposed under all alternatives can be one source of potential disturbance to breeding landbirds during aerial or ground applications. Application of insecticides to refuge forested or emergent wetland habitats may reduce populations of non-target invertebrate species, have negative impacts to food webs, and therefore impact breeding landbirds. Passerines are primary insectivores, and measures taken to protect and conserve insects on the refuge could mitigate the potential adverse impacts of reducing nutritional resources required to sustain and increase landbird populations. Studies conducted along riparian zones during early spring migration have documented the importance of

adult chironomid swarms as a food resource for migrating landbirds (Smith et al. 1998, Smith et al. 2007).

Although much of the literature suggests that little to no impacts on bird species are sustained from open marsh water management construction, most bird species studied were generalists; there was little focus on obligate salt marsh bird species. However, research conducted in 2006 and 2007 focused on areas of the refuge with varying degrees of open marsh water management alterations, all conducted a number of years prior to the research being conducted. Study results suggested that marsh areas with extensive open marsh water management excavations and ditching have lower marsh bird community integrity. Heavily ditched and excavated open marsh water management areas were found to support lower breeding densities and abundance of seaside sparrows, as well as lower reproductive output (Pepper 2008). Areas with lower open marsh water management intensity may have more available breeding habitat than extensive sites. Limitations in the study design prevent any definitive cause-and-effect conclusion, which underscores the need for more research on the effects of open marsh water management on salt marsh obligate productivity.

There is concern about the impacts of open marsh water management on black rail, a species of concern associated with tidal high marsh, which prompted the state of Maryland to cease such management in the early 1990s (DNREC 2005). Circumstantial evidence from at least one site in Delaware supports this concern, and the issue warrants further study. No open marsh water management construction has been permitted on the refuge since 2002, and no new construction is proposed at this time. Any ongoing impacts from open marsh water management to the local ecology are limited to extant sites. The refuge considers maintenance of extant sites to pose minimal additional impact, if any.

Public Use

All of the alternatives predict some increase in annual visitation; however, the impact varies with the types of habitat management and visitor use in each alternative proposal. We can expect direct, adverse impacts on landbirds by disturbance wherever humans have access on the refuge, and the degree of that disturbance may vary depending on the type of habitat. In general, the presence of humans disturbs most wildlife, which typically results in temporary displacement without long-term effects on individuals and populations.

The location of recreational activities on the refuge will impacts species in different ways, depending on the bird's proximity to refuge trails. Miller et al. (1998) found that nesting success for landbirds was lower near recreational trails, where human activity was common, than at greater distances from the trails. A number of species have shown greater reactions when pedestrian use occurred off-trail (Miller 1998). Disturbance to landbirds in areas open to wildlife observation, photography, and fishing is expected to be negligible since all visitors are required to be on designated access routes. Some other species, such as wood thrush, will avoid refuge areas frequented by people, such as near trails and buildings, while other species, particularly highly social species such as tufted titmouse, Carolina chickadee, or Carolina wren, will likely be unaffected or even drawn to the human presence. For songbirds, Gutzwiller et al. (1997) found that singing behavior of some species was altered by low levels of human intrusion. When visitors approach too closely to nests, or go off the trail, they may cause the adult bird to flush, exposing the eggs to weather events or predators. Provided that visitor use is confined to refuge trails, which are not placed in area-sensitive habitat interiors, disturbance during the breeding season will be limited to the trail area. The extent of this disturbance on either side of the trail also depends on visibility and the density of vegetation through which the trail is laid.

Disturbance to non-hunted migratory birds could have local, regional, and flyway impacts. Regional and flyway effects would not be applicable to species that do not migrate such as most woodpeckers, and some songbirds including cardinals, titmice, wrens, and chickadees. The continual effects of disturbance to non-hunted migratory birds under this plan are expected to be negligible because the hunting season would not coincide with the nesting season. Long-term impacts that could occur if reproduction were reduced by hunting are not likely for this reason. Disturbance to the daily wintering activities of birds might occur, such as feeding and resting and are lessened by the establishment of sanctuary areas, seasonal closures, and hunting hour restrictions.

The limited amount of hunting resident game species on the refuge, such as turkey and quail does, may negligibly impact local populations, but does not have any regional impact on their respective populations due to their restricted home ranges. Delaware Division of Fish and Wildlife periodically reviews populations of all harvested resident species, and has determined that populations are adequate to support hunting efforts throughout the State. The refuge contributes minimally to the State's total harvest for resident game species. For example, the number of quail taken per year has been no more than 14 per year on the refuge in recent years (Table 5.9).

For migratory birds such as mourning dove, an estimated 36,300 birds were harvested in Delaware during the 2009 season (Table 5.10; Raftovich et al. 2011) when none were taken on the refuge. Similarly, very few snipe and woodcock were harvested. Direct, indirect, and cumulative impacts on these species on the refuge are negligible. See Impacts to Waterfowl for a description of how the Federal and State migratory bird hunting frameworks are established.

Table 5-9. Number of Upland Game, Small Game, and Webless Migratory Birds Harvested and Hunter Visits on Prime Hook NWR

Year	Dove Harvest	Snipe Harvest	Woodcock Harvest	Quail Harvest	Rabbit Harvest	Refuge Hunter Visits*
1996	110	0	0	5	83	126
1997	77	0	0	0	117	169
1998	30	0	0	0	46	112
1999	90	0	0	0	98	123
2000	13	0	0	0	29	81
2001	6	0	0	0	65	128
2002	58	0	0	0	163	114
2003	13	0	0	0	79	81
2004	12	0	0		75	53
2005	6	0	0	0	257	129
2006	20	0	0	14	115	106
2007	22	0	0	11	145	178
2008	0	0	1	10	176	171
2009	0	0	6	1	163	149

**Hunter visits include all species combined; majority are hunting rabbits*

Table 5-10. Comparison of Mourning Dove, Woodcock, and Snipe Harvest at Prime Hook NWR to State, Flyway, and United States Harvest in the 2009 Hunting Season

Harvest Area	Dove	Woodcock	Snipe
Prime Hook NWR	0	6	0
Delaware*	36,300	200	0
Eastern Management Unit*	7,639,200	63,300	43,600
United States*	17,354,800	238,400	83,500

**Harvest estimates from (Raftovich et al. 2011); Estimates for snipe are from the Atlantic Flyway*

The hunting of deer can be a beneficial impact to landbirds because the reduction of the vegetation's physical structure and diversity due to overbrowsing by deer also can negatively impact landbirds. Casey and Hein (1983) have found greatly reduced bird species diversity in areas with long term, high density populations of deer. These changes were mainly attributed to habitual landscape alteration with pronounced browse line and sparse cover caused by overbrowsing.

Impacts on Landbirds in Alternative A

Impacts on landbirds under Alternative A ("No Action") serve as a baseline for comparing and contrasting Alternatives B and C to the refuge's existing management activities.

Managing and Protecting Habitat
Allowing natural succession to continue across refuge upland landscapes, representative of a mixed hardwood forest matrix with a 10 to 20 percent shrubland component typical of Delmarva coastal plain ecosystem, will result in an increase in native vegetation communities available to migrating and breeding landbirds. However, the passive management approach will result in a potentially lower quality forest to occur in the next 15 years compared with alternative B, because desired forest conditions may not be met. Alternative A would also contribute to achieving Statewide landbird population objectives more than alternative C but not as much as alternative B.

Landbird species that prefer dense understory and early successional forest vegetation would experience direct benefits in the short term as agricultural fields and other open areas undergo a slower successional process to climax into woodland habitats. Breeding landbird species such as prairie warbler, blue-winged warbler, brown thrasher, whip-poor-will, willow flycatcher, eastern towhee, field sparrow, and northern bobwhite would gain additional acreage for a longer period of time compared to alternative B.

These breeding landbird species, plus other migrating landbirds, would receive maximum benefits as diverse flowering and fruiting shrub and young tree species develop during successional seral stages. Beneficial impacts to landbirds include the provision of a greater abundance of fruit and insect food resources during the migrating and breeding seasons compared to agricultural vegetation. Indirectly, the long term beneficial impacts for canopy forest birds would accrue beyond the 15-year planning horizon of this CCP, when successional forested habitats start to mature 45 to 75 years from now.

An increase in salt marsh acreage through passive return of salt marsh in Unit II and eventual conversion of Unit III, would benefit salt marsh obligate passerines, such as seaside sparrows and salt marsh sharp-tailed sparrows, which are of tremendous conservation concern. However, the restoration of tidal flow may initially increase the amount of surface water on a marsh and eliminate breeding habitat for birds that nest on or near the marsh surface. In the absence of active salt marsh restoration, there may be less habitat available for landbirds that breed in salt marsh wetlands, but which make only limited use of persistent open water areas.

Public Use
Beneficial impacts on landbirds from public use are the same as those described in Impacts on Landbirds That Would Not Vary by Alternative.

The presence of dogs accompanying refuge visitors may flush incubating birds from nests alongside trails (Yalden and Yalden 1990), disrupt breeding displays (Bayback 1986), disrupt foraging activity in shorebirds (Hoopes 1993), and disturb roosting activity in ducks (Keller 1991). Many of these authors indicate that people with dogs on a leash and loose dogs provoked the most pronounced disturbance reactions from their study animals. The greatest stress reaction resulted from unanticipated disturbance; animals show greater flight response to humans moving unpredictably than to humans following a distinct path (Gabrielsen and Smith 1995). Dogs that are unleashed or not under the control of their owners may disturb or potentially threaten the lives of some wildlife. In effect, off-leash dogs increase the radius of human recreational influence or disturbance. Continuing to restrict dog walking to the established trail and educating dog walkers on these expectations will reduce the potential disturbance of landbirds.

Conclusions for Management Actions in Alternative A
Management actions in alternative A would result in short-term local minor impacts, such as increased landbird use as former agricultural fields proceed through natural succession, but would also have opposing local minor-to-moderate impacts because the loss of marsh to open water would reduce habitat available for salt marsh obligate passerines. No impairment of the refuge's BIDEH is expected unless the impounded wetland areas revert to open water.

Impacts on Landbirds in Alternative B

Managing and Protecting Habitat
The direct benefits to landbirds would resemble those in alternative A, but there would be additional impacts due to the increase of 1,000 acres of restored native plant habitats as agricultural fields undergo reforestation or revert to shrubland and other early successional cover-types and other open areas are reforested to create two contiguous patches of 450 acres of mixed hardwood habitats. Native vegetation acreage increases enhance habitat connectivity on the refuge, enabling landbirds to move between habitat patches and subpopulations. Restoring and widening riparian buffer zones near water courses and wetlands with native shrubs and trees will provide direct beneficial impacts for both breeding and migrating landbirds. Reducing habitat fragmentation on refuge forested habitats will have direct impacts on forest interior dwelling landbirds by increasing breeding niches and occupancy rates.

We have considered how our proposed alternative actions can contribute to the continental population objectives of the North American Landbird Conservation Plan, as down-stepped to State population objectives. We identified refuge focal landbird species to manage for to help prioritize management actions with limited resources and maximizing beneficial impacts for landbird species with the greatest conservation need (Appendix D). The habitat management strategies and proposed conservation actions in alternative B would have direct beneficial impacts on State populations by providing habitat to help support Delaware-wide population objectives for numerous focal landbird species.

Effective management of forest interior breeding bird populations means effective management of forests in tracts large enough so different successional stages can occur (Anderson and Robbins 1981). Management for land birds and forests can be compatible provided it fits into a regional strategy to maintain the proper mixture of older and younger stands. Some approaches to forest management may need modifying to achieve forest conditions needed by interior specialists, but these modifications will not drastically alter current forestry management practices. There is no single management strategy that will benefit all species, and as Lynch and Whigham (1984) pointed out, almost any conceivable habitat enhancement strategy will have negative impacts on some species. As with all forest management activities, particularly concerning the removal of trees or wood products from the site, the implementation of best management practices would minimize or eliminate negative impacts on overall landbird communities. Whenever possible, forest alterations would not occur during the breeding season, due to the sensitivity of nesting birds to any disturbances. Because a combination of forest management techniques would be implemented as determined to be necessary for forest health, a combination of the following impacts would result.

Timber stand improvement techniques, such as thinning, that encourage or enhance understory development will be beneficial for certain forest interior birds, particularly those species that nest or forage in the shrub layer, such as hooded warbler (Whitcomb et al. 1981). Other species that may benefit include Louisiana waterthrush, prothonotary warbler, worm-eating warbler, and Kentucky warbler. There should be minimal negative impacts of light thinning on many of the forest interior specialists such as the red-eyed vireo, yellow-throated vireo, Swainson's warbler, and others (James 1976, Collins et al. 1982, Eddleman et al. 1980), because proposed canopy cover is >80%. Prescribed burning used throughout all forest cover types and age classes as a form of timber stand improvement, would have similar impacts on understory development, with the similar associated bird species responses.

Timber stand improvement practices that result in standing dead trees, or snags, will be beneficial for hairy and pileated woodpeckers, prothonotary warbler, and barred owl (Conner 1978, Evans and Conner 1979). Standing dead wood not only provides nesting sites for cavity nesters, but also acts as reservoirs for insects on which many forest interior species feed. Snags protruding above the forest canopy will be removed, as they serve as perches for nest predators and brown-headed cowbirds (Robbins 1979).

Regeneration cuts, involving the removal of most or all of the timber from an area, may be tolerated by many forest interior birds depending on the size and shape of the cut, number and type of trees left uncut, and rotation length. Webb et al. (1977) found that clearcutting caused overall population declines in only 1 of 9 forest interior specialists on their study areas in New York, while 3 species increased in numbers. Small or narrow clearcuts of 5 to 25 acres (2 to 10 ha) in larger woods may be tolerated by birds that accept a partially open canopy (Crawford et al. 1981). These include yellow-throated vireo, black-and-white warbler, worm-eating warbler, Kentucky warbler, hooded warbler, northern parula, and scarlet tanager. Bird species associated with more open woods, such as whip-poor-will, may tolerate even larger clearcuts.

Many warbler species are able to inhabit a clearcut area earlier if small trees are left uncut (DeGraaf 1992). Conner and Adkisson (1975) found hairy woodpeckers and hooded warblers utilizing a 3-year-old clearcut in Virginia when several hardwood trees 3 inches (7cm) dbh and greater were left at the time of cutting. They also found whip-poor-will, worm-eating warbler, and Kentucky warbler in a 7-year-old clearcut, and red-eyed vireo, black-and-white warbler, and scarlet tanager in a 12-year-old clearcut where small trees had been left during cutting. A regeneration cut does not need to grow to maturity before it is inhabited by forest interior birds. Birds such as `-scarlet tanager, Kentucky warbler, and black-and-white warbler, which are most abundant in medium-aged stands, may benefit from regenerating mature forests and allowing them to progress through this stage. However, Crawford et al. (1981) reported closed-canopy obligatory species, such as ovenbird and American redstart, would decline with any intermediate or harvest cutting that opens the canopy.

Selective cutting, such as single-tree selection, diameter-limit cutting, and group selection involves removal of fewer trees than in regeneration cuts, but harvesting may take place more often. While regeneration cuts generally produce even-aged stands, selective cutting tends to produce uneven-aged stands. Selective cutting may open the canopy to varying degrees or improve a closed canopy, with the understory vegetation density and bird response varying accordingly (Adams and Barrett 1976; Whitcomb et al. 1977). The practice of selective cutting is conducive to many forest interior birds.

Leaving uncut buffers along streams and roadsides benefits cavity nesters (Conner et al. 1975, Evans and Conner 1979) and other birds that use those habitats. Examples of such species are prothonotary warbler, Swainson's warbler, Louisiana waterthrush, and northern parula. Leaving dead, dying, and decaying trees standing and a 0.25-acre (0.1 ha) clump of trees permanently uncut in each 5 acres (2 ha) of clearcut will greatly benefit cavity-nesting birds (Conner et al. 1975, Conner 1978, Evans and Conner 1979).

As the canopy is opened through selective cutting, increased sunlight reaches the forest floor encouraging understory growth. As with certain timber stand improvement practices, this may enhance the habitat for species preferring moderate to dense shrub and understory levels. Whitcomb et al. (1977) found a greater number of territorial male hooded warblers and Kentucky warblers in a selectively logged area 4 and 5 years after cutting, compared to an undisturbed forest. Conversely, Adams and Barrett (1976) found fewer breeding pairs of Kentucky warblers in a selectively logged forest then in an undisturbed tract. They attributed this to the presence of more spicebush (*Lindera benzoin*) in the undisturbed forest, which Kentucky warblers selected to nest in. But, not all interior specialists will benefit from encouraging development of a moderate to dense understory. Whip-poor-will, Acadian flycatcher, and ovenbird prefer fairly open understories. Crawford et al. (1981) reported a decrease in black-and-white warbler populations with an increase in the density of shrubs 6 to 15 feet (2 to 5 m) tall. Species dependent on a closed canopy, such as Acadian flycatcher, ovenbird, and American redstart, may experience declines with selective cutting that opens the canopy. Red-eyed vireo numbers have also reported to decline in selectively logged forests (Adams and Barret 1976, Whitcomb et al. 1977). Forest interior birds that require an open understory may be negatively impacted by selective harvesting practices. Adams and Barrett (1976) found fewer Acadian flycatchers in a selectively logged woodland, but observed more ovenbirds. In contrast, Whitcomb et al. (1977) found fewer ovenbirds on their selectively logged study area than on their control site, which is the predicted response.

In general, forest management actions conducted to increase patch sizes with a greater diversity of species composition and structure of existing forest stands, reduce forest fragmentation by reforestation of certain areas, and improve forest health and biological integrity of existing forest stands will have beneficial long-term impacts on focal forest management bird species.

Temporary adverse impacts, particularly on migrating and wintering landbird species, would result from setting back succession and maintaining grassland and shrubland habitats, as when we burn prescribed fires and mow to remove biomass or set back succession, or brush-hog woody growth or spot-treat young trees and stumps in the winter months. However, staggering treatments between years can reduce disturbance factors for landbird-use during the late winter and early spring, and areas would be available again for breeding landbirds after winter treatments.

An increase in salt marsh acreage through restoration would benefit several high priority tidal creek and saltmarsh-dependent species, such as salt marsh sharp-tailed sparrows and seaside sparrows (USFWS2006), through an increase of nesting habitat (*Spartina*-dominated marsh) and foraging opportunities (estuarine fish). Other species, including but not limited to osprey, northern harrier, and belted kingfisher, will benefit from the restoration of foraging habitat. Although impounded marshes may support a greater diversity of birds, they represent unsuitable habitat for declining marsh species such as willets and seaside and saltmarsh sharp-tailed sparrows (Brawley). Burger (1982) noted that species restricted to salt marshes only occurred in unimpounded study sites. In addition, important stopover habitat would be created or restored for migratory birds. The restoration of the salt marsh would reduce storm surge and erosion impacts on upland forest habitats, which are especially critical habitats during the migration (Dawson and Buler 2010).

The restoration of tidal flow may initially increase the amount of surface water on a marsh and therefore eliminate breeding habitat for birds that nest on or near the marsh surface. Direct minor-to-moderate impacts to migratory birds may result from construction activities associated with disposal of dredge material for marsh restoration, such as the installation of temporary retention dikes to contain dredged material in shallow open water or low elevation marshes (USACOE 2010). Birds utilizing these areas would be temporarily displaced to adjacent habitats.

Efforts to reduce predation pressure on migratory birds of concern, especially to benefit species that nest on beaches and overwash habitats, would entail lethal removal of individual predatory birds from suitable nesting and brood rearing habitat. We have placed predatory birds within the landbird segment of this EIS, even though potential predatory birds are representative of several guilds, e.g., crows (American and fish), gulls (laughing, herring, ring-billed and great black-backed), grackles (common, boat-tailed), black-crowned night herons, great-horned owls and others. The removal of a few individual birds from within localized nesting areas would be designed to remove offending (problem) animals, and would have very limited impact on each avian predator population as a whole.

Public Use
Not permitting dog walking in the refuge is one action that will reduce impacts to landbirds.

We expect indirect impacts to landbirds to increase due to proposed expansions in public use activities including fishing, hunting, wildlife observation, wildlife photography, and environmental education and interpretation. Direct impacts to landbirds such as quail, woodcock, and snipe are expected to be similar to those in alternative A since no increase in upland game hunting is expected. Impacts are expected to be negligible.

The level of recreation use and ground-based disturbance from visitors would largely be concentrated at trails and other access points. This, combined with the addition of increased hunting opportunities, may have a negative effect on nesting bird populations. However, the hunting season (except for spring turkey hunt) is during the winter and not during most birds' nesting periods.

Turkey hunting is proposed only if a huntable population is found to exist, which will be determined through coordination with the Delaware Division of Fish and

Wildlife. Turkey hunting, which occurs in April and May, is expected to negligibly affect non-target wildlife since only a very small number of hunters (≤5) will be permitted to hunt in 3,472 designated acres of the refuge.

Conclusions for Management Actions in Alternative B
Management actions in alternative B would result in short- and long-term local moderate-to-major impacts, such as increased landbird use by restoring and protecting wintering and migrating habitat and restoring a large acreage of salt marsh habitat for landbird species of conservation concern. However, it would also have opposing local short-term minor impacts during management or restoration efforts. No impairment of the refuge's BIDEH is expected unless the impounded areas revert to open water, which would have a negative effect on diversity and biological integrity. Through the restoration of the impounded marshes to salt marsh, the refuge may be sacrificing diversity at the local scale for biological integrity and diversity at the regional or landscape scale.

Impacts on Landbirds in Alternative C

Managing and Protecting Habitat
The direct, long-term benefits for landbirds under Alternative C stem from the availability of 775 acres of mature upland forested cover-types with some patches greater than 250 acres for area-sensitive forest interior dwelling bird species in addition to 2,200 acres of salt marsh habitats, 1, 238 acres of forested wetland habitats, and some early successional habitats that would have beneficial impacts on focal species of breeding landbirds. All these habitat cover-types are also suitable for migrating and wintering landbirds. Indirect beneficial impacts for continental landbird populations would be the continued refuge contribution to State and regional populations to sustain healthy populations over the long term.

Alternative C's management of upland fields using cooperative farming would render 600 acres of potential native forest or early successional habitats unavailable for focal breeding grassland, shrubland-dependent, or forest-interior dwelling landbird species and migrating and wintering landbirds. The cooperative farming program in alternative C involves the use, as approved, of glyphosate-tolerant corn and soybeans. This is considered by most experts to be less toxic to wildlife than other herbicide technologies employed by farmers. However, the use of these crops can affect landbirds indirectly by altering habitat and food sources, such as by reducing weed seed biomass or changing weed species composition (Cerdeira and Duke 2006).

Public Use
Proposed expansions in hunting opportunities are expected to cause more impacts to landbirds in alternative C than those outlined in alternative A, but fewer than alternative B. All other types of recreation will have similar impacts to those in alternative A. The reduction in hunting days for deer and waterfowl will decrease disturbance to landbirds from that in alternative B.

Conclusions for Management Actions in Alternative C
Management actions in alternative C would continue to result in short-term local minor impacts, such as continued landbird use by providing wintering and migrating habitat, but it would also have local long-term minor-to-moderate opposing impacts by limiting some upland areas from use by landbirds, and by limiting habitat available for salt marsh obligate passerines. No impairment of the refuge's BIDEH is expected.

Impacts on Secretive Marsh and Waterbirds

As previously mentioned, marsh management and conservation are compelling priorities for the refuge as reflected in our wetlands habitat management goals 1 and 3. Each refuge alternative has included an emphasis on wetlands in the objectives and strategies. Focal species include Virginia rail and least and American bitterns.

We evaluated the benefits of the following actions for their potential impact on open water and wetland habitats for secretive marsh and waterbirds:

- Maintaining quality migrating and wintering habitats for waterbirds (September to March)
- Conserving insect and other invertebrate food resources to provide high quality habitats for breeding secretive marsh and waterbirds
- Managing 800 acres of shallow water habitats (5 to 15 inches deep) within patches of perennial wetland plants that also support fish, aquatic invertebrates, amphibians, and other prey food sources for nesting bitterns, coupled with drier marsh areas required by rails during summer for brood foraging
- Managing to prevent and control the growth and proliferation of invasive plant species
- Restoring salt marsh communities within Unit II
- Invasive species treatments that might adversely affect nesting and migrating waterbirds
- Activities of visitors and users that might directly impact wetland habitats or disturb breeding focal species (rails and bitterns) or migratory waders

Impacts on Secretive Marsh and Waterbirds That Would Not Vary by Alternative

In addition to gradual losses of wetland acreage due to sea level rise and climate change, we expect any impacts on secretive marsh and wader habitats would most likely result from changes in local vegetation, water quality, flood, droughts, direct human disturbance, or an influx of invasive species.

Managing and Protecting Habitat
Across all of the alternatives, controlling invasive plant species will increase the availability of preferred nesting substrate and associated insects of native plant communities for forage during breeding season periods.

Most invasive plant treatments would occur in late August and September, which would preclude any impact to breeding secretive marsh birds or waders. By that time most waterbirds have completed their breeding cycles, and disturbance factors due to spraying activities would be minimal.

Insecticides used in refuge wetland habitats may have adverse impacts on insects and other non-target invertebrates important for breeding, secretive marsh birds like black rail, clapper rail, Virginia rail, least bittern, and American bittern. To the extent that secretive marsh birds and waders consume non-target aquatic and terrestrial insects, the birds may experience negligible-to-minor reduction in food availability under all three alternatives. The degree to which adulticides and larvicides will impact food resources will likely vary by time, location, chemical used, concentration, treatment interval, and number of treatments. The ability of these birds to move to alternate feeding sites or shift their diet within the treatment site to alternative food resources is unknown. Certainly, fish or crustaceans available will be readily consumed. However, site-specific indirect impacts to pre-fledging secretive marsh birds, in particular, are unknown. Mosquito spraying activities that commence in April and end in October can also have site-specific adverse disturbance impacts from both monitoring and spraying activities.

There is concern over the impacts of open marsh water management on black rail, a species of concern associated with tidal high marsh, which prompted the state of Maryland to cease open marsh water management in the early 1990s (DNREC 2005). Circumstantial evidence from at least one site in Delaware supports this concern, and the issue warrants further study. No open marsh water management construction has been permitted on the refuge since 2002, and no new construction is proposed at this time. Any ongoing impacts from open marsh water management to the local ecology are site-specific, and limited to extant sites. The refuge considers maintenance of extant sites to pose negligible additional impacts to secretive marsh and other waterbirds, if any.

Public Use

Resident waterbirds tend to be less sensitive to human disturbance than are migrants, and thus will be less impacted by disturbance from public use on the refuge. However, wading birds have been found to be extremely sensitive to disturbance in the northeastern U.S. and may be adversely impacted by disturbance from public use on the refuge (Burger 1981). The impacts of intrusion through public use are generally negligible for this group of birds, but can vary by species and between years (Gutzwiller and Anderson 1999).

Direct disturbance to secretive marsh birds and waders from waterfowl hunting would start in September and usually end in January. Waterfowl hunting pressure may disturb migrating or wintering waterbirds, but these negligible impacts would be mitigated by bird sanctuary areas that secretive marsh birds and waders would utilize to avoid hunting disturbance factors.

Visitors at designated fishing areas may flush wading birds and secretive marsh birds that are within view of a trail, boat launch, beach, or pier. We anticipate less public use at these locations in the winter.

Bank fishing by anglers is restricted to designated areas off State-maintained highways at Slaughter Creek, Slaughter Canal, and Petersfield Ditch. These areas are also accessible to wildlife observers and photographers. Higher rates of public use would occur during the warmer months, but there are protected and secluded areas nearby where disturbed birds can relocate. Adverse impacts resulting from disturbance are therefore anticipated to be minor, temporary, and infrequent.

A potential direct adverse impact exists for wetland and open waterbird species, such as osprey, herons, and waterfowl, from lost fishing gear, specifically, hooks, lures, and litter become entangled in fishing line or hooks and ingestion of lead sinkers are sources of concern throughout the region. The extent to which these bird species are currently impacted by fishing tackle is unknown. Discarded fishing line and other fishing litter can entangle migratory birds and marine mammals, causing injury and death. We will continue to work with our fisheries assistance office and the State in implementing a public education and outreach program on these issues. Increased law enforcement is also planned.

For additional impacts, refer to the previously discussed section on Impacts to Waterfowl.

Impacts to Secretive Marsh and Waterbirds in Alternative A

Impacts on secretive marsh and other waterbirds under Alternative A (“No Action”) serve as a baseline for comparing and contrasting Alternatives B and C to the refuge’s existing management activities.

Managing and Protecting Habitat
Permitting the natural return of salt marsh into the degraded impounded wetlands may potentially result in an increase of open water, which could increase foraging areas used by long-legged wading birds such as great blue heron, great egret, snowy egret, and glossy ibis. This minor beneficial impact would be local and potentially short-term, as salt marsh vegetation may eventually colonize open areas. Shorter-legged birds may be displaced by the higher water levels likely to occur under alternative A, and may experience a decrease in food availability. The vegetation and water quality will be changed unless and until the salt marsh system is established.

Public Use
Same as those discussed in Impacts to Secretive Marsh Birds and Waterbirds That Would Not Vary by Alternative.

Conclusions for Management Actions in Alternative A
Management actions in alternative A would result in minor-to-moderate local long-term adverse impacts and minor local beneficial impacts. No restoration or management of the marsh will likely increase the amount of open water and many areas will be eliminated for potential nesting sites for water birds. There would be minor local increase in foraging habitat for wading birds with the increased surface water available. Under the existing conditions of sea level rise and insufficient marsh accretion, we would anticipate local adverse impacts to waterbirds sometime in the future. As full daily tidal flow continues to impact the impounded wetlands, the vegetation composition, water quality, fish, invertebrate, and amphibian populations will be changed as the transition from fresh water to salt water takes place, potentially decreasing the food available for waterbirds.

Impacts to Secretive Marsh and Waterbirds in Alternatives B

Managing and Protecting Habitat
Secretive marsh and waterbirds nesting in the vicinity of beach and overwash habitats would likely have short-term direct benefits from the proposed active removal of predators.

Active restoration of salt marsh will benefit certain secretive marsh bird and waterbird species, such as clapper rails and willets. With the reintroduction of saltwater into the freshwater areas, some trees may die along the adjacent uplands, providing possible nesting habitat for wading birds such as herons and egrets. In addition, with reestablished tidal flow, fish can enter into the shallow waters and provide food to wading birds.

However, restoration of some areas from freshwater marsh to salt marsh may impact other secretive marsh bird species that prefer freshwater wetlands, such as bitterns and sora, to the extent they are present in refuge wetlands. Initially the restoration process will potentially have local adverse impacts for all secretive marshbirds and waterbirds in the area. The direct human disturbance, presence of construction equipment, presence of people, and noise may cause secretive marshbirds and water birds to temporarily leave the restoration area (ACOE 1996). Salt marsh restoration programs attempt to be timed to reduce impacts to wildlife, so much of this activity may be conducted outside of the breeding season.

Public Use
Disturbance to secretive marsh birds and waders from hunting would start in September and usually end in January, unless hunting is allowed during the snow goose conservation order into mid-April. This disturbance may have direct effects on migrating and wintering secretive marsh birds and waders. However, these birds would receive added benefits from the establishment of new sanctuary

areas or zones, where 3,000 acres would be protected from hunting activities that cause disturbances to secretive marsh and waterbirds.

In addition to alternative A, we expect adverse impacts to secretive marsh and waterbirds to increase due to proposed expansions in public use activities including fishing, hunting, wildlife observation, wildlife photography, and environmental education and interpretation. Impacts are expected to be negligible. An increase in the number of hiking trails and new areas open to fishing and hunting, particularly in or near wetland areas, has the potential to increase disturbance to secretive marsh and waterbirds.

Conclusions for Management Actions in Alternative B

Management actions in alternative B would result in both short-term local minor impacts and opposing long-term local moderate impacts. The long-term impact would result from the sustainable salt marsh habitat provided to the local secretive marshbirds and waterbirds. However, actively restoring the freshwater system to a sustainable tidal salt marsh will change the vegetation composition and initially cause an increase in the amount of surface water and decrease the amount of breeding habitat on the marsh surface (Brawley et al. 1998), at least for the short-term.

Alternative B will also achieve a higher biological diversity of species and healthier natural structure and function of the marsh through the reestablished tidal exchange, which will ultimately improve habitat conditions for most secretive marsh birds and wading birds on the refuge. The restoration of the salt marsh may reduce diversity at the local scale but help maintain diversity and biological integrity at the landscape scale.

Impacts to Secretive Marsh and Waterbirds in Alternative C

Managing and Protecting Habitat

Secretive marshbirds and waterbirds would use the freshwater impoundments for migrating and wintering habitat. Alternative C would continue to provide appropriate structural habitat characteristics for waders and secretive marsh birds by managing shallow freshwater habitats within patches of annual and perennial wetland plants that also support fish, aquatic invertebrates, amphibians, and other prey food sources for nesting bitterns, coupled with drier marsh areas required by rails during summer for brood foraging. However, alternative C would provide unfavorable habitat for salt marsh species such as clapper rail and willet.

Public Use

Proposed expansions in hunting opportunities are expected to cause more impacts to secretive marsh and waterbirds in alternative C than those outlined in alternative A, but less than alternative B. All other types of recreation will have similar impacts to those in alternative A. Impacts are expected to be minimal. The reduction in hunting days for deer and waterfowl, the closure of Unit IV salt marshes to waterfowl hunting, and the closure of Prime Hook Creek to waterfowl and deer hunting will decrease disturbance to secretive marsh and waterbirds from that in alternative B.

Conclusions for Management Actions in Alternative C

Management actions in alternative C would result in short-term local minor impacts, such as continued impoundment use by providing wintering and migrating habitat, but would also have opposing local minor-to-moderate impacts causing the naturally occurring salt marsh-dependent species to be displaced from the freshwater area. During times when the artificial dunes are breached and saline water enters the freshwater system the vegetation composition, water quality, fish, invertebrates and amphibian populations will be impacted, and potentially decrease the food availability for waterbirds.

Impacts on Mammals

We evaluated the management actions and public uses for each of the alternative proposals for their potential to beneficially or adversely affect large and small aerial, terrestrial, or wetland mammals:

- Conserving wetland and upland habitats
- Controlling invasive plant species or restoring native plant communities
- Managing and maintaining early successional habitats (grasslands and shrublands) using prescribed fire, brush-hogging, and other mechanical treatments
- Managing deer populations with hunting
- Controlling beavers and nutria
- Managing and protecting federally and State-listed beach-nesting birds from mammalian predators

Impacts on Mammals That Would Not Vary by Alternative

Managing and Protecting Habitat

The management actions that hold potential for minor-to-moderate beneficial impacts on mammals, and that would continue regardless of the alternative we select, are our strategies for conserving and maintaining biological integrity, diversity, and environmental health, restoring native plant communities, improving habitat conditions for the endangered Delmarva fox squirrel, and controlling invasive or nuisance species. Each of these actions directly or indirectly benefits mammalian populations over the long term by ensuring the continuation of quality natural habitats on the refuge for resident and migratory (bats) mammalian wildlife.

Habitat enhancement and creation of large continuous tracts of forested habitats and outreach programs to the public on our conservation practices are the best strategies for ensuring the continued availability of quality forest, riparian, early successional, and wetland habitat conditions for mammals. The carrying capacity of each of these habitat types with respect to the 34 native species of mammals found on the refuge will depend on the size of each tract, vegetation composition, corridor connectivity, surrounding land uses, weather patterns, availability of food resources, and the interactions of mammals with these habitats.

Some mammals exert a greater influence than others when considering mammalian-habitat relationships. For example, the largest mammalian species on the refuge, white-tailed deer, has been identified as a significant ecosystem engineer that plays a large role in physically structuring its habitat (Baiser et al. 2008). Native forested habitats in the eastern U.S. evolved with deer densities of approximately 20 per square mile. When densities exceed 25 per square mile or roughly one deer per 25 acres, signs of habitat degradation begin to appear (DeCalesta 1994). Continued management of the refuge deer herd through hunting will reduce these habitat impacts for the benefit of all terrestrial mammals, including deer, and other wildlife.

Controlling invasive plant species, particularly those that quickly colonize an area and form dense, monotypic stands, will benefit mammals by maintaining the balance of food resources and native vegetative communities with which they evolved or adapted to for cover, nesting, and diverse quality food resources.

For smaller, insectivorous mammals, maintenance of native plant diversity and structural integrity by controlling invasive species will have a particular impact because those species rely on the biodiversity and availability of invertebrate food resources that are only associated with native floral assemblages.

Wetland mammals such as marsh rice rat, muskrat, beaver, and river otter benefit through our conservation and management of forested wetlands, bottomlands, and emergent wetland habitats, while the remaining 29 native species will thrive where the composition of refuge forests contains a diversity of mast-bearing species and other mixed hardwood resources. At the time of this writing, the population size of non-native mammals on the refuge are so small as to have negligible impact on any of the refuge's habitats or other mammal populations.

Occasional control of beavers where they are girdling and felling swamp cottonwood (*Populus heterophylla)* trees in coastal plain habitats would have only a negligible and local impact on the beaver population. Additionally, on occasion beavers and muskrats will be controlled where there is localized damage to refuge infrastructure, e.g. damage to dikes, or flooding of neighboring private property from within the refuge. Individual animals will be impacted, but the population as a whole will experience no long-term adverse impacts because these species are well-established statewide and beyond.

Public Use
In general, the presence of humans will disturb most mammals, which typically results in indirect negligible short-term adverse impacts without long-term effects on individuals and populations.

Adverse impacts on resident game populations from hunting would be negligible. The Delaware Division of Fish and Wildlife periodically reviews populations of all harvested resident species and has determined that populations are adequate to support hunting efforts throughout the State. Hunter visits and harvest of upland and small game such as rabbit on the refuge have been relatively low and thus impacts are expected to be negligible. The refuge does not allow hunting of eastern gray squirrel to minimize conflicts with endangered Delmarva fox squirrel.

Overall impacts from hunting on non-hunted mammals, such as voles, moles, mice, shrews, and bats, are expected to be negligible. Since small mammals are less active during winter when hunting season occurs, and since these species are mostly nocturnal, hunter interactions with small mammals are very rare. Vehicles are restricted to roads and harassment or taking of any wildlife other than legal game species is not permitted. Except for some species of migratory bats, these species have very limited home ranges and hunting would not affect their populations regionally. Impacts of hunting to migratory bat species would be negligible. These species are in torpor or have completely passed through Delaware by peak hunting season in November through January. Some hunting occurs during September-October and March-April when these species are migrating; however, hunter interaction would be commensurate with that of non-consumptive users.

The Delaware Division of Fish and Wildlife recently finalized a new statewide 10-year deer management plan (Rogerson 2010). The plan was created with input from a 22-member advisory group, a public phone attitude survey, a mail survey to hunters, comments solicited from the general public, and technical reviews from deer experts outside the division. The resultant plan identifies population objectives based on habitat capability and societal tolerances.

Prime Hook NWR is located in the State's deer management zone 9, which encompasses the northeastern coastal portion of Sussex County (Rogerson 2010). The Division of Fish and Wildlife manages deer populations, in part, through recreational hunting. Based on their monitoring programs, the Division of Fish and Wildlife adjusts hunting levels in terms of season length, sex ratio in the harvest, and number of hunters (tag availability) to move population levels toward desired objectives. Of course, other factors such as disease, severe weather, predation, and automobile collisions influence mortality are taken into account by annual monitoring.

Delaware deer herd statistics indicate that the deer density in zone 9 was estimated in 2009 at 22.5 deer per square mile with a variability of plus or minus 20.75 percent (Rogerson 2010). This is a decrease of 58 percent from the 2005 estimated density of 39.2 deer per square mile (Rogerson 2010). The total Statewide post-hunting season deer population in 2005 was estimated at 37,563 deer, while in 2009 it was estimated at 31,071 deer, a 17.3 percent Statewide reduction. Major land use changes over the last 100 years have created a deer herd that exceeds normal deer densities of 10 to 20 deer per square mile.

High deer numbers are associated with crop damage, reduction of some forest understory species, and reduction of reforestation seedling survival, which all impact habitat that is important for a variety of wildlife. White-tailed deer hunting is the single most important public use on the refuge that would impact mammals, including deer, and other forest-dependent wildlife. It serves both as a wildlife-dependent recreational use and a method to reduce and stabilize deer densities. This benefits other mammals, including the endangered Delmarva fox squirrel.

Based on a nationwide survey of all states (Krausman 1992), deer populations are effectively controlled with hunting and habitat manipulation in many areas where they were overpopulated. In a 10-year study in northwestern Pennsylvania examining the impacts of varying densities of deer on deer health and habitat, starvation mortality resulted when densities reached higher than 25 deer per square kilometer (247 acres). Also, no prevention or control of epizootic hemorrhagic disease exists to date except by keeping populations below the carrying capacity of their habitats. Such breakouts have occurred on the refuge in the past. Based on these considerations, it is anticipated that hunting would have short-term and long-term minor-to-moderate beneficial impacts on deer health and quality and habitat condition.

Hunting resident game species on the refuge, such as deer, will result in negligible impacts on their populations because of their restricted home ranges. The refuge contributes negligibly to the State's total harvest for resident game species (figure 5.1 and tables 5.11 and 5.12). For example, since 1999, deer harvest at the refuge has ranged from 0.8 percent to 1.5 percent of Delaware's total deer harvest each year. The current harvest level of deer on the refuge (107) has a negligible impact on the Statewide deer population of 31,071 deer (Table 5-12). Given the low numbers of animals harvested from the refuge in respect to the total Statewide harvest and deer population, no cumulative impacts to local, regional, or Statewide populations of white-tailed deer are anticipated from allowing hunting of the species on the refuge. Additional information on the status of the Delaware deer herd and the Delaware hunting program can also be found in the Refuge Hunt Plan (appendix C).

Figure 5-1. Delaware Annual Deer Harvest 1954 to 2008/09 Seasons (Rogerson (2010)

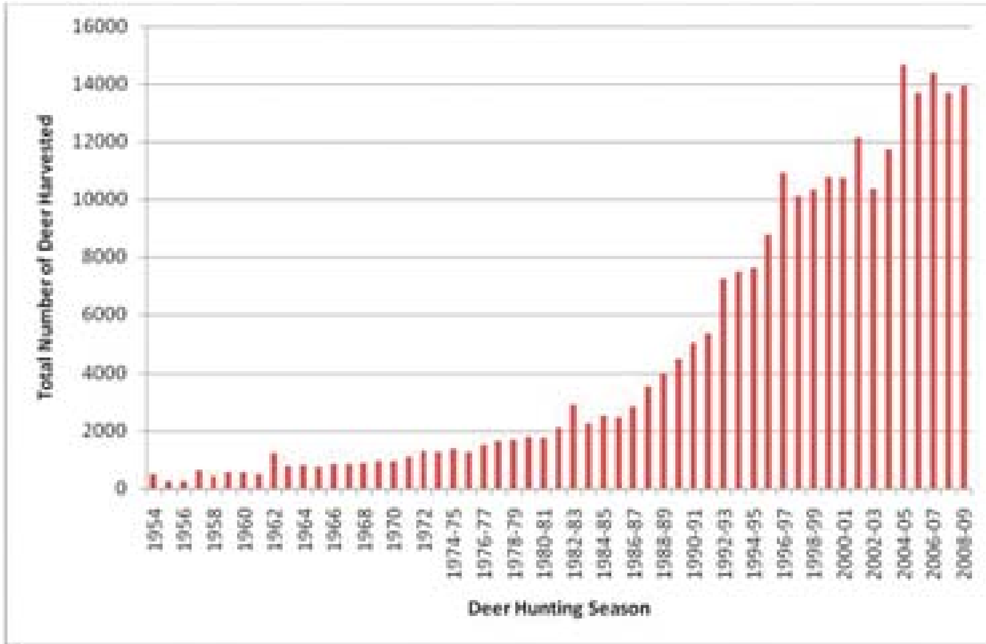

Table 5-11. Number of Deer Harvested and Hunter Visits on Prime Hook NWR Compared to Statewide Harvest

(Source: DNREC 2010b, refuge harvest data, *http://www.dnrec.state.de.us/fw/deer.pdf*; *http://www.fw.delaware.gov/Hunting/Documents/2007-08%20Historical%20Delaware%20 White-tailed%20Deer%20Summary.pdf*;accessed February 2012.)

Year	Statewide Deer Harvest	Refuge Deer Harvest	Refuge Hunter Visits
1988	3,998	141	1,289
1989	4,504	155	1,131
1990	5,066	178	1,689
1991	5,336	163	1,703
1992	7,245	257	1,608
1993	7,465	219	1,616
1994	7,615	169	1,568
1995	8,781	217	1,184
1996	10,915	221	1,326
1997	10,091	187	1,510
1998	10,312	138	1,335
1999	10,756	114	870
2000	10,741	125	941
2001	12,133	188	1,003

Year	Statewide Deer Harvest	Refuge Deer Harvest	Refuge Hunter Visits
2002	10,357	160	913
2003	11,712	175	891
2004	14,669	143	841
2005	13,670	133	884
2006	14,401	120	825
2007	13,369	108	790
2008	13,926	106	670
2009	12,400*	107	552

Table 5-12. Cumulative Impacts of Existing Deer Hunting on Prime Hook NWR/State Deer Management Zone 9 (2009 to 2010 data) Compared to Statewide Harvest

Hunt Location and Type	Harvest
Prime Hook NWR	107
State Deer Management Zone 9	767
Statewide Harvest (all 17 Deer Management Zones)	12,400

Delaware permits hunting for red fox, which assists State management efforts in reducing the incidence of mange outbreaks to maintain a healthy population and reducing the predatory impact of this species on migrating and breeding birds, particularly State and federally endangered or threatened species. Hunting would be opportunistic in most cases. In other states, the incidental harvest of fox occurs during other open seasons such as deer season and the pelts are often retained for personal use. Though no county-specific data are available, healthy populations of fox exist in the State and anticipated harvest rates would result in negligible impacts to local or State populations (Reynolds, personal communication 2010).

Impacts on Mammals in Alternative A

Impacts on mammals under Alternative A ("No Action") serve as a baseline for comparing and contrasting alternatives B and C to the refuge's existing management activities.

Natural conversion of upland fields to early successional habitat and forest cover would impact mammals by increasing natural habitat availability. Short-term and long-term minor-to-moderate beneficial impacts are expected for mammals such as voles, moles, shrews, mice, rabbits, groundhogs, and deer with increased acreage of these natural habitat types.

Bats will utilize managed open habitats on the refuge for nighttime aerial foraging as these habitats have high abundances of insect prey species. Grasslands, shrublands, wet meadows, and marshes that lie close to refuge forests where bats roost will provide critical foraging habitats. Upland forest-dependent mammals, especially Delmarva fox squirrel, would experience long-term moderate beneficial impacts due to increases in forest cover, although desired forest conditions may not be met as quickly or readily as under Alternative B. Bats also would gain increased roosting habitat when trees mature enough to form cavities and crevices in their bark. Along riparian buffer zones, increased forest cover would benefit otter, mink, weasel, and beaver