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

Indirect short-term and long-term minor-to-moderate beneficial impacts would result from the long-term persistence of patches of grasslands across the refuge landscape. Such habitat patterns contribute to the enhanced survival and population growth of small mammals with limited home ranges. A continuous supply of palatable herbaceous plants also contributes to the overall health of the deer herd. Carnivores and omnivores such as fox, skunk, mink, long-tailed weasel, coyote, opossum, and raccoon, which feed on small mammals, will thrive at the interface between refuge field and forest habitats.

Conclusions for Management Actions in Alternative A

Passive habitat management associated with alternative A would result in short-term and long-term minor-to-moderate direct impacts to mammals through increases and improvements in natural habitats Hunting provides short-term and long-term minor-to-moderate impacts on deer herd health and forest-dependent wildlife, such as the Delmarva fox squirrel, by stabilizing deer densities and enhancing forest health. Alternative A would contribute negligible short-term, site-specific, local, and regional adverse impacts on hunted and non-hunted species.

Impacts on Mammals in Alternative B

Managing and Protecting Habitat

Overall, beneficial impacts to mammals would be the same as under Alternative A, although desired forest conditions most suitable for the Delmarva fox squirrel would be achieved sooner and more effectively.

Early successional habitat maintenance activities such as brush-hogging and burning prescribed fires carry a direct risk to some individuals among small mammals, but the adverse impacts are short-term and negligible at the population level. These activities never occur more than once a year in a given area and rarely during the breeding season. Most mammals can scurry out of the way or escape underground. Fire flashes across fields quickly, often burning only the top few centimeters of duff. Small mammals such as mice, shrews or voles escape injury. In addition, back-burning or stripping prescribed fire techniques used to better manage and control the rate of spread and intensity of heat provide opportunities for most non-burrowing mammals to flee.

Sometimes the removal of native mammalian predators is necessary to increase post-breeding numbers of targeted endangered, threatened, or rare beach-nesting shorebird species. Shorebird eggs and chicks are highly susceptible to depredation by numerous mammalian species, especially raccoons, foxes, feral and domestic cats, and dogs. Some form of mammalian predator management and control will be required to conserve these bird species locally and help achieve refuge bird nesting conservation and productivity objectives listed in alternative B goals and objectives. Predator management alternatives include lethal and non-lethal predator control. Lethal control of predators can be very controversial, time consuming, and temporary (USFWS 1988). The lethal removal of a few individual mammals from such localized areas would have a negligible adverse impact on the population as a whole.

The use of non-lethal methods, such as electric fencing, metal barriers, and wire mesh enclosures, will impact mammals by interfering with normal foraging behavior. However, non-lethal techniques will not promote self-sustaining bird populations in the long term because it does not eliminate predators (Johnson and Oring 2002).

Public Use

We expect negligible-to-minor short-term adverse impacts to mammals due to proposed expansions in public use activities, including fishing, hunting,

wildlife observation, wildlife photography, and environmental education and interpretation. The level of use and ground-based disturbance from visitors would be largely concentrated at trails and other access points, which consist of previously maintained interior roads and access routes. Despite increased opportunities for hunting, hunter participation on the refuge and in the State is decreasing. Direct short-term, long-term, and cumulative adverse impacts to mammals are expected to be negligible.

Conclusions for Management Actions in Alternative B

Management actions in alternative B would result in short-term and long-term minor-to-moderate direct impacts to mammals through increases and improvements in natural habitats. Alternative B would contribute negligible-to-minor short term indirect adverse impacts from expansion of public use, negligible-to-minor indirect adverse impacts from removing protective cover through maintenance activities such as mowing, forest management activities, or prescribed fires, and negligible short-term, long-term, and cumulative impacts due to hunting. Alternative B contributes to the BIDEH of the refuge through habitat improvement and enhanced natural ecological processes which will improve the quality and quantity of soil, water, plant, and invertebrate resources that should benefit healthy and thriving mammalian populations.

Efforts to reduce predation pressure on migratory birds of concern, especially to benefit species that nest on beaches and overwash habitats, would entail a combination of non-lethal control methods and lethal removal of individual mammals from suitable nesting, brood rearing, or foraging habitat. The removal of a few individual mammals from such localized areas would have negligible-to-minor adverse impacts on refuge populations as a whole of raccoons or gray or red foxes.

Impacts on Mammals in Alternative C

Managing and Protecting Habitat

Overall, alternative C would have the same impacts as reviewed in Impacts on Mammals That Would Not Vary by Alternative. In addition, 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, especially regarding mammalian toxicity, than other herbicide technologies employed by farmers. However, the use of these crops can affect wildlife indirectly by altering habitat and food sources, such as by reducing weed seed biomass or changing weed species composition (Cerdeira and Duke 2006). Some mammal species may feed on waste grain in refuge farm fields, although this is negligible as a food resource.

Public Use

Impacts to mammals from hunting will be similar to those in alternative B and impacts from other public uses will be similar to those in alternative A.

Conclusions for Management Actions in Alternative C

Management actions in alternative A would result in indirect long-term minor-to-moderate benefits to mammals by ensuring the continuation of quality natural habitats on the refuge for resident and migratory mammalian wildlife through strategies for BIDEH, restoring native plant communities, improving habitat conditions for the endangered mammal, and controlling invasive or nuisance species. For hunting and all other public uses, alternative C would have impacts on mammals similar to alternative A. Alternative C contributes to the BIDEH of the refuge through habitat improvement.

Impacts to Reptiles and Amphibians

The conservation and protection of the refuge's reptiles and amphibians, collectively referred to as herpetofauna, is another wildlife management priority, which fits into all alternative goals and objectives for wetland, upland, and riparian habitats. Reptile and amphibian conservation management principles

endorsed by Partners in Amphibian and Reptiles Conservation (PARC) will promote the sustainability and health of herpetofauna on refuge lands.

We evaluated the impacts of the following actions on the refuge's herpetiles species and communities:

- Augment forested habitat patch sizes and increase connectivity between patches.
- Expand riparian and wetland buffer zones.
- Managing habitat by mowing, brush-hogging and prescribed fire burning
- Restoration of freshwater impoundments to salt marsh
- Control of invasive plant and animal species.
- Public outreach and education on PARC habitat management guidelines and conservation practices
- Mosquito control
- Disturbing wildlife by recreation activities

Impacts on Reptiles and Amphibians That Would Not Vary by Alternative

Improving and enhancing existing habitat types to augment their patch size and connectivity, restore at least some areas to native vegetation, ensure adequate forest buffers around wetlands and waterways, control invasive species in all habitat types, and enhance access and opportunities for public use will occur regardless of the alternative selected and all of these actions will have impacts on reptiles and amphibians.

Managing and Protecting Habitat
Managing existing forested habitats for the long-term viability of the endangered Delmarva fox squirrel and augmenting effective interior size of these habitats for area-sensitive landbird species will also have a moderate beneficial impact on the herpetiles that require and use these same habitats. Upland mixed hardwood habitats will benefit red-backed salamander, spotted salamander, wood frog, Cope's gray tree frog, Fowler's toad, five-lined skink, water snake, rough green snake, milk snake, and eastern box turtle, while bottomland forests and creek courses are important areas for mud salamander, carpenter frog, and spotted and eastern painted turtles.

Large tracts of mature forest are more likely to contain vernal pool habitats and large tracts of wetlands hold more areas of still fresh water for breeding amphibians. Restoring and enhancing connectivity between refuge wetlands and uplands will facilitate movement of reptiles and amphibians that promotes better genetic mixing and avoids adverse impacts of inbreeding. Travel corridors will also reduce mortality during dispersal movements.

Under all alternatives, we will allow dead trees and other coarse woody debris to decompose naturally by leaving stumps, blowdowns, and standing snags. This will have a moderate beneficial impact on herpetofauna, as many reptiles and amphibian species nest, forage, seek shelter, or hibernate inside or underneath rotten logs, windblown trees, and stumps.

Shallow vernal pools shaded by canopy trees are crucial for breeding from February to late summer and for overwintering. Buffering is essential to protect these areas from drying out too quickly, and to absorb the runoff of nutrients, pesticides, and sediments before they reach wetland or vernal pool habitats.

The same objectives and strategies for providing buffer zones around wetland and waterways for enhancing fish nurseries and wetland bird habitats will also provide moderate beneficial impacts to amphibians, turtles, and snakes.

Controlling invasive species will benefit herpetiles on the refuge by contributing to the restoration and propagation of native plants and the associated insects that are essential prey resources. Studies have shown that gray tree frogs declined in body mass and weight where habitats were degraded by invasive species and that *Phragmites* over time has negative impacts on the hydrology of wetland habitats (Blossey 1999). Controlling invasive species in uplands is important for tree frogs and box turtles that feed on some host-specific caterpillars associated with native tree species that thrive in mixed deciduous forests.

Applying herbicides to control invasive species can cause impacts to amphibians if herbicide chemicals and surfactants intended for terrestrial use are applied along roadsides and get into ditches or leach into vernal pools or wetland areas where they would be lethal to developing amphibian eggs, larval stages, and tadpoles. Similarly, disposing of waste water after rinsing tanks, backpacks, and other equipment is another potential source for adverse impacts on frogs and toads, which are attracted to rinsates. Great care will be taken to mitigate potential damage by adhering strictly to label directions and best management practices.

The potential use of insecticides for control of mosquitoes, gypsy moths and other invasive insects, can impact non-targeted insects, specifically native moths, in turn impacting the prey base of amphibians and reptiles. The refuge's use of pesticides for invasive plant control could have negative impacts on local herpetile populations, as there is a growing body of evidence highlighting the synergistic impacts of all forms of chemical pesticides on amphibians (Kiesecker 2002, Relyea 2005).

Public Use

We evaluated refuge public uses for their potential to benefit or adversely impact amphibians and reptiles or their habitats used for mating, reproduction, overwintering, and foraging. Although most species that occur on the refuge are very common and widespread, there is some concern for eastern box and spotted turtles populations. Because amphibians everywhere are considered to be experiencing a general decline, public outreach and education efforts by the refuge that emphasize buffering of wetlands, connectivity and easy access between forest, grassland, and wetlands, protection of vernal pools, and augmentation of patch size will benefit amphibians and reptiles on an even larger scale where embraced by other landowners.

Sometimes maintenance actions for public use may involve preparations or outcomes that have direct negative impacts to amphibians and reptiles. Mowing of grassy access roads and public use trails occasionally kills turtles, snakes, or frogs if conducted during times of movement (warm months). The refuge will minimize this direct type of negative impact by keeping public use and access roads mowed short so that they do not become attractive habitat.

Disturbance to basking or nesting turtles may occur where public use on the refuge is concentrated at points where land and water interface. Basking turtles can usually find alternate resting surfaces. Nesting turtles, once engaged in the act of digging usually will not allow their attention to be drawn to anything else, and at such times are vulnerable to predators. A turtle wishing to make landfall to attempt egg-laying, however, may be dissuaded by the presence of humans at the site.

The effects of hunting disturbance to non-hunted wildlife under this plan are expected to be negligible for several reasons. Hibernation or torpor by reptiles

and amphibians also limits their activity during the hunting season when temperatures are low. Hunters would rarely encounter reptiles and amphibians during most of the hunting season. Non-hunted reptiles and amphibians include species such as snakes, skinks, turtles, lizards, salamanders, frogs, and toads. These species have very limited home ranges and hunting would not affect their populations regionally.

Because there will be ample wetland-forest-grassland interface elsewhere, we expect that the impact of roads, trails, and proposed recreational activities to amphibians and reptiles at the landscape scale will be negligible.

Impacts to Amphibians and Reptiles in Alternative A

Impacts on amphibians and reptiles 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
The continued maintenance of early successional habitats proposed for some areas of the refuge under alternative A provides direct benefits for reptiles and some amphibians due to the abundance of natural food resources, particularly in older fields with a rich diversity of plant and invertebrate life and complex soil communities. A number of refuge snake species use these habitats for foraging, especially if they are located near woodlands with ample cover. Carnivorous reptiles such as snakes benefit from the abundance of small mammals, such as mice and voles, in refuge grasslands. Grassland habitats near forested vernal pools and wetlands will enhance the survival and weight gain of post-breeding amphibians on the refuge.

The passive conversion of upland fields to early successional and forested vegetation will increase the natural habitat available for reptiles and amphibians. The resulting decrease in refuge forest fragmentation and increase in connecting corridors benefits herpetile species that are subjected to exposure, desiccation, and predation when crossing spaces between habitat fragments.

In wetland and aquatic habitats, the exlusion of agricultural uses will maintain connectivity between wetlands and upland forest habitats that serve as travel corridors for herpetiles. Prescribed fire in open wetland areas embedded with fire maintained habitats (oak-dominated forests, grasslands, etc.) will encourage plant diversity, thus providing quality habitat for herpetiles. Restoration of natural surface water and ground water hydrology in prior converted freshwater wetlands will have a beneficial impact on herpetiles through an increase in habitat.

In impounded wetlands, return of tidal flow will create brackish/saline wetland habitat that will likely be colonized by the State-listed northern diamondback terrapin. However, the return of saltmarsh in Units II and III may have minor-to-moderate adverse impacts on individual reptiles and amphibians (mortality) if they are not capable of emigrating upstream to areas with reduced salinities. Reptile and amphibian species that utilize the freshwater impoundments would be permanently displaced. The distribution of reptiles and amphibians on the refuge will shift in response to this wetland restoration, although impacts will be local and not affect these species at the population level.

Passive habitat management will provide less aggressive habitat management strategies and conservation actions than alternative B, with a slower progression and timeframe to achieve desired mature forest and salt marsh conditions.

Public Use
Impacts associated with public use are the same as those described under Impacts on Reptiles and Amphibians That Would Not Vary by Alternative.

Conclusion for Management Actions in Alternative A

Management actions in alternative A, including passive return of native vegetation to fields would, on the whole, result in local, long-term minor-to-moderate impacts to reptile and amphibian populations by increasing or restoring habitat availability. Salt marsh increases in the impounded wetlands may have minor-to-moderate adverse impacts on some local herpetofauna populations that require freshwater wetlands, while also providing a beneficial impact to the northern diamondback terrapin. However, the passive management of alternative A would require significantly more time than alternative B, possibly on the order of centuries, to achieve the same habitat conditions, and numbers and distribution of herpetiles.

Impacts to Amphibians and Reptiles in Alternative B

Habitat Management and Public Use

During forest thinning and other stand improvement operations, vernal pools will remain buffered by a least 500 to 1,000 feet to protect them from drying out. Forest management strategies aimed at maintaining >80% close canopy in refuge forests will include seasonal forested wetlands, which is especially important for adult amphibians that spend the non-breeding seasons in the surrounding forest. This constitutes the core terrestrial habitat necessary to ensure refuge amphibian population survival outside of the breeding season.

In mixed hardwood forests, protection of stands with older trees and maintaining a diversity of forest age classes, densities, and structure will have direct and indirect beneficial impacts on many mesic hardwood-related amphibians and reptiles. Many such species require mature forest stands, while others require a variety of habitat structure. Similarly, allowing limbs and snags to stay in place and decompose naturally conserves salamanders and their prey, notably invertebrates, which extensively use such microhabitats. Decreasing refuge forest fragmentation and creating connecting corridors benefits herpetile species that are subjected to exposure, desiccation, and predation when crossing spaces between habitat fragments.

The refuge will minimize the use of insecticides for pest management to avoid killing the non-target insects, which serve as an imortant food base of amphibians and reptiles. Elimination of adulticides and improved mosquito integrated pest management strategies and actions that consider the importance of the ecology of non-target species will mitigate potential indirect adverse impacts on wetlands and reptile and amphibian feeding ecology.

In wetland and aquatic habitats, the exlusion of agricultural uses will maintain connectivity between wetlands and upland forest habitats that serve as travel corridors for herpetiles. Prescribed fire in open wetland areas embedded with fire maintained habitats (oak-dominated forests, grasslands, etc.) will encourage plant diversity, thus providing quality habitat for herpetiles. Restoration of natural surface water and ground water hydrology in prior converted freshwater wetlands will have a beneficial impact on herpetiles through an increase in habitat.

In impounded wetlands, newly restored brackish/saline wetland habitat will likely be colonized by the State-listed northern diamondback terrapin. However, saltmarsh restoration of Units II and III may have minor-to-moderate adverse impacts on individual reptiles and amphibians (mortality) if they are not capable of emigrating upstream to areas with reduced salinities. Reptile and amphibian species that utilize the freshwater impoundments would be permanently displaced. The distribution of reptiles and amphibians on the refuge will shift in response to this wetland restoration, although impacts will be local and not affect these species at the population level.

In addition to Impacts on Reptiles and Amphibians That Would Not Vary by Alternative, we expect impacts to amphibians and reptiles 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.

Conclusion for Management Actions in Alternative B
Management actions in alternative B, including restoring native vegetation to agricultural fields, restoring hydrology in former farmed wetlands and preventing the use of agricultural chemicals (fertilizer and pesticides) would, on the whole, result in local, long-term minor-to-moderate impacts to reptile and amphibian populations by increasing or restoring BIDEH. Salt marsh restoration may have minor-to-moderate impacts on some local herpetofauna populations that require freshwater wetlands, while also providing increasing habitat to the northern diamondback terrapin. In terms of BIDEH, the refuge would be reducing diversity at the refuge scale, but contributing to biological integrity and diversity at the landscape scale.

Impacts to Amphibians and Reptiles in Alternative C

Managing and Protecting Habitat
Management of Unit II and Unit III wetlands as freshwater impoundments would have a moderate beneficial impact on a number of amphibian species that prefer freshwater wetlands.

The refuge farming program implemented under alternative C would have a moderate adverse impact on herpetofauna. Maintaining up to 600 acres of row cropped agricultural fields, continued drainage of farmed wetlands and fragmenting native habitats, essentially precludes optimal use of potential habitats by herpetiles, resulting in moderate local long-term adverse impacts on amphibian and reptile populations. Chemicals utilized in conjunction with the farming program could have an adverse impact on the quality of water in wetlands near farmed fields, thus impacting the health of amphibians breeding and feeding in those wetlands. Because the cooperative farming program utilizes, as approved, glyphosate-tolerant corn and soybeans, glyphosate is the primary means of crop pest control. The use of such herbicides has been associated with adverse impacts on amphibians (Cadreira and Duke 2008, Relyea 2005), but this can be mitigated by utilizing surfactant-free glyphosate products and adding a safer surfactant (those with a low LC50 value).

A potential adverse impact to herpetofauna from alternative C 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, freshwater wetland communities preferred by many amphibians die back, and high water salinities render the wetlands inhabitable to most herpetiles. This inherent instability of the freshwater impoundments could lead to minor adverse impacts to herpetofauna, which would need to seek suitable habitat elsewhere during such times. This adverse impact would likely be recurring.

Public Use
In addition to Impacts on Reptiles and Amphibians That Would Not Vary by Alternative, we expect impacts to amphibians and reptiles to increase in alternative C from those outlined in alternative A, but less than alternative B. Impacts are expected to be negligible.

Conclusion for Management Actions in Alternative C
Management actions under alternative C would result in short-term local minor-to-moderate benefits and long-term local minor-to-moderate adverse impacts to existing herpetiles. Due to their vulnerable long-term sustainability, the

freshwater impoundments provide only short-term benefits to herpetiles, with periodic adverse impacts when saltwater intrusion occurs.

Impacts on Fisheries

Wetland and aquatic resource management to protect water quality and habitats for trust fishery resources is a priority at the refuge. Refuge aquatic resources provide important nursery and foraging habitats for native anadromous and catadromous fish. Targeted refuge focal species include river herring (alewife and blueback herring), American eel, and striped bass.

We evaluated the management actions and public uses for each of the alternative proposals for their potential to benefit or adversely affect wetland and aquatic habitats used for nurseries, foraging, migrating, and wintering areas. Fishing, which is one of the six priority wildlife-dependent public uses, is a consumptive activity with additional direct effects on fisheries resources.

Evaluation of beneficial conservation activities that would enhance or improve water quality and aquatic resources included the following actions:

- Maintain fish weir passages in Unit II and III water control structures to allow the unimpeded passage of river herring and other anadromous fish species and priority resources of concern.
- Repair, replace, and upgrade water control structures, fish weirs, and flapgates to improve or restore water circulation in ditched systems of all the refuge's impounded wetland areas.
- Maintain or improve water quality by establishing or widening existing forested upland buffers parallel to all refuge waterways and protect all wetland habitats with vegetated buffer areas.
- Protect and conserve insect and other invertebrate food resources for fish.
- Control the growth and spread of invasive plant species.
- Restore saltmarsh in impounded wetlands.

Evaluation of activities of alternatives A, B & C that would potentially cause adverse effects on fisheries resources include the following actions:

- Management actions to clean existing ditch systems
- Management actions to maintain freshwater marshes or restore them to tidal salt marshes
- Accidental introductions of non-native fish by anglers
- Accidental introductions of invasive plants, pathogens, or exotic invertebrates attached to fishing boats and trailers
- Use of pesticides to control mosquitoes and nuisance and non-native invasive plant species which may might adversely affect fisheries resources

Impacts on Fisheries That Would Not Vary by Alternative

Managing and Protecting Habitat
Many best management practices from refuge management activities will provide beneficial impacts to the fisheries resource. Many of these actions for protecting wetlands, such as controlling non-native invasive plants and providing and increasing forested buffers around wetland-upland interfaces and refuge waterway edges, will filter out contaminants from off-refuge sources and benefit

wetland and aquatic resources and fish nursery habitats by protecting good water quality and well-functioning wetland ecosystems.

Refuge ditch maintenance will improve water circulation and quality. The mechanical means of cleaning existing ditch systems within refuge impoundments would be through the use of a cookie cutter or rotary ditcher. To minimize disturbance and adverse impacts to fishery and migratory bird resources, the cookie cutter will be operated only during certain seasons when water temperatures and water levels are at or below recommended thresholds.

Ditch maintenance would occur between February 1 and March 15, when impoundment water levels are below half pool levels and water temperatures are below 60^{0} F. Lower water levels are necessary to assure that an acceptable transport of silt and particulate matter from the ditch is removed during cookie cutter operation since this timeframe (late winter) occurs when water temperatures are at or below 60 ^{0}F, it precedes the peak spawning migration of anadromous fish and resident warm water fish (sunfish). This temperature threshold minimizes the potential adverse impacts of depleted oxygen levels from decomposition of vegetation and from silt suspension.

The use of the cookie cutter or rotary ditcher may have some short-term minor adverse impacts . Sediment redistribution and temporary increases in turbidity and total suspended solids in the water column around the machine will be higher during operation but should return to normal several weeks after work is completed. This increase in total suspended solids and turbidity causes a higher biological oxygen demand, which reduces the available oxygen to fish and may cause stress or mortality. The magnitude of increases in biological oxygen demand is dependent on the rate of decay of the particulate matter, which is dictated by water temperature.

Through routine ditch maintenance, short-term adverse impacts will be followed by long-term beneficial consequences for wetland systems and aquatic resources with improved water circulation, enhanced water level management capability, and improved water quality.

If used according to label directions, the mosquito adulticide naled (alternative A only), should not directly impact fishery resources. However naled, as well as the larvicides Bti and methoprene (under all alternatives), may have indirect adverse impacts due to their ability, under proper conditions, e.g., chemical concentration, humidity, wind, suspended organic material, and light intensity, to kill non-target insects. Insects are crucial food components in aquatic habitats for foraging fish species on the refuge.

Public Use
Use of boats and canoes will cause increased suspension of bottom sediments, which should have negligible impacts on the biological oxygen demand for fisheries resources, because the impacts would be localized when they occur. Similarly, boat motors may harm submerged or emergent vegetation, which would cause negligible impacts to protective cover for fisheries.

Fishing seasons and limits are established by the State of Delaware and adopted by the refuge. These restrictions ensure the continued well-being of overall populations of fish. Fishing results in the taking of many individuals within the overall population, but restrictions are designed to safeguard adequate populations and recruitment from year to year.

Important concerns of any refuge fishing program are accidental or deliberate introductions of non-native fish (used for bait), accidental introduction of

invasive plants, pathogens, or exotic invertebrates attached to fishing boats, and overharvesting. Another common concern is the reduction or alteration of prey base important to fish-eating wildlife. Refuge-specific regulations address this concern by following the Delaware regulations and would adopt any State harvest limits that should become applicable to the fish species in refuge waterways. These limits are set to ensure that harvest levels do not cumulatively impact native fish resources to the point they are no longer self-sustainable. We also follow recommendations of Service fisheries biologists who conduct periodic sampling of refuge ponds and waterways. Effects on interjurisdictional fishes, those which migrate beyond an individual state and/or national boundaries, are expected to be negligible from hunting because the majority of the refuge will experience minimal, transitory use by hunters.

Impacts on Fisheries in Alternative A

Managing and Protecting Habitat

Habitat management proposed in Alternative A would have many of the same impacts as those described in alternative B. For example, with the return of tidal flow to the impounded wetlands and conversion of the refuge's impounded marshes to tidal marsh, the refuge would expect increases diversity and abundance of species as noted by Able et al. (2004). However, in the absence of active salt marsh restoration as proposed in alternative B, there is likely to be a greater amount of non-vegetated open water habitat for marine species. A vegetated marsh appears to have a higher nursery value than a non-vegetated marsh (Minello 2003). The inability of emergent wetland species to colonize impounded wetland areas of the refuge due to lack of substrate and excessive water depths would fail to provide the necessary cover utilized by fisheries resources during their life cycle. Additionally, the open water fetch potential of this system would promote shoreline erosion on the western edge of the open water system, likely causing an increase in turbidity and suspended solids within the water column.

Additional adverse impacts in alternative A include:

- Loss of freshwater marsh habitat would result in a decline in abundance of freshwater fish species such as largemouth bass, sunfish, and other piscivores, and forage species including amphibians and invertebrates.
- Open water habitat would have a limited high quality juvenile fishery component as suitable nursery and foraging areas.
- Shallow, semi-enclosed, sparsely vegetated open water habitat has the potential to capture nonpoint source pollution which could negatively impact fisheries resources, e.g., fish kills due to low dissolved oxygen and eutrophication.

Conclusions for Management Actions in Alternative A

Management action in alternative A would result in a measurable or perceptible effect on freshwater fisheries as stated above. Long-term minor-to-moderate impacts and opposing local long-term minor-to-moderate impacts on fisheries within or near the refuge are expected. Although alternative A contributes to the BIDEH of the refuge, the loss of salt marsh vegetation and subsequent conversion of the habitat to open water would result in a decrease in diversity and integrity of the system for the short to intermediate term.

Impacts on Fisheries in Alternative B

Managing and Protecting Habitat

Impacts on fisheries resources in Alternative B ("Preferred Alternative") through proposed habitat management changes meet habitat and wildlife objectives through the maintenance, enhancement, or restoration of natural wetland ecosystems.

Refuge salt marshes provide critical nursery habitat for fish and shellfish (Tiner 1985; *http://www.dnrec.delaware.gov/Admin/DelawareWetlands/Pages/DelawareWetlandTypesSaltBrackish.aspa*; accessed February 2012). Estuarine aquatic beds provide important cover for juvenile fishes and other estuarine organisms (Tiner 1985). Tiner (1985) reported that 98 percent of Delaware's commercially important fishes are wetland-dependent. Common fishes in Delaware's tidal marshes and estuaries include American eel, alewife, American shad, blueback herring, carp, white catfish, channel catfish, brown bullhead, white perch, striped bass, yellow perch, silver perch, sea trout, Atlantic croaker, summer flounder, winter flounder, menhaden, and spot (Tiner 1985). Increased tidal flushing into impounded areas may increase water column aeration, reduce summertime oxygen stress, and promote survival of all aquatic animals, including migratory river herring (Full Report of Herring River Technical Committee 2006).

Restoration of impounded marsh areas to tidal salt marsh and its impacts on fish species in the Delaware Bay have been well documented. Able et al. (2004) reported that the return of tidal flow and creation of creeks during the restoration of salt marshes in the Delaware Bay provided an immediate, dramatic increase in fish species diversity and abundance, particularly by resident and transient young-of-year fish species that once again have access to the marsh area. With the restoration of the refuge's impounded marshes to tidal marsh, the refuge would expect increases diversity and abundance of species as noted by Able et al. (2004). However, the uncertainty of the success of the restoration effort, the refuge acknowledges only moderate success may be achievable. The refuge may expect short-term moderate beneficial impacts. Able et al (2004) found the most abundant species included bay anchovy (*Anchoa mitchilli*), weakfish (*Cynoscion regalis*), spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonias undulatas*), Atlantic silverside (*Menidia menidia*), American eel (*Anguilla rostrota*), mummichog (*Fundulus heteroclitus*), and Atlantic menhaden (*Brevoortia tyrannus*). With access to these marsh habitats, productive fish species such as mummichog thrive; they also serve as prey for other species such as young-of-year *M. undulatas* or larger predators such as striped bass (*Morone saxatilis*).

Returning tidal action will allow degraded marshes to restore ecological attributes and functions, reconnect these wetlands to the larger estuarine-coastal ecosystem, and result in a self-maintaining tidal salt marsh. Frisk et al. (2011) concluded through model simulations of recent field studies of fish assemblages in restored salt marshes in the Delaware Bay that restoring this type of habitat likely resulted in increased system biomass of a wide range of fish species including important forage and commercially important species. This biomass increase most likely changed the structural composition of the Delaware Bay ecosystem, potentially increasing its long-term health and stability. Tupper and Able (2000) further concluded that the movement, habitat use, and diet composition of striped bass (*M. saxatilis*) in restored salt marshes were similar to reference or restoration target salt marshes, signifying the importance these restored sites in the management of commercially important large predators in the Delaware Bay. The refuge can expect long-term moderate beneficial results as suggested by the above research along the Delaware Bay.

The use of the cookie cutter or rotary ditcher will be utilized under Alternative B as a refuge management tool to sustain tidal flushing and circulation in the restored marshes, which can benefit marsh restoration, refuge hydrology and fisheries. However, if the marsh restoration plan determines that existing ditches and drainage channels are inappropriate in particular locations, then this activity is anticipated to be reduced or eliminated.

Under alternative B, changes in mosquito integrated pest management practices and strategies with more restrictions on adulticide and larvicide use will result in minor-to-moderate indirect beneficial impacts for refuge fisheries resources by reducing minor-to-moderate adverse impacts to insect communities and other non-target invertebrates that provide diverse food sources to fish, and maintaining and enhancing healthy fish populations.

In an effort to minimize fishing mortality and increase the quality of fishing, the refuge proposes to adopt catch-and-release regulations, including mandatory use of barbless hooks, for Turkle Pond, Fleetwood Pond, Goose Pond, Flaxhole Pond, and Prime Hook Creek.

During the marsh restoration process, short-term minor adverse impacts may occur when a thin layer of silt is applied to the marsh surface, potentially causing an increase in the suspension of sediments and affecting the biological oxygen demand on fisheries resources. These adverse impacts would be followed by long-term moderate beneficial impacts by providing additional nursery and foraging habitat for fish species.

The refuge may experience short-term minor-to-moderate direct adverse impacts to certain fish species in restored marshes if these fish become restricted to areas of low dissolved oxygen and elevated temperatures. Tupper and Able (2000) found during a comparison of a restored and a reference salt marsh in the Delaware Bay that striped bass did not migrate far upstream from the creek mouth due to low dissolved oxygen concentrations in upstream areas of the reference marsh. Tupper and Able (2000) also noted that a series of creeks and ditches were designed in the restoration marsh habitat to provide the proper hydroperiod for revegetation by *Spartina alterniflora*. The restored tidal flushing provides an exchange and mixing of water that helps to buffer fish species from extremes in temperature and dissolved oxygen.

Public Use
Expanded freshwater and saltwater fishing and crabbing opportunities could coincide with increased adverse effects on fish populations and habitat degradation due to increased public use. New opportunities for night fishing at Fowler Beach and daytime fishing at Goose and Flaxhole Ponds are expected to have negligible impacts on the fisheries resource. Goose and Flaxhole Ponds will not be open until fishery surveys are completed and management recommendations made. Direct fishing impacts to fisheries resources on Prime Hook Creek are negligible and will be further lessened by seasonal closures to fishing for deer and waterfowl hunting.

The refuge will consider crabbing along Prime Hook Road, Broadkill Road, and Fowler Beach Road in the future, if visitor safety and adequate parking can be guaranteed. Adequate parking and visitor safety along State-maintained roads have historically been an issue. Crabbing decreased significantly from 3,644 visits in 1976 to 880 visits in 1977 as a result of new regulations making State highway bridges into refuge waterways off-limits in an effort to increase pedestrian safety along these roads.

Increased deer and waterfowl hunting on Prime Hook Creek and Unit III impoundments will cause increased suspension of bottom sediments from boat motors. Since hunting occurs during the fall and winter months, the impacts of this sediment suspension would be negligible and would not adversely affect biological oxygen demand for fisheries resources. Early season hunters may harm submerged or emergent vegetation by accessing small ditches, which may cause negligible impacts to protective cover for fisheries.

Recreational gill-netting, commercial fishing, crabbing using pots or trot lines, and food fishing with equipment other than hook and line are not permitted on the refuge. The use of gill netting by commercial or recreational fishermen has occurred in the tidal waterways of Slaughter Canal for over 30 years by a small number of fishermen. These activities, whether commercial or recreational, are not consistent with goals and objectives in any refuge management plan, conflict with rod and reel recreational fishermen and wildlife observers using canoes and kayaks, and have the potential to harm non-targeted fisheries through incidental by-catch. Fishing for bait fish is permitted for recreational uses only, subject to regulations stated in title 7 (Conservation) of the Delaware State Code.

Conclusions for Management Actions in Alternative B

Management action in alternative B would result in short-term minor-to-moderate impacts and opposing long-term moderate local and regional beneficial impacts on fisheries resources as described above. Alternative B would contribute a short-term minor-to-moderate direct adverse impact on fisheries resources as the marsh is being restored. Local long-term moderate beneficial impacts on fisheries within or near the refuge are expected as the restored salt marsh provides its ecosystem services. Alternative B contributes to the BIDEH of the refuge through the restoration of salt marsh function and value resulting in an increase in diversity and integrity of the system. Maintaining, enhancing, and restoring native salt marsh vegetation, biological diversity, and ecological integrity of refuge marsh habitats will create a mosaic of native salt marsh species conducive to providing nursery ground habitat(s) for both juvenile and adult fish species, thus maximizing long-term benefits for priority trust fisheries resources.

Impacts on Fisheries in Alternative C

Managing and Protecting Habitat and Public Use Habitat

The focus of the Refuge would remain the same as occurred prior to 2008: to provide habitat and maintain current active management practices and continue to manage and provide habitat for trust fisheries resources. Impacts on fisheries resources in Alternative A ("No Action") serve as a baseline for comparing and contrasting Alternatives B and C to the refuge's existing management activities.

Upstream freshwater systems (impounded marshes and Prime Hook Creek) provide spawning habitat for anadromous fish such as adult alosids (shad and river herring) and semi-anadromous fish such as white perch, and as nursery habitat for juvenile fish. Freshwater systems also support habitat for a multitude of freshwater fish species, including largemouth bass, white and black crappies, yellow perch, bluegill, pumpkinseed, brown bullhead, and chain pickerel (Tiner 1985). These freshwater habitats provide food requirements for juveniles, such as cladocerans, copepods, and dipteran larvae (Dove and Nyman 1995).

The recent salt water intrusion into freshwater impounded marshes resulted in direct mortality or stress on freshwater fish species due to increased salinity. Large fish kills may result if saltwater intrusion is rapid. Love et al. (2008) reported that the abundance of freshwater-dependent fishes declined as salinity increased seasonally in the Little Blackwater River in Cambridge, Maryland. The stress of salt water on freshwater marsh vegetation may result in the loss of vegetative cover and subsequent decrease in dissolved oxygen levels due to decaying biomass. Love et al. (2008) also reported that identifying and protecting processes that enhance connectivity among spatially distinct ecosystems, such as brackish and freshwater habitats of coastal wetlands, are essential for managing fish populations and maintaining healthy ecosystems.

Adverse impacts under alternative C are expected to be similar to those in alternative B. Negligible impacts to fisheries resources such as sedimentation from the motors of visiting boaters affecting biological oxygen demand and damage to submerged or emergent vegetation are expected. Increased sediment

in the water can bury or block sunlight from reaching submerged aquatic vegetation. Submerged aquatic vegetation (SAV) produces dissolved oxygen that fish need to survive, filters pollution, and serves as a food source, hiding place, and home for fish, shellfish and crustaceans. SAV is valued at about $12,000 per acre per year because of its importance to overall aquatic health and fisheries (*http://water.epa.gov/type/oceb/nep/challenges.cfm*). Open water, shallow, non-vegetated habitat would have local long-term minor-to-moderate adverse impacts to the fisheries component of the BIDEH on the refuge.

Conclusions for Management Actions in Alternative C

Management actions in alternative C would result in local long-term minor to moderate impacts and opposing local long-term minor adverse impacts on fisheries within or near the refuge. Alternative C contributes to the BIDEH of the refuge through the improved water quality of 4,000 acres of impounded marsh, aquatic habitats, and delineated buffer zones that will ultimately provide clean water to safeguard and enhance the quality of breeding and nursery habitats for river herring (alewife, blueback herring), American and hickory shad, striped bass, American eel, and other fishery resources.

Impacts to Invertebrates

Invertebrates are by far the most numerous animals on the refuge and play significant roles that link abiotic elements in all native habitat types to ecological processes and to biological integrity, diversity, and environmental health. Invertebrates are part of every food chain and represent the most important component of food webs responsible for directly maintaining birds, fish, amphibians, reptiles, mammals, insects, and native plant resources on the refuge. As such, invertebrate community health and diversity are directly linked to our conservation of trust resources, such as all guilds of migratory birds. Invertebrates also provide many essential ecosystem services on the refuge, such as pollination, nutrient cycling through decomposition and herbivory, and can serve as indicator species of environmental health for specific habitats of interest. Benthic aquatic invertebrates are essential to the healthy functioning of wetland ecosystems, which account for 80 percent of the refuge's cover-types.

We evaluated the alternatives and various proposed actions and activities with respect to their beneficial impacts on invertebrates. We considered the value of the following actions for the conservation and maintenance of diversity of insect communities, long-term persistence, and overwintering survival of invertebrate species and communities in habitats where we are most certain to conduct the following management actions:

- Restoring and enhancing native plant communities
- Maintaining early successional habitats using prescribed fire, 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
- Proactively pursuing pollinator conservation on refuge lands
- Maintaining roads
- Mosquito control
- Artificial lighting around facilities

Impacts on Invertebrates That Would Not Vary by Alternative

Managing and Protecting Habitat
Strategic native plant restoration and refuge habitat management will provide a wide array of diverse microhabitat types that serve as foraging, breeding, overwintering, roosting, and stopover sites for many groups of invertebrates. Concern about the decline of pollinators, especially of wild native insect species, has prompted the Service to collaborate with the North America Pollinator Protection Campaign. The Refuge System is incorporating insect pollinator conservation into refuge habitat management planning, strategies, and conservation actions. Service staff in Region 5 have been directed to consider the needs of pollinators during our planning and habitat management activities. This will have a minor-to-moderate beneficial impact on these groups of invertebrates.

Because of the close ecological relationship between native plants and wild native pollinators, managing for one will often have a positive effect on the other. Herbicide control of invasive plants in all three alternatives will support pollinator insects by providing three main needs: a diversity of native flowers available throughout the growing season, egg-laying or nest sites for generalist pollinator species, and provision of certain native host plants for specialist insect pollinator species. In addition to controlling invasive plants, enhancing native plant diversity on the refuge will provide specialist pollinator species with sources of nectar and pollen found in specific host plants for their young. refuge examples include Delaware skippers that use big bluestem or switchgrass, marbled underwing whose host plant is swamp cottonwood, little wife underwing moth that uses only southern bayberry as a larval host plant, and the rare maritime sunflower borer moth that is completely dependent on the native giant sunflower found in early successional grassland habitats.

However, the use of chemical herbicides can have an adverse impact on invertebrates if native non-target plants are killed. To avoid invasive herbicide damage to host plants associated with pollinator insects, precautions will be taken, such the use of spot treatment or other similarly well-targeted techniques rather than broadcast spraying. This would allow for selective control of undesirable plants while avoiding negative impacts on non-target beneficial larval host plants required by insect pollinator species. In early successional habitats, targeted herbicide spraying, combined with mechanical removal of large shrubs is a very effective way of maintaining butterfly and arthropod habitats. Herbicide applications will be specific enough to avoid killing non-target forage plants for generalist pollinators and host plants for specialist pollinator insect species. Overall, adverse impacts to pollinators would be negligible.

Integrated pest management is also an integral part of forest management and protection. The primary strategy under our integrated pest management program will be to improve the overall health of forested habitats in an effort to reduce their susceptibility to forest insect pests and diseases. Until this objective is achieved, we will continue to rely on the latest and most effective control measures developed by the U.S. Forest Service. Currently, the most effective and widely used control tactics are the use of biological insecticides such as Bacillus thuringiensis and Gypchek. Gyspy moth surveys conducted on the refuge during the past 10 years have not detected any problems to date but, if the need arose to control these invasive moths, Btk would be used instead of the more detrimental insecticide, Dimilin, to reduce negative impacts to non-target invertebrates. This action would have the desired minor-to-moderate adverse impacts on target invertebrates (gypsy moths), but potentially have negligible-to-minor adverse impacts on non-target invertebrates.

The arachnid, *Limulus polyphemus* (horseshoe crab) is another very important refuge invertebrate species listed as a sensitive and significant Delaware

keystone species in the Delaware wildlife action plan (DNREC 2005). It is also considered a species of conservation concern by the Atlantic States Marine Fisheries Commission. The horseshoe crab is listed as a managed species with its own ASMFC Interstate Fishery Management Plan for the mid-Atlantic to conserve and protect these unique invertebrates. Refuge beach habitats provide spawning habitats for horseshoe crabs and we participate in annual census activities to monitor population status which also benefits this species. The conservation of horseshoe crab spawning habitat is incorporated into all three alternatives.

Public Use
Both beneficial and adverse impacts to invertebrates associated with public use are expected to be negligible. Visitors participating in recreational activities other than hunting are restricted to designated trail routes and interior roads, which minimizes disturbance to invertebrates. Invertebrates such as butterflies, moths, other insects and spiders are not active during the majority of the hunting seasons due to cold weather and would have few interactions with hunters.

A refuge volunteer who is a professional entomologist partnered with the Friends of Prime Hook NWR on a 4-year insect appreciation project, which involved preparing an impressive collection of pinned and labeled invertebrates, cataloging more than 700 insects commonly found on the refuge. Under all three alternatives, this collection will be used for educational purposes and to provide scientific information to local communities, visitors, and the general public. Educating refuge users about the importance of invertebrates in conserving migratory birds, the need to improve pollinator conservation, and ecological services that invertebrates contribute to maintaining the refuge's biological integrity, diversity, and environmental health, will have an indirect beneficial impact on invertebrates.

Impacts on Invertebrates 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
In contrast, invertebrate community structure is different in salt marsh areas of the refuge, which will continue to persist in a natural state under alternative A. The most abundant invertebrates are gastropods (snails), both in water column and benthic habitats; these are important food items for waterfowl, especially black ducks. Chironomids are usually the second most abundant invertebrate group, followed by shore flies (*Ephyridae*), long-legged flies (*Dolichopodidae*), and biting midges (*Ceratopongidae*). Native invertebrate species also benefit from invasive plant control activities conducted on salt marsh habitats.

In alternative A, both aquatic and terrestrial invertebrates will be impacted by invasive plant control activities. Passive succession of open fields to natural vegetation in early successional seral stages surrounding open emergent wetland habitat provides hundreds of acres of flowering plants with plentiful nectar resources and beneficial direct and indirect impacts for both terrestrial and aquatic insect pollinator species.

Under alternative A, the activity with the greatest adverse impacts on invertebrates is chemical control of mosquitoes. Adulticides using the active ingredient naled are organophosphates, which are toxic to bees, terrestrial invertebrates, and aquatic invertebrates if subjected to sufficient concentration.

Mosquito adulticides are broad spectrum, i.e., they kill mosquitoes as well as non-target invertebrates, especially insects, if encountered in sufficient concentrations. Non-target adverse effects may be direct or indirect. Direct

impacts result in the death or reproductive failure of unintended insects in wetland and upland habitats. Indirect adverse effects potentially ripple through the food chain. At times, the abundance and density of non-target insects may outweigh that of mosquitoes. The loss of mosquitoes, as well as non-target insects may have adverse impacts on food supplies for birds, fish, amphibians, bats, and other wildlife.

Another direct impact of mosquito insecticides is that they may kill non-target and aquatic invertebrates that are effective natural mosquito predators. Impounded emergent marsh habitats create environmental conditions that often favor chironomid production with, in some cases, limited mosquito production (Pinkney et al. 1998), Larvicides, including the permitted chemicals with the active ingredients methoprene and Bti, also have the potential to kill non-target invertebrates but to a much lesser extent, as they target specific insect taxa or are limited to larval control only.

Impacts to invertebrates associated with public use are the same as those described under Impacts on Invertebrates That Would Not Vary by Alternative.

Conclusion for Management Actions in Alternative A

Management actions in alternative A would result in local minor impacts and opposing local short-term and long-term minor-to-moderate impacts. Continued use of broad spectrum adulticides would have minor-to-moderate short term local adverse impacts to a wide range of invertebrates, with potential long-term adverse impacts to rarer species or those with restricted distributions.

The passive management of alternative A would require significantly more time than alternative B, possibly on the order of centuries, to achieve the same habitat conditions and numbers and distributions of invertebrate fauna. No impairment of the refuge's BIDEH is expected.

However, current degraded marsh conditions of impounded wetlands that have already reverted to open marsh conditions will remain in a degraded condition without pro-active restoration actions. It is uncertain as to the degree of impacts to invertebrate populations from allowing nature to take its course, but it is very likely that there will be significant decreases in terrestrial invertebrates and increases in aquatic invertebrates. It is also expected that large expanses of stable open water areas and significant reduction in emergent marsh areas will also result in a decline in mosquito production on refuge lands.

Impacts on Invertebrates in Alternative B

Managing and Protecting Habitat

An important direct benefit for refuge invertebrate populations is the conversion to native plant communities of several hundred acres of prior crop cultivation by ending the cooperative farming program. Eliminating the use of genetically modified crops on the refuge reduces adverse impacts to invertebrates, although biological contamination of invertebrates can occur from off-site sources (Rosi-Marshall et al. 2007). The restoration of native grassland, shrubland, and early successional forested habitats will significantly increase habitat acreage for pollinating, herbivorous, and predatory invertebrates by increasing the floral diversity lost to the agricultural practices of the past. Greater availability of suitable habitats has direct beneficial impacts on generalist and specialist insect pollinator species. In alternatives B and C, habitat management actions will incorporate the needs of native insect pollinators to proactively ensure the conservation of all pollinator species as well as other invertebrates.

Prescribed fire can have adverse impacts on invertebrates with substantial effects on local pollinator populations. To avoid undue mortality of insects, a number of considerations will be integrated into fire management protocols with respect to scale and timing of prescribed burns and maintaining invertebrate

refugia adjacent to or near treatment areas. A habitat management program of rotational burning where small sections (30 percent or less of total habitat-type) are burned every 3 to 10 years will provide adequate colonization potential and refugium for insects to mitigate adverse impacts to insect pollinators (Black 2009). High intensity fires will be avoided as much as feasible. Low intensity prescribed burns conducted early or late in the day, or from late fall to early winter, are not only preferable for pollinators but also reduce impacts to other wildlife species such as reptiles and ground-nesting birds.

Similarly, the difference between causing beneficial or adverse impacts to invertebrates from mowing as a habitat management strategy is based on timing, scale, and techniques used. Because mowing can completely remove all floral resources from a treated area, it will not be conducted when flowers are in bloom, but rather when flowers have died back or are dormant. Mowing at these times will reduce adverse impacts to nesting and migrating insect pollinators. To minimize adverse impacts from mowing and allow sufficient space and time for pollinator populations to recover, mowing will occur in a mosaic of patches over several years, and no single areas will be mowed or burned more than once a year (Di Giulio et al. 2001).

Beach overwash processes would be permitted to occur unimpeded in alternative B, having a beneficial impact on invertebrates that utilize the intertidal area. Surf zones and tidal inlets are important nursery and foraging areas for fishes and waterbirds because of high densities of invertebrates (McLachlan 2006; Defeo et al. 2009). Storm surge channels that cut through foredune ridges move invertebrates from nearshore environments to the beach face and back-barrier environments. Horseshoe crabs will use natural beaches and overwash deltas as spawning sites. Blue crabs will use restored salt marsh as a nursery area. Restoration of salt marsh in impounded wetlands will benefit invertebrate species that favor salt marsh (Gratton and Denno 2005), though the shift in invertebrate species composition may lag behind the shift in vegetation communities by a decade or more (Craft et al. 1999).

Depending on the particular salt marsh restoration strategies employed under alternative B, there may be limited periods of heavy equipment operation in the wetlands or on the beach for manipulation of sediment, in order to facilitate the deposition of supplemental material in the wetland to restore elevation and promote revegetation. Such actions may have a temporary adverse impact on invertebrates, including crab species, by compacting sediment and disturbing the physical environment that supports invertebrates (Peterson et al. 2000), although research suggests invertebrates may experience more pressure during high tide than when equipment is overhead (Herrera et al. 2010). It is expected that due to the sheer volume of invertebrates, populations adversely impacted by any shoreline or wetland sediment manipulation would recolonize and recover quickly (Levisen and Van Dolah 1996, Nelson 1993, CSA 1991, Lankford et al. 1988, Baca and Lankford 1988, Lankford and Baca 1987).

In many specific instances on the refuge, we have chosen to use the presence or absence of a rare invertebrate species as an indicator of environmental health based on its highly specific habitat requirements and its sensitivity to the condition and health of that habitat type. Such indicator species have been incorporated into habitat management objectives for alternatives B and C. Examples include the long-horned beetle as an indicator of large, mature, and healthy southern red oak/heath forest habitats, or the beach dune tiger beetle found on overwash, grassland dune, and Atlantic coastal interdune swale communities.

Other rare invertebrates representative of the environmental health of rare native plant communities include the pitcher plant moth, elfin skimmer,

sphagnum sprite, blueberry dart, and several fire fly species found only in twig-rush peat mat bog habitats, and little wife underwing associated with southern bayberry, an important shrub component of mid-Atlantic (G-2) maritime salt shrub habitats. Restoring and maintaining these habitats to enhance biological integrity and diversity will also have beneficial impacts on these rare invertebrate species.

Mosquito Control
A direct beneficial impact to invertebrates under alternatives B and C is the elimination of mosquito adulticide use on the refuge, except in the event of a documented public health emergency, or as mandated by the Secretary of the Interior. This would minimize the potential adverse impacts of these chemicals on non-target insect species and other indirect impacts on aquatic invertebrates, fish, birds, and amphibians.

Under alternative B, the State of Delaware will still be permitted the limited use the larvicides Bti and methoprene. Use of Bti and methoprene on the refuge will result in the intended temporary reduction in larval mosquito density, and a subsequent temporary local reduction in gross numbers of adult mosquitoes and potential shift in mosquito diversity. There may be a temporary adverse impact on both aquatic non-target invertebrate density and diversity, as well as adult non-target invertebrate density and diversity, e.g., chironomids and dragonflies. There could be short-term or long-term indirect impacts within the aquatic or terrestrial ecosystem due to the reduced density or diversity of invertebrates, including shift in predator-prey relationships, altered rates of detrital decomposition, and shift in relative numbers and diversity within the pollinator community.

Bti is a stomach poison that must be ingested by the larval form of the insect in order to be effective. Bti is specific to certain primitive dipterans, especially mosquitoes, black flies, and some chironomid species (Boisvert and Boisvert 2000) and is not known to be directly toxic to nondipteran insects. When controlling salt marsh mosquitoes, Bti is most effective on larval instar stages 1 and 2, considerably less effective against instar stages 3 and 4, and does not affect pupae or adult mosquitoes. The concentration of Bti used is important with regard to adverse impacts on non-target organisms. Of particular concern is the potential for Bti to kill midge larvae (family *Chironominae*), which are often the most abundant aquatic insect in wetland environments and form a significant portion of the food base for other wildlife (Batzer et al. 1993, Cooper and Anderson 1996, Cox et al. 1998). Laboratory and field studies have shown that Bti is toxic to some larval chironomids, particularly those species that are filter feeders or grazers. Other factors, such as temperature, water depth, aquatic vegetation, and suspended organic matter, may act to reduce its toxicity to chironomids in the environment (Charbonneau et al. 1994, Merritt et al. 1989).

The impacts of a single application of Bti are difficult to predict because of documented differences in toxicity due to formulation, potency, application rate, and timing. There is only one (Hershey et al. 1998; Niemi et al. 1999) published study that examined the long-term, non-target effects of Bti. In this study conducted in Minnesota, 27 wetlands were sampled for macroinvertebrates over a 6-year period. It appears from this study that any effects would most likely occur within the aquatic communities, as no effects were observed on the bird community (Niemi et al. 1999). In judging the potential for adverse ecological effects of Bti applications, one should consider the non-target aquatic organisms of concern that would be impacted from the potential loss of both mosquito and chironomid larvae. The refuge's mosquito management plan will apply this scientific information for creating the refuge's thresholds for treatment, types of control, and application plans.

Methoprene ranks as a toxicity class IV, and is considered slightly toxic to practically nontoxic (EPA 2001). Methoprene compounds like Altosid Liquid Concentrate and Altosid Single-Brood Granule product, all mimic the action of an insect growth hormone that is used to interfere with the normal mosquito maturation process, preventing mosquito larvae from pupating and reaching the adult stage. Methoprene is a contact insecticide that does not need to be ingested like Bti (Tomlin 1994). Methoprene products are more toxic than Bti products, killing a wider range of non-target larval insects. This makes methoprene more likely to have adverse impacts on non-target invertebrate populations and cause disruptions to invertebrate food webs.

Use of short-term residual methoprene formulations, and avoidance of briquets and other extended residual products, will help mitigate any adverse impacts to non-target species. Altosid was found to have very little effect, if any, on 35 species of exposed non-target organisms including earthworms, waterfleas, damselflies, snails, tadpoles, and mosquito fish when used at lower concentrations (Zoecon Corporation -1973). Stipulations on the use of these larvicides will be designed to limit non-target mortality and ecological integrity, as outlined in the mosquito management plan and annual special use permit.

The greatest concern the Service has with mosquito chemical use is the impact on biological integrity and diversity and disruption of vital food webs. Larvicide application can adversely affect non-target insects, especially chironomids (non-biting midges). Chironomid larvae are often the most abundant aquatic insect in freshwater wetlands and form a significant component in food webs for many wetland dependent wildlife (Miller 1987, Euliss et al. 1991, Helmers 1992, Skagen and Oman 1996). Chironomids also frequently comprise the largest proportion of wetland invertebrate biomass (Elridge 1992, Rehfisch 1994, Davis and Smith 1998). Under several water level management regimes, chironomids have been consistently found to be the most abundant invertebrate species found within refuge freshwater and brackish impounded marshes. They represent greater than 75 percent of total numbers of benthic insects from refuge impounded marshes (Larsen 1996, 1997, 1998).

Refuge-specific studies have provided staff with considerable information about dominant invertebrate taxa present in refuge salt marsh, impounded fresh and brackish marsh, stable pond environments, and creek habitats (Pinkney et al. 1998, Cook and Hill 2000, 2001, McGee et al. 2003), and about dominant invertebrate groups and invertebrate community structure present during summer months.

In these studies as well as in other refuge invertebrate monitoring efforts, mosquitoes commonly represented a very small portion of all invertebrate taxa sampled. Many of the taxa recorded also included predators of mosquitoes. Dominant invertebrate groups produced annually included the following:

- Oligochaeta (aquatic worms)
- Crustacea (copepods, shrimp)
- Gastropoda (snails)
- Amphipoda (scuds, side-swimmers, freshwater shrimp)
- Trichoptera (caddisflies)
- Ephemeroptera (mayflies)
- Odonata (dragon and damselflies)
- Lepidoptera (butterflies and moths)
- Diptera (mostly chironomids, some flies, a few mosquitoes)
- Hemiptera (water boatmen, backswimmers, water striders, other true bugs)
- Coleoptera (beetles)

Methoprene is likely to be lethal to non-target terrestrial invertebrates in their larval stages (including pollinating species), if they come into direct contact with this chemical. Lepidopterans (butterflies and moths) may be highly susceptible. However, larval stages that develop in tree tissues or underground are unlikely to come in contact with methoprene, thus adverse impacts to that group are expected to be negligible.

Insects of the order Diptera are among the most common flower visitors, and many are known pollinators. Mosquitoes are dipterans; the male mosquito is a nectar feeder and the female mosquito, which only requires blood to produce eggs, also feeds on flowers. In addition, there are at least 200 species of native bees recorded in Delaware (Sarver 2007*);* many of these species likely inhabit the refuge and may be exposed to some negligible adverse impacts from chemical mosquito control.

Methoprene and Bti also have the potential to negatively affect the local chironomid (midge) population. Though often discounted as inefficient pollinators, some researchers have suggested that the efficiency of pollinating flies (dipterans), mosquitoes (dipterans), and midges can exceed that of bees (NBII 2010). Further, dipterans appear to be crucial for the pollination of certain flowers in some habitats. Although plants in Delaware are not currently considered to be dependent upon mosquitoes for pollination, the importance of dipteran pollination is poorly understood (Kearns 2001).

Insecticide applications will also avoid areas that are known to contain butterfly and moth host-plants in order to conserve and protect rare or specialist insect pollinators and ensure that adequately buffered habitat around host plants or refugia is available during and after insecticide spraying.

The refuge has no jurisdiction over mosquito control on lands outside the refuge boundary. The Service recognizes that spray drift will likely enter the refuge from the three neighboring barrier island communities during mosquito control on those lands. Since the State employs best management practices and follows the EPA-approved label directions, the Service expects impacts to refuge resources to be negligible.

Public Use
Impacts in alternative B are the same as alternative A and as Impacts on Invertebrates That Would Not Vary by Alternative.

Conclusion for Management Actions in Alternative B
Management actions in alternative B, including eliminating use of broad spectrum adulticides for mosquito control, restoration of row cropped agricultural fields to native vegetation communities, restoration of wetland hydrology, and restoration of impounded freshwater wetlands to native salt marsh would, on the whole, result in moderate local, long-term impacts to invertebrate populations by increasing or restoring the refuge's BIDEH. Restoration of salt marsh will result in a local aquatic invertebrate community shift from organisms adapted to fresh water to brackish or saline conditions. Permitting use of larvicides for mosquito control will continue to result in local short-term adverse impacts to dipteran species.

Impacts on Invertebrates in Alternative C

Managing and Protecting Habitat
The management of macro-aquatic invertebrates, especially benthic invertebrates, is an important impoundment objective under alternative A to supply food resources for waterfowl and shorebirds during critical migration and wintering periods. Refuge impoundment management includes producing

diverse native wetland plants that have beneficial direct and indirect impacts on invertebrates. Since 1996, the refuge has studied and monitored invertebrate responses to water level management to enhance annual invertebrate production as reliable food resources for migratory birds. Such invertebrate information and data collected in all three impoundments revealed that irrespective of the impoundment, midge larvae (Chironomidae) were the most dominant and abundant invertebrate group in all years at all seasons (table 5-13; Prime Hook NWR Marsh and Water Management Programs 1996, 1997, 1998). Impoundment management has a substantial impact on this particular group of invertebrates.

Table 5-13. Invertebrate Taxa and Relative Abundance Collected in Units III and IV Impounded Wetlands at Prime Hook NWR, Milton Delaware

Emerging insects collected in 1997 were identified by Dr. Leonard C. Ferrington, Department of Entomology, University of Kansas.

	Unit III-D	Unit IV-A
DIPTERA	(Relative Abundance)	
Chironimidae		
Chironomus spp.	0.56	0.90
Glyptotendiptes spp.	0.26	0.02
Parachironomus spp.	0.04	----
Tanytarsini spp.	0.03	----
Chironomini spp.	0.02	0.01
Zavereliella spp.	0.01	----
Tanypus neopunctatus	----	0.005
Cricotopus spp.	----	0.005
Polypedilium spp.	0.01	----
Dolichopodidae	0.02	----
Ceratopogonidae	----	0.005
Aedes spp.	0.005	0.005
Ephydridae	0.03	0.005
ODONATA		
Libelludidae	0.02	----
Coenagrionidae	0.03	----
COLEOPTERA		
Hydrophilidae	0.01	----
Berosus spp.	----	0.01
Troposternus laterallis	----	0.005
HEMIPTERA		
Saldidae	0.01	----
Corixidae	----	0.04

In contrast, invertebrate community structure is different in salt marsh areas of the refuge, which will continue to persist in a natural state in Unit I and Unit IV under alternative C. The most abundant invertebrates are gastropods (snails), both in water column and benthic habitats; these are important food items for waterfowl, especially black ducks. Chironomids are usually the second most abundant invertebrate group, followed by shore flies (*Ephyridae*), long-legged flies (*Dolichopodidae*), and biting midges (*Ceratopongidae*). Native invertebrate species also benefit from invasive plant control activities conducted on salt marsh habitats.

In alternative C, both aquatic and terrestrial invertebrates benefit from water level management and invasive plant control activities in freshwater environments. Restoration or maintenance of open fields in native vegetation in early successional seral stages surrounding open emergent wetland habitat provides hundreds of acres of flowering plants with plentiful nectar resources and beneficial direct and indirect impacts for both terrestrial and aquatic insect pollinator species.

Cooperative farming practices under alternative C involve the use of glyphosate-tolerant soybean and corn, which are genetically modified. No direct impacts of glypohsate resistance transgenes in plant material have been found on insects (Cerdeira and Duke 2006). However, general management actions associated with the farming program, including maintaining up to 600 acres of row cropped agricultural fields, continued drainage of farmed wetlands, and fragmenting native habitats, preclude optimal use of potential habitats by invertebrates.

The beneficial impacts to invertebrates associated with alternative C are largely the same as those associated with alternative B, particularly with regard to limiting the use of adulticides for mosquito control and restoring native vegetation communities. However, in the absence of proactive restoration of salt marsh habitat, the benefits of salt marsh for certain invertebrates will not be realized as quickly, or possibly to the same extent.

The adverse impacts to invertebrates associated with Alternative C are also largely the same as those associated with Alternative B. Under Alternative C, the State of Delaware will still be permitted the limited use the larvicides Bti and methoprene, thus would still result in the adverse impacts to invertebrates described above. In the absence of proactive restoration of salt marsh, there would be no adverse impacts associated with mechanical restoration activities, as there would be in Alternative B.

Impacts associated with public use are the same as alternative B and as Impacts on Invertebrates That Would Not Vary by Alternative.

Public Use
Adverse impacts associated with public use are the same as alternative A and as Impacts on Invertebrates That Would Not Vary by Alternative.

Conclusion for Management Actions in Alternative C
Management actions in alternative C will have mainly the same moderate local, long-term impacts on invertebrates as alternative B, and mosquito control under alternative C will have the same minor local short-term adverse impacts on invertebrates.

The land management associated with the farming program will have minor-to-moderate local long-term adverse impacts on invertebrate populations.

Maintenance of freshwater impoundments would have minor beneficial impacts to existing freshwater invertebrate populations. However, because we know that alternative A is not sustainable under the existing conditions of sea level rise and insufficient marsh accretion, we would anticipate a minor-to-moderate local long-term shift in the invertebrate community occurring in the future. The impairment to refuge's BIDEH with the use of adulticides is minimized through the use of best management practices and special use permit conditions.

Impacts on Public Use and Access

As described previously, the Delmarva Peninsula is a major attraction for outdoor enthusiasts. Although the refuge is not typically the primary destination of most visitors, it does enhance the experience by offering public access to premiere sites with outstanding opportunities for wildlife-dependent recreational activities. Since refuge lands are held in the public trust by the Service, we seek to permit access for compatible, priority wildlife-dependent public uses unless, Federal trust resources would be impacted, the activity would detract from achieving refuge purposes or the Refuge System mission, or administrative resources are not available to ensure a safe, quality experience. As discussed in Chapter 3 Affected Environment, Prime Hook NWR is currently open to all six priority public uses (hunting, fishing, wildlife observation and photography, environmental education and interpretation).

We evaluated the following management actions for their potential beneficial or adverse impacts on public use and access that would result from implementing each alternative as described in detail in chapter 4:

- Opening existing refuge areas for approved public access and appropriate, wildlife-dependent activities
- Improving or constructing visitor infrastructure
- Collaborating in partnerships with local, regional, and state recreation interests
- Improving outreach and Service visibility

We considered the following potential short- and long-term direct, indirect, and cumulative impacts on public use and access that could result from the actions above:

- Conflicts among users—both actual (e.g., consumptive vs. non-consumptive) and perceived (e.g., outreach for one activity may deter the interest of other users)
- Conflicts among uses (e.g., conflicts about safety and access)
- Changes in use (e.g., existing non-wildlife-dependent uses may cease)
- More informed public (e.g., about species, their habitats, and their conservation)
- More supportive public (e.g., of the refuge, the Refuge System, and the Service)
- Increases in visitation and its associated effects on the quality of the experiences and our ability to meet the demand

Impacts on Public Use and Access That Would Not Vary by Alternative

Below is a breakdown of impacts that affect public use and access including visitor facilities, existing priority public use opportunities, hunting, fishing, wildlife observation & photography, environmental education & interpretation, and non-priority public uses. In all the alternatives, we will continue to open the

refuge for public use from one-half hour before sunrise to one-half hour after sunset, seven days a week. However, emergency situations may arise on the refuge resulting in closures that are not anticipated at this time. Impacts of these hours of operation are expected to be negligible based on past observations by refuge staff.

Visitor Facilities
Having well-maintained visitor facilities is important for encouraging and welcoming visitors to public lands. It reflects on the Service's responsibility to spend taxpayer dollars effectively and efficiently. It is also important to protect public safety and refuge resources, both of which can be directly impacted or compromised when facilities deteriorate. Under all alternatives, we would continue to take this responsibility seriously and insure all facilities are up to Service standards and safe conditions.

Existing Priority Public Use Opportunities
In all alternatives, the Refuge would be promoting wildlife-oriented recreational opportunities that are compatible with the purpose for which the refuge was established. The public would have an increased awareness of the refuge and the National Wildlife Refuge System. The beneficial impacts of providing the existing level of wildlife-dependent activities, with some modest increases, include helping meet existing and future demands for outdoor recreation and education, as documented in the State comprehensive outdoor recreation plan (DNREC 2003) and in our visitor and community survey (Sexton et al. 2007). Visitors interested in wildlife-dependent recreation would find high quality opportunities to engage in their favored pastimes. Visitor use is increasing over time as local residents and visitors become more aware of refuge opportunities, and as we progress in creating new facilities and programs. The economic benefits of increased tourism likely would also benefit local communities. There are also opportunities for disabled individuals such as wheelchair-accessible trails, an observation platform, and fishing pier.

Over time, it is reasonable to believe that public awareness of the refuge would increase, and, in turn, visitation would increase on the areas open for public use. The refuge may or may not be capable of meeting the demand as it increases: providing programs, maintaining facilities, and providing adequate facilities for increased numbers of visitors, e.g., parking areas. Whether the refuge would be capable of meeting increasing demand depends on our coinciding levels of staffing or the availability of partners and volunteers to assist.

Eventually, the level and means of use resulting from this increase in visitation could change the nature of the experience for many visitors. Some may choose either to forgo these recreational opportunities due to issues of crowding or behavior, or to go elsewhere. Because the refuge provides opportunities now for only a small portion of the area's visitors, if that shift occurs, it is not imminent and would likely occur outside the 15-year period of this plan. If it does occur, it could put additional strains on other public lands, or diminish the refuge's contribution to the mission of the National Wildlife Refuge System. We would work to avoid that by continuing to distribute our programs and facilities to minimize conflicts among users.

As public use levels expand across time, unanticipated conflicts between user groups may occur. The refuge's visitor use programs would be adjusted as needed to eliminate or minimize each conflict and provide quality wildlife-dependent recreational opportunities. The Service's law enforcement efforts will be increased.

Hunting
In all alternatives, annual refuge hunts would continue for deer, waterfowl, and upland game on designated areas of the refuge. Those areas would be open for hunting during designated times during the State hunting season, which usually begins in September and ends in May.

Hunters would also have the opportunity to harvest a renewable resource in a traditional manner, which is culturally important to the local community. Under all alternatives, the public will be able to enjoy hunting at no or little cost in a region where private land is leased for hunting, often costing a person several hundred to several thousand dollars per year for membership. We also make special accommodations for mobility-impaired hunters and youth hunters, which will provide the opportunity to experience a wildlife-dependent recreation, instill an appreciation for and understanding of wildlife, the natural world, and the environment, and promote a land ethic and environmental awareness.

We may close the refuge to other public uses on those areas during hunt days, unless we can safely sequester the locations of those uses from the locations of hunting activity. Experience has proven that time and space zoning (e.g., establishment of separate use area, use periods, and restriction on the number of users) is an effective tool in eliminating conflicts between user groups. Currently, we restrict other wildlife-dependent recreation on days when we allow hunting on the refuge, and impacts are negligible. Seasonal closures on Prime Hook Creek minimize conflicts between anglers, wildlife observers, and hunters and minimize disturbance to waterfowl. The headquarters area, which contains the visitor contact station, hiking trails, and fishing opportunities, is closed for one to two days to facilitate a deer hunt. Closed areas of the refuge along Slaughter Beach Road, Cods Road, Prime Hook Beach Road, and Broadkill Beach Road are open only to permitted hunters during designated times of the hunting season. For the remainder of the year, these areas are closed to the public.

Fishing
In all alternatives, recreational fishing and crabbing would continue on designated areas of the refuge except for seasonal closures on Prime Hook Creek.

We would reevaluate the fisheries populations in waterbodies open to fishing, such as Turkle Pond, Fleetwood Pond, Prime Hook Creek, and any proposed areas every five years or as necessary to ensure the continued health of the fish population. Should those populations demonstrate unhealthy conditions, we could close or otherwise restrict the program until we studied the problem further or corrected it. However, we would make every effort to prevent confusion by explaining the situation to the public through the refuge Web,site, signs, and news releases.

Wildlife Observation and Photography
In all alternatives, wildlife observation and photography will be provided in designated areas on the refuge, except for seasonal closures for hunting in designated areas. Hiking is limited to the trail proper and may not range into adjacent areas. Conflicts between user groups offer the primary potential for adverse impacts, which are discussed in the impacts of hunting.

Guided tour activities may also conflict with other refuge users. For example, commercial or non-commercial tours will most likely use the same areas as independent wildlife viewers, kayakers and canoeists, and hunters and anglers during open seasons. Unregulated or inadequately regulated commercial guiding operations may adversely affect the safety of other refuge users, the quality of their experience, and the equity of opportunity. Stipulations for commercial guides should mitigate these concerns by volume and space restraints. Guide

operations may increase use of some refuge facilities, such as boat launch ramps, but, if regulated, the impacts of this increase would be negligible.

Environmental Education and Interpretation
Providing environmental education and interpretive programs in the refuge auditorium, environmental education pavilion, and public use areas is expected to continue with negligible impacts, regardless of the alternative.

As regional tourism and coastal populations increase, the demand for local outreach and environmental education and interpretation programs is also increasing. In all of the alternatives, we would continue to provide at least limited environmental education and outreach, as staffing is a limiting factor in the refuge's ability to provide these opportunities. Programs will continue to include providing outdoor classroom sites or programs for visiting school groups, taking part in local events, speaking to local organizations, releasing newspaper articles, and providing refuge brochures to Chambers of Commerce and information centers upon request. The continued involvement of the Friends of Prime Hook NWR, Inc., volunteers, and partners is essential to the long-term success of this wildlife-dependent activity.

Non-Priority Public Uses
Canoeing, walking, hiking, and jogging are uses allowed across all alternatives. These uses were individually found compatible in alternative A, but were considered as a means of access under the compatibility determinations in alternatives B and C. Specialized uses such as commercially guided tours for wildlife observation (including commercially guided tours for continuing education) are also permitted.

Activities previously and currently being evaluated by the refuge manager and determined not to be appropriate or compatible on refuge lands include recycling trash using State-sponsored recycle containers located on the refuge, ice skating, camping, horseback riding, geocaching/metal detecting, off-road and mountain biking, off-road vehicles including ATVs, commercial dog walking, operation of model boats and airplanes, swimming and sunbathing, waterskiing, personal watercraft, air thrust boats, soliciting funds (per 50CFR 27.97 for private operations and per 50CFR 27.86 for begging), and other activities identified in 50CFR Part 27. Of these uses, the only one with a documented appropriateness finding is recycling trash using State-sponsored recycle containers on the refuge. The other uses listed here were never formally evaluated and documented under current management; however, it is our professional judgment that these uses were never allowed. Very few complaints have been received by not allowing these activities.

Impacts on Public Use and Access in Alternative A

Demand and Access
Alternative A would maintain the current level of programs and types of public use opportunities on the refuge. We would not expand permitted uses, programs, or facilities. Visitation may increase in alternative A and impacts are expected to be negligible based on past observations by Refuge staff of fluctuations in annual visitation levels.

Failing impoundment infrastructure and more frequent and severe annual coastal storms are having and will continue to have moderate adverse impacts on refuge vegetation with changes in abundance, distribution, and composition of wetland vegetation. The response of fish and wildlife resources to these habitat changes may affect the quality of priority public uses such as hunting, wildlife observation & photography, and fishing. Impacts are uncertain at this time.

Hunting
Public opportunities to hunt on the Delmarva Peninsula are decreasing with increasing private land development. Refuge lands are thus become increasingly important in the region as a place to engage in this activity. A recent study found that 78 percent of hunters in Delaware hunt on private land (U.S. Department of the Interior 2006). When asked the importance of hunting activities in the U.S. Geological Survey visitor and community survey (Sexton et. al 2007), a little over half of the responses rated them as moderately to very important.

This alternative would have negligible impacts on current hunting opportunities on the refuge as discussed in the previous section. The current annual refuge hunts for deer (3,876 acres), waterfowl (1,723 acres), and upland game (1,957 acres) would continue on designated areas of the refuge. Since this alternative involves little to no change in regulations and hunting methods and practices, hunters would find little disruption to their expectation and routines.

Fishing
Public opportunities for tidal and non-tidal fishing abound on the Delmarva Peninsula. We are currently able to meet the demand for fishing according to staff observation of the level of use on the refuge. The use is steady, but not crowded. However, the demand for public fishing is growing quickly in the immediate area of the refuge. Delaware's comprehensive outdoor recreation plan identified that providing fishing areas is a high priority for Sussex County (DNREC 2003). Providing canoe and kayak access is listed as a moderate priority. The U.S. Geological Survey visitor and community survey also supports these findings (Sexton et. al 2007). When asked the importance of angling activities, all were rated as moderately important.

This alternative would have negligible impacts on current fishing program as discussed in the previous section. Since this alternative involves little or no change in the regulations that affect fishing, anglers would encounter little or no disruption of their expectations or routines.

Wildlife Observation, Photography, Environmental Education, and Interpretation
According to the Delaware's comprehensive outdoor recreation plan, 3 of the top 10 needs for outdoor recreation are walking and hiking trails, fishing areas, and canoe and kayak access (DNREC 2003). The Geological Survey visitor and community survey report further reveals that most visitor and community residents visit the refuge for wildlife observation (Sexton et al. 2007). Being in a natural, undeveloped area and experiencing a serene environment are equally important to their refuge experience as well as the trails that afford this opportunity (Sexton et al. 2007). These activities are equally important to consumptive and non-consumptive use visitors. Furthermore, survey respondents reported that they would like to see increases or improvements in wildlife viewing opportunities, environmental education, interpretive exhibits, and hiking and nature trails (Sexton et al. 2007). Our present facilities meet the existing demand; however, that will not be the case if populations and subsequent demands considerably increase.

In alternative A, opportunities for wildlife-dependent activities would continue and impacts would continue to be negligible.

Non-Priority Public Uses
The following non-priority public use activities are allowed: commercial fishing, commercial trapping of muskrat, raccoon, etc., turtle trapping, picnicking, 5K road race, beekeeping, waterfowl retrieval permits, dog walking, roller blading, competitions or organized group events, and non-competitive organized events.

Activities not allowed are discussed under Impacts on Public Use and Access That Would Not Vary by Alternative.

Conclusion for Management Actions in Alternative A
Management actions in alternative A in the short-term and long-term would result in site-specific, negligible impacts on public use and access. The response of fish and wildlife resources to habitat changes may affect the future quality of priority public uses such as hunting, wildlife observation & photography, and fishing.

Impacts on Public Use and Access in Alternative B

Demand and Access
Alternative B would increase opportunities for wildlife-dependent public use and access by enhancing those programs and facilities at the refuge. Providing new public recreation opportunities would enable people to participate in outdoor activities where they otherwise could not. Increased public awareness, improved community relations and enhanced support of the refuge mission would result as a byproduct of this new interaction. We would help meet demands from the communities where we are located, and from tourists, for outdoor recreation and education, as documented in the Delaware comprehensive outdoor recreation plan and our visitor and community survey. By attracting visitors from outside the area, local communities should experience economic benefits from sales of food, lodging, and supplies.

Alternative B proposes to reduce nearly all hunting permit fees (except for lottery hunts) and boat launching fees. This change should be well received by hunters, anglers, and wildlife observers and photographers. For the hunting program, this alternative reduces the administrative burden and minimizes the amount of staffing resources needed to conduct the hunt by 54 staff days and $17,890 from current management in alternative A. The reduction in the cost to hunt provides a minor beneficial impact to the hunter.

Fees will still be required to manage the lottery hunts for deer, waterfowl, and turkey. The Refuge Recreation Act requires that funds are available for the development, operation, and maintenance of the permitted forms of recreation. The proposed permit fee ($10 for deer and turkey; $15 for waterfowl), preseason application fee ($5/hunter), and processing fee for permits acquired after the preseason drawing ($2 to 3 per hunt) are the minimal amounts needed to offset the cost of facilitating the preseason drawings and manage the lottery hunts. Due to the uncertainty in the level of hunter participation with these new program changes, permit fees may need to be adjusted (increased or decreased) and therefore will be evaluated. New fees for preseason application for waterfowl and turkey hunting, new processing fees for standby permits, and charging a flat blind fee for waterfowl rather than an individual fee are anticipated to be unpopular with the hunting public.

The level and means of use resulting from this increase in visitation would change the overall experience for some visitors and could result in their changing their patterns of activity or site preferences due to issues of crowding or behavior. Again, given that the refuge provides opportunities for a small portion of the area's visitors, if that shift occurs, it would not be imminent, and could occur outside the 15-year period of this plan. If it does occur, it could put additional strains on other public lands.

Overall, alternative B would have moderate adverse impacts on a certain segment of the public that does not desire any change in public use programs and regulations, or that may hold differing views on the course of action. In addition, while new visitors become familiar with those changes, violations could increase. Some conflict between refuge users is expected to result in short-term moderate adverse impacts, which will be managed through seasonal closures. These

seasonal closures are highlighted below and apply mostly to non-consumptive users during the hunting season. Other seasonal closures are in place to minimize wildlife disturbance.

- Designated beach dunes and overwash areas: closed from March 1 through September 1 due to nesting State endangered least terns and American oystercatchers, and the potential for use by federally threatened piping plovers. Areas may be reopened if no nesting activity occurs or when nesting ends for the season.

- Western Prime Hook Creek (from old shop ramp to Waples Pond): closed every day during the deer and waterfowl hunting seasons, which typically start on September 1 and end in early February. Additional seasonal closures may apply through the second Saturday in May for hunting during the snow goose conservation order or turkey hunting.

- Deep Branch Road Trail (includes Goose and Flaxhole Ponds) and Eastern Prime Hook Creek (from old shop ramp to the headquarters ramp): closed every day from September 1 through March 15. Additional seasonal closures may apply through the second Saturday in May for hunting during the snow goose conservation order or turkey hunting.

- Headquarters area (includes Turkle and Fleetwood Ponds): closed for a maximum of 2 days for deer hunts.

- The northern portion of Unit IV (includes trail overlooking Vergie's Pond): closed from the Monday before Thanksgiving through March 15. Additional seasonal closures may apply through the second Saturday in May for hunting during the snow goose conservation order and/or turkey hunting.

- Hiking Trails on Fowler Beach Road, Prime Hook Road, and Slaughter Beach Road and Slaughter Canal: Closed except for Sundays from September 1 through the deer and waterfowl hunting seasons, which typically end in early February. Additional seasonal closures may apply through the second Saturday in May for hunting during the snow goose conservation order or turkey hunting.

- Roadside pull-offs and water control structures and fishing areas at Petersfield Ditch, Slaughter Canal and Cods Road: open year-round.

Negative reactions by some visitors may be caused by the closure of the western end of Prime Hook Creek to all uses (mainly fishing, canoeing, and kayaking) other than hunting from September 1 through the end of the deer and waterfowl hunting seasons; the closure of the eastern end of Prime Hook Creek from September 1 through March 15; and the temporary closure of the general public use area near the refuge headquarters to conduct deer hunts. Seasonal closures for hunting occur during the fall and winter months, which is typically a slower period of use due to weather conditions. Refuge officers would enforce these and other current refuge regulations, where appropriate, and would seek the assistance and cooperation of Delaware Division of Fish and Wildlife in enforcing common regulations to provide a safe environment for refuge visitors and promote activities that are compatible with protecting the resources.

Currently, the public can travel to the Delaware Bay at Fowler Beach via Fowler Road, which is a State-maintained road. If this roadway from the bridge at Slaughter Canal to Fowler Beach becomes impassable or unsafe due to environmental conditions such as water erosion, public access (vehicular and pedestrian) would be lost, as the road surface would eventually become marsh. Loss of public access to this area would result in a loss of opportunities for wildlife observation, wildlife photography, and fishing. These recreational

opportunities may still exist at the bridge area, where there is currently a parking lot and unimproved boat launch, pending the extent of environmental conditions on public use infrastructure.

The proposed restoration of freshwater impounded wetlands to salt marsh and proposed reforestation of uplands will have long-term moderate-to-major beneficial impacts and negligible-to-minor short-term adverse impacts on refuge vegetation. The response of fish and wildlife resources to these habitat changes may affect the quality of priority public uses such as hunting, wildlife observation & photography, and fishing. Impacts are uncertain at this time, but are expected to be beneficial.

Visitor Facilities
The proposed expansion of facilities for environmental education and visitor services programs is expected to increase public awareness of, and visitation to, the refuge and enable staff to provide better customer service. Constructing new interpretive and informational signs and small pavilions on new and existing tracts is expected to provide greater opportunities for conveying conservation messages to visitors, thus increasing their awareness, and possibly their support of the refuge. Minor beneficial impacts to visitors are expected.

We would expect a certain level of inconvenience during the construction of refuge facilities; however, our use of practices that alert and safeguard refuge visitors should mitigate these effects. The minor adverse impacts generally are short-term, and more than offset by the long-term gains in public education and appreciation.

Hunting
Alternative B proposes to expand hunting on refuge lands to offer quality opportunities for hunting deer, waterfowl, upland game and webless migratory birds (dove), and turkey, which will provide moderate beneficial impacts to hunters. The hunting program provides an administratively simple program that balances other public use activities. The program supports the Presidential executive order: facilitation of hunting heritage and wildlife conservation and regional directives, and parallels State hunting regulations. In addition, it provides seasonal closures to minimize wildlife disturbance and avoid conflicts with other uses (see previous section on demand and access for more information), eliminates hunting fees except for lottery hunts, enhances disabled hunting opportunities, further develops an appreciation for fish and wildlife, and expands public hunting opportunities.

Due to an increase in new hunting areas and by allowing hunters to free roam, an increase in violations may occur until hunters become familiar with the refuge boundaries and regulations. As a result, short-term minor adverse impacts may occur with some landowners due to hunter trespassing. These impacts will be minimized through enhanced law enforcement efforts. We anticipate some conflict between concurrent hunting programs (i.e., waterfowl, deer, and upland game hunting seasons overlapping). For the majority of the hunting seasons, the Delaware Division of Fish and Wildlife has made efforts to avoid these overlaps in the various hunting programs.

Preseason lottery drawings at the refuge provide hunting opportunities for local, in state, and out-of-state hunters. Advance knowledge of a hunting opportunity allows hunters to prepare, plan, and scout, which ultimately helps to provide a quality hunting experience.

We should note that, according to the U.S. Geological Survey visitor and community survey (Sexton et al. 2007) the overall mean desirability of additional hunting opportunities was not as high as that of other public use activities. However, upon further breakdown between hunters and non-hunters, the

additional hunting opportunities listed were very desirable to the hunting community. We detail below the impacts that may result from the different types of hunting: white-tailed deer, waterfowl, upland game and webless migratory birds (dove), and wild turkey.

White-tailed deer hunting: A total of 5,389 acres is open for deer hunting, which includes archery (to include the use of crossbows), muzzleloader, handgun, and shotgun hunting. Seasonal closures would occur to protect wildlife and minimize conflicts between different hunting activities and other non-consumptive recreational uses (e.g., minimize conflict with anglers on Prime Hook Creek, offset hunting days for deer and waterfowl hunting on Prime Hook Creek and for disabled hunters in the disabled hunt area; close hunting in late November in designated areas to minimize bald eagle and waterfowl disturbance). Disabled hunting areas in Unit III and IV would limit access to individuals who are permanently confined to a wheelchair, which ensures quality opportunities for hunters with limited mobility.

The Refuge proposes to open 1,513 additional acres for deer hunting under alternative B. Additional acreage proposed for hunting includes an area located north of Prime Hook Road commonly referred to as Oak Island, an area of red maple swamp along Prime Hook Creek and west of the existing Headquarters Area, an area north of Route 16 referred to as the Millman Tract, and an expansion of the Headquarters Area. Of these "new areas," Oak Island was previously hunted up until 1995 and the Millman Tract was hunted under private ownership up until the Service purchased it in 2001. Prime Hook Creek and its associated red maple swamp will provide additional opportunities and will be limited by access. Hunter numbers are expected to initially increase based on the opening of these areas and the opportunity for hunters to free-roam; however, cumulative impacts are expected to be negligible.

Permanent deer hunting stands will be phased out over a 5-year period in all areas except the disabled hunting area. We will limit the number of permits to approximately 30 in the lottery hunt area to minimize hunter conflict in an area historically known to attract large hunter numbers. In the regular hunt area, hunting will be open every day during designated seasons (except the October antlerless and handgun seasons).

The phasing out of all permanent deer hunting stands (except non-ambulatory hunt blinds) will require hunters to find a suitable hunting location within designated hunting areas through effective scouting. Use of portable deer climbing stands is recommended but not required. Hunters have expressed an interest in scouting and choosing their hunting locations to enhance the quality of their hunt. Maintenance mowing will no longer occur to provide trails to facilitate hunting. Minor-to-moderate short-term adverse impacts are expected among hunters over desired hunting locations and we will continue to encourage proper hunting ethics.

Waterfowl hunting: A total of 3,455 acres is open to migratory bird hunting, which is 40 percent of the refuge (includes lands purchased with Land and Water Conservation Funds which are excluded from the 40 percent rule). Seasonal closures would occur to not only protect wildlife, but also to minimize conflicts between different hunting activities and other non-consumptive recreational uses (e.g., offset hunting days for deer and waterfowl hunting on Prime Hook Creek and for disabled hunters in the disabled hunt area; close hunting in late November in designated areas to minimize bald eagle and waterfowl disturbance, provide access for non-consumptive users on Sundays during the hunting season). In the lottery hunt area, hunting will occur three days per week and cease at noon. In the regular hunt area, hunting will be open every day during all waterfowl hunting seasons. Although the loss of one hunting day per week

and an earlier closure at noon rather than the current 3:00pm will not be well received by the hunting public; this perceived decrease in hunting is offset by the additional 1,732 acres being proposed to open under this alternative for waterfowl hunting.

This additional hunting acreage includes: an area between Slaughter Beach Road and Fowler Beach Road referred to as Unit I, an area located south of Prime Hook Road, Prime Hook Creek, an area along the Broadkill River in Unit IV, and a reconfiguration of the existing waterfowl hunt area in Unit III. Of these "new areas," Unit I was already open to dove hunting and Prime Hook Creek was hunted up until 1991. Hunter numbers are expected to initially increase based on the opening of these areas and the opportunity for hunters to free-roam in the regular waterfowl areas; however, cumulative impacts are expected to be negligible.

Although the permanent waterfowl blinds on the refuge will be phased out over a 5-year period, we still require hunters in the lottery hunt area to hunt within a defined area around a designated blind site (marker). This will minimize hunter conflict in an area historically known to attract large hunter numbers. In past years for daily drawings on opening days, it was common to see more than 60 to 80 duck hunting parties compete for 27 available hunting opportunities.

The phasing out of all permanent waterfowl hunting blinds (except non-ambulatory blinds) in lieu of blind sites in the lottery hunt area will now require hunters to provide their own means to camouflage themselves (e.g., boat blind, pop-up blind, etc.). Hunters would be required to find a suitable hunting location within a specified area around the blind site marker. Hunters have expressed an interest in scouting and having the flexibility to adjust their hunting locations for weather conditions to enhance the quality of their hunt. In free roam areas, hunters may hunt anywhere in the designated area. Minor-to-moderate short-term adverse impacts are expected among hunters over desired hunting locations and we will continue to encourage proper hunting ethics.

The creation of sanctuaries in Unit III will result in the elimination of 6 hunting blinds from the 19 available blinds; however, an additional 8 new blinds sites will be available, for a total of 24 blind sites (plus 8 State blinds). The addition of new free roam waterfowl hunting areas in salt marsh habitats in Unit I and IV will also provide quality opportunities as well as the additional acres in the lottery hunt area.

Hunt zones in the proposed waterfowl hunt area in Unit IV along the Broadkill River have the potential to conflict with nearby existing blinds on private lands. We will monitor this activity and adjust these zones accordingly. Hunters will most likely opt to hunt within the marsh areas of these zones and not along the Broadkill River, which would lessen any direct conflicts with hunters on these nearby private lands.

Upland game and webless migratory bird hunting: A total of 1,957 acres is available for hunting upland game and webless migratory birds. Dove hunting will not be open on 105 of these acres, which should affect few hunters. Some conflict with concurrent hunting and the potential for trespassing on adjacent private land are expected and previously discussed in this section. As a result, some landowner conflicts may erupt due to hunter trespassing. These minor short-term adverse impacts will be minimized through enhanced law enforcement efforts.

Wild turkey hunting: A total of 3,472 acres is open for hunting wild turkey until noon on selected hunt days. In recent years, hunter and staff observations indicate that a huntable population of turkeys may exist on the refuge. Limited

opportunities exist on public lands to hunt turkey and the refuge may contribute to providing additional quality opportunities for hunters.

Fishing
Alternative B proposes to open Fowler Beach to night fishing by permit only and open Goose and Flaxhole Ponds as a primitive fishing area (boat-only access; manual propulsion only; boats must be ported in). Goose and Flaxhole Ponds have never been open to fishing. Fishery assessments and management recommendations will need to be conducted prior to their opening. Minor beneficial impacts are expected.

Increasing fishing opportunities on the refuge would serve the demand for more fishing opportunities in Sussex County. The improving habitat quality resulting from ongoing habitat restorations on the refuge would likely result in improving water quality and increasing some fish populations. That could positively affect the fishing experience and fishing success.

Under alternative B, we would not allow recreational gill-netting, commercial fishing, crabbing using pots or trot lines, and food fishing with equipment other than hook and line on the refuge. The use of gill netting by commercial or recreational fishermen has occurred in the tidal waterways of Slaughter Canal for over 30 years by a small number of fishermen. These activities, whether commercial or recreational, are not consistent with goals and objectives in any refuge management plan, conflict with rod and reel recreational fishermen and wildlife observers using canoes and kayaks, and has the potential to harm non-targeted fisheries through incidental by-catch. Fishing for bait fish is permitted for recreational uses only, subject to regulations stated in title 7 (Conservation) of the Delaware State Code. Minor adverse impacts are expected.

The closure of Prime Hook Creek to fishing from fall to early spring is expected to cause discontent among anglers due to the loss of opportunity; however, additional freshwater fishing opportunities have been provided through the opening of Goose and Flaxhole Ponds, which have never been open. The fishing program would not adversely affect people enjoying other, non-consumptive uses of the refuge. Some negative comments may be received by anglers not agreeing with catch-and-release regulations and the use of barbless hooks on designated waterways. Adverse impacts are expected to be minor and short-term.

Wildlife Observation and Photography
In alternative B, we propose to expand opportunities in wildlife observation, wildlife photography, and environmental education and interpretation by adding new trails using existing and already maintained trail and road networks off Slaughter Beach Road, Fowler Beach Road, Prime Hook Road, Deep Branch Road, and Broadkill Road. Using existing roads will minimize impacts to refuge resources. Moderate beneficial impacts are expected.

Nature photographers and other visitors would benefit directly from those additional facilities and the new opportunities they would provide. To enhance wildlife viewing areas, trails, pull-offs, etc., that can be accessed from public roads and highways, an interpretive brochure outlining these areas would be created to enhance the enjoyment of the visitors' experience. The elimination of boat launching fees should be well received by visitors.

The expanded use of new areas will affect, and be affected by, visitors participating in the refuge hunting program. We will enact seasonal closures to ensure the safety of non-consumptive users, as well as the quality of both programs (see information earlier in this section or in chapter 4 alternatives). Adverse impacts generally would be short-term and more than offset by the long-term gains in public awareness and support of refuge resource programs.

Environmental Education and Interpretation
Alternative B proposes that we increase educator-led programs, which will cause minor beneficial impacts and is an attempt to meet increasing demand. We also propose expanding the existing facility to accommodate increased environmental education and interpretive programs. This alternative also proposes that we continue to provide onsite and offsite interpretive programs, reaching out to civic groups, conservation organizations, and community events. In addition, we propose using a variety of public use materials, including signage, brochures, and kiosks with interpretive panels

More opportunities exist to provide public education and information for visitors. Those opportunities would foster increased public understanding and appreciation of resource issues and needs, which could lead to increased support and funding and positively affect fish and wildlife resources on the refuge. Increased outreach could also positively affect land use decisions by local governments and private landowners outside the refuge, and lead to increased populations of fish and wildlife over a broader area.

Impacts to other recreational activities are expected to be negligible, since most of the environmental education programs occur on trails adjacent to the refuge office. Visitors have several other trails to observe or photograph wildlife if school groups are present. Most likely, interpretive activities would be not performed in conjunction with other existing public use activities and therefore would not cause user-conflicts on these areas.

Non-Priority Public Uses
Commercial nature photography is allowed under alternative B. All allowed uses described in alternative A are not allowed under alternative B such as commercial fishing, commercial trapping of muskrat, raccoon, etc, turtle trapping, picnicking, 5K road race, beekeeping, and waterfowl retrieval permits. We expect substantial negative criticism of no longer allowing dog walking on the refuge, but it is an activity which causes disturbance and negative impacts to wildlife.

Conclusion for Management Actions in Alternative B
Management actions in alternative B in the short-term and long-term would result in site-specific, negligible to moderate beneficial impacts on public use and access due to expanded opportunities for both consumptive and non-consumptive users. Alternative B would contribute short-term minor-to-moderate adverse impacts to public use and access due to possible hunter conflicts and a perceived loss of opportunity for non-consumptive users from seasonal closures during the hunting season. The response of fish and wildlife resources to habitat changes may affect the future quality of priority public uses such as hunting, wildlife observation & photography, and fishing.

Impacts on Public Use and Access in Alternative C

Demand and Access
Alternative C would have similar opportunities for wildlife-dependent public use and access as alternative A, except for hunting which provides fewer opportunities than proposed in alternative B. Fees for visitor access are the same as alternative B.

The response of vegetative communities from refuge management under alternative C will be similar to alternative B except there will not be active reforestation and the potential for more wetlands to become open water is greater. The response of fish and wildlife resources to these habitat changes may affect the quality of priority public uses such as hunting, wildlife observation & photography, and fishing. Impacts are uncertain at this time.

Hunting
In alternative C, hunting overall is the same as alternative B except the number of days and areas are decreased for deer and waterfowl hunting. Beneficial impacts are similar to alternative B. Minor short-term adverse impacts are expected due to hunter conflicts.

White-tailed deer hunting: The reduction in hunting days from every day during the State hunting season to three days per week (Tuesday, Thursday, Friday) and the closure of Prime Hook Creek to hunting is not expected to result in negative feedback from the hunting public because there is still an overall increase in hunting opportunity from current management under alternative A.

The closure of Prime Hook Creek to hunting will provide access to other non-consumptive users, as represented under alternative A, and would reduce conflict between these user groups. Also, non-consumptive users will have additional access to the public use infrastructure in the headquarters area.

Waterfowl hunting: The reduction in hunting days from everyday in the free roam area (regular waterfowl hunting area) during the State hunting season to three days per week (Monday, Wednesday, Saturday) and the closure to hunting of Prime Hook Creek and Unit IV along the Broadkill River is not expected to result in negative feedback from the hunting public because there is still an overall increase in hunting opportunity from current management under alternative A.

As with deer hunting, the closure of Prime Hook Creek to hunting will provide access to other non-consumptive users, as represented under alternative A, and would reduce conflict between these user groups. The closure of hunting areas in Unit IV along the Broadkill River will eliminate any conflict hunters on adjacent private property.

Upland game and webless migratory bird hunting: Same as the impacts listed under alternative B in Impacts on Public Use and Access.

Wild turkey hunting: Same as the impacts listed under alternative A in Impacts on Public Use and Access.

Fishing
Similar to impacts listed under alternative A, except Slaughter Canal will only be open on Sundays from September 1 through the end of the hunting season.

Wildlife Observation and Photography
Similar to impacts listed under alternative A.

Environmental Education and Interpretation
Similar to impacts listed under alternative B.

Conclusion for Management Actions in Alternative C
Management actions in alternative C in the short-term and long-term would result in site-specific negligible-to-moderate beneficial impacts on public use and access due to expanded hunting opportunities. Alternative C would contribute short-term negligible-to-minor adverse impacts to public use and access due to possible hunter conflicts. The response of fish and wildlife resources to habitat changes may affect the future quality of priority public uses such as hunting, wildlife observation & photography, and fishing.

Cumulative Impacts

According to the CEQ regulations on implementing NEPA (40 CFR 1508.7), a cumulative impact is an impact on the environment that results from the incremental impact of the action when added to other past, present, and

reasonably foreseeable future actions, regardless of what agency (Federal or non-Federal) or person undertakes the other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over time.

Our cumulative impacts assessment includes the actions of other agencies or organizations, if they are interrelated and influence the same environment. This analysis considers the interaction of activities at the refuge with other actions occurring adjacent to the refuge and over a larger state and regional spatial and temporal frame of reference.

Cumulative Impacts of Climate Change on Refuge Lands

Department of the Interior Secretarial Order 3226 states that "there is a consensus in the international community that global climate change is occurring and that it should be addressed in governmental decision making. This order ensures that climate change impacts are taken into account in connection with Departmental planning and decision making." Additionally, it calls for the incorporation of climate change considerations into long-term planning documents, such as a CCP.

The Wildlife Society published an informative technical review report in 2004 titled Global Climate Change and Wildlife in North America (Inkley et al. 2004). It interprets results and details from publications such as the Intergovernmental Panel on Climate Change reports (1996 to 2002) and describes the potential impacts and implications on wildlife and habitats. It mentions that projecting the impacts of climate change is hugely complex because it is important to predict changing precipitation and temperature patterns, their rate of change, and the exacerbated effects of other stressors on the ecosystems. Those stressors include loss of wildlife habitat to urban sprawl and other developed land uses, pollution, ozone depletion, exotic species, disease, and other factors. Projections over the next 100 years indicate major impacts such as extensive warming in most areas, changing patterns of precipitation, and significant acceleration of sea level rise. According to the Wildlife Society report, "…other likely components of ongoing climate change include changes in season lengths, decreasing range of nighttime versus daytime temperatures, declining snowpack, and increasing frequency and intensity of severe weather events" (Inkley et al. 2004). The Wildlife Society report details known and possible influences on habitat and wildlife, including changes in primary productivity, changes in plant chemical and nutrient composition, changes in seasonality, sea level rise, snow, permafrost, and sea ice decline, increased invasive species, pests and pathogens, and impacts on major vertebrate groups.

The effects of climate change on populations and range distributions of wildlife are expected to be species specific and highly variable, with some effects considered negative and others considered positive. Generally, the prediction in North America is that the ranges of habitats and wildlife will generally move upwards in elevation and northward as temperature rises. Species with small or isolated populations and low genetic variability will be least likely to withstand impacts of climate change. Species with broader habitat ranges, wider niches, and greater genetic diversity should fare better or may even benefit. This will vary depending on specific local conditions, changing precipitation patterns, and the particular response of individual species to the different components of climate change (Inkley et al. 2004). The report notes that developing precise predictions for local areas is not possible due to the scale and accuracy of current climate models, which is further confounded by the lack of information concerning species-level responses to ecosystem changes, their interactions with other species, and the impacts from other stressors in the environment. In other words, only imprecise generalizations can be made about the implications of our refuge management on regional climate change.

Our evaluation of the proposed actions concludes that only two activities may contribute negligibly, but incrementally, to stressors regionally affecting climate change: our prescribed burning program and our use of vehicles and equipment to administer the refuge. We discuss the direct and indirect impacts of those activities elsewhere in this chapter. We also discuss measures to minimize the impacts of both. For example, with regard to prescribed burning, we follow detailed burn plans operating only under conditions that minimize air quality concerns. In addition, many climate change experts advocate prescribed burning to manage the risk of catastrophic fires (Inkley et al. 2004). With regard to our equipment and facilities, we are trying to reduce our carbon footprint wherever possible by using alternative energy sources and energy-saving appliances, and using recycled or recyclable materials, along with reduced travel and other conservation measures.

In our professional judgment, the majority of management actions we propose would not exacerbate climate change in the region or project area, and some might incrementally prevent or slow local impacts. We discuss our actions relative to the 18 recommendations in the Wildlife Society report to assist land and resource managers in meeting the challenges of climate change when working to conserve wildlife resources (Inkley et al. 2004).

- ***Recommendation #1:*** Recognize global climate change as a factor in wildlife conservation: this recommendation relates to land managers and planners becoming better informed about the consequences of climate change and the variability in the resources they work with.

  The Service is taking a major role among Federal agencies in distributing and interpreting information on climate change. There is a dedicated Web page to this issue at *http://www.fws.gov/home/climatechange/*; accessed February 2012. The Service's Northeast Region co-hosted a workshop in June 2008 titled Climate Change in the Northeast: Preparing for the Future. The goal of the workshop was "to develop a common understanding of natural and cultural resource issues and to explore management approaches related to climate change in the Northeast." Its primary target audience was land managers. Experts in climate change gave presentations and facilitated discussion. The stated outcomes were to have participants more fully understand the present and anticipated impacts from climate change on forested, ocean and coastal ecosystems, and to be able to identify effective management approaches that include collaboration with other local, state and Federal agencies. All of the Northeast Region refuge supervisors and planners attended, as did more than 20 refuge field staff.

- ***Recommendation #2:*** Manage for diverse conditions. This recommendation relates to developing sound wildlife management strategies under current conditions, anticipating unusual and variable weather conditions, such as warming, droughts, and flooding.

  Our proposed habitat management actions described in chapter 2 promote healthy, functioning native forests, shrublands, and grasslands. Protecting the integrity of wetlands and managing for fully functioning riparian areas is also a priority. We have identified monitoring elements, which will be fully developed in the inventory and monitoring step-down plan, to evaluate whether we are meeting our objectives and to assess changing conditions. We will implement an adaptive management approach as new information becomes available.

- ***Recommendation #3:*** Do not rely solely on historical weather and species data for future projections without taking into account climate change. This recommendation relates to the point that historical climate, habitat and wildlife conditions are less reliable predictors as climate changes. For example, there

may be a need to adjust breeding bird survey dates if migratory birds are returning earlier to breed than occurred historically. A 3-week difference in timing has already been documented by some bird researchers.

We are aware of these implications and plan to build these considerations into our inventory and monitoring plan and annual habitat work plans so that we can make adjustments accordingly. Our results and reports, and those of other researchers on the refuge, will be shared within the conservation community.

- ***Recommendation #4:*** Expect surprises, including extreme events. This recommendation relates to remaining flexible in management capability and administrative processes to deal with ecological surprises such as floods or pest outbreaks.

  Refuge managers have flexibility within their operations funds to deal with emergencies. Other regional operations funds would also be redirected as needed to deal with an emergency.

- ***Recommendation #5:*** Reduce non-climate stressors on the ecosystem. This recommendation relates to reducing human factors that adversely affect resilience of habitats and species.

  Similar to our response to #2 above, the objectives of our habitat management program are to maintain and enhance the biological integrity, diversity, and health of refuge lands. Objectives to enhance riparian habitat for watershed protection and establish healthy, diverse native forests in large tracts will help offset the local impacts of climate change.

- ***Recommendation #6:*** Maintain healthy, connected, genetically diverse populations. This recommendation relates to the fact that small isolated populations are more prone to extirpations than larger, healthy, more widespread populations. Large tracts of protected land facilitate more robust species populations and can offer better habitat quality in core areas.

  We will continue to work with our many conservation partners at the State and regional levels to support and complement restoration and protection efforts.

- ***Recommendation #7:*** Translocate individuals. This recommendation suggests that it may sometimes be necessary to physically move wildlife from one area to another to maintain species viability. However, it is cautioned that this tool has potential consequences and should only be used as a conservation strategy in severely limited circumstances.

  Extensive salt water intrusion into our freshwater emergent and forested wetlands from even more rapid sea level rise than is predicted could result in the catastrophic loss of forested upland habitats and convert them to open water. This may warrant a rapid translocation of endangered Delmarva fox squirrels to inland national wildlife refuges as the only mitigation to avoid jeopardy.

- ***Recommendation #8:*** Protect coastal wetlands and accommodate sea level rise. This recommendation relates to actions that could ameliorate wetland loss and sea level rise, such as purchasing wetlands easements, establishing riparian and coastal buffers, restoring natural hydrology, and refraining from developments or impacts in sensitive wetlands and coastal areas.

  Our four habitat goals and associated objectives identify restoring natural hydrology in salt marshes and prior converted wetlands for croplands, protecting barrier beach island habitats from erosion, conserving sensitive

wetlands and coastal maritime shrub and forest communities, establishing riparian and coastal buffers and reforesting open field areas.

- ***Recommendation #9:*** Reduce the risk of catastrophic fire. This recommendation acknowledges that fire can be a natural part of the ecosystem, but that climate change could lead to more frequent fires or greater likelihood of a catastrophic fire.

  Our plans to conduct prescribed burns to maintain grasslands, control invasive plants, and reduce fuel loading in overstocked forest stands would reduce the overall risk of a catastrophic event occurring on or near refuge lands.

- ***Recommendation #10:*** Reduce likelihood of catastrophic events affecting populations. This recommendation states that increased intensity of severe weather can put wildlife at risk. While the severe weather cannot be controlled, it may be possible to minimize the effects by supporting multiple, widely spaced populations to offset losses.

  Our response to recommendations #2, #5, and #6 above describes the actions we are taking to minimize risks to wildlife.

- ***Recommendation #11:*** Prevent and control invasive species. This recommendation emphasizes the increased opportunities for invasive species to spread because of their adaptability to disturbance. Invasive species control will be essential, including extensive monitoring and control to preclude larger impacts.

  Invasive species control is a major initiative within the Service. The Northeast Region, in particular, has taken a very active stand. In chapter 2, we provide detailed descriptions of our current and future plans on the refuge to control existing invasive plant infestations. We also describe monitoring and inventorying strategies to protect against any new infestations.

  Our wildland urban interface program, established in 2002, has been an aggressive program to reduce heavy accumulations of dead fuels (*Phragmites* sprayed canes and other highly flammable vegetation) on the refuge and immediately adjacent to the refuge. We have been and will continue to work with many landowners in the refuge area to control *Phragmites* and other fire prone wildland vegetation to avoid catastrophic fire and aggressively treat any fuel hazards immediately.

- ***Recommendation #12:*** Adjust yield and harvest models. This recommendation suggests that managers may have to adapt yield and harvest regulations in response to climate variability and change to reduce the impact on species and habitats.

  We do not have plans for any significant harvest activities. We plan to phase out our cooperative farming program, and will only harvest trees in overstocked, naturally succeeding, forested habitats to improve forest diversity, composition, and health. Our monitoring program will include detecting population trends in focal species to alert us to any significant changes.

  Regarding animal harvest through hunting programs, the refuge does not set harvest regulations. For resident wildlife, regulations are established at the State level. For migratory game birds, the harvest framework is established at the flyway level, and further refined at the State level.

- ***Recommendation #13:*** Account for known climatic conditions. This recommendation states we should monitor key resources through predictable short-term periodic weather phenomena, such as El Nino, to aid us in future management efforts.

  We plan to develop a monitoring program that will help us evaluate our hypotheses, assumptions, and successes in achieving objectives, as well as help us make future management decisions. Any restoration activities or proactive habitat management actions will be carefully planned and their effectiveness monitored and documented so we can use the information in future management decisions.

- ***Recommendation #14:*** Conduct medium- and long-range planning. This recommendation states that plans longer than 10 years should take into account potential climate change and variability as part of the planning process.

  This 15-year CCP addresses climate change with its emphasis on restoring and maintaining healthy, contiguous, native habitat areas, reducing and mitigating human stressors on refuge lands, working with private landowners to improve the health, integrity, and fire safety of their lands, and pursuing larger conservation connections and corridors with partners to enhance protected core areas. Our monitoring program and adaptive management strategies will also facilitate our ability to respond to climate change.

- ***Recommendation #15:*** Select and manage conservation areas appropriately. This recommendation states that establishment of refuges, parks, and reserves is a conservation strategy to try to minimize the decline of wildlife and habitats in North America. Decisions on locating future conservation areas should take into account potential climate change and variability. For example, it is suggested that decisions on new acquisitions consider the anticipated northward migrations of many species, or the northern portion of species ranges. Managers of existing conservation lands should consider climate change in future planning.

  Our response to recommendation #14 also should be noted here.

- ***Recommendation #16:*** Ensure ecosystem processes. This recommendation suggests that managers may need to enhance or replace diminished or lost ecosystem processes. Manually dispersing seed, reintroducing pollinators, treating invasive plants and pests, are examples.

  While we plan to take an aggressive approach to treating invasive plants, we do not believe at this time there is any need to enhance or replace ecosystem processes. Further, none of our proposed management actions will diminish existing natural ecosystems processes. Should our monitoring results reveal that we should take a more active role in enhancing or replacing those processes, we will reevaluate or refine our management objectives and strategies.

- ***Recommendation #17:*** Look for new opportunities. This recommendation states that managers must be continually alert to anticipate and take advantage of new opportunities that arise. Creating wildlife conservation areas from abandoned or unusable agricultural land, and taking advantage of industry interest in investing in carbon sequestration or restoration programs are two examples.

Refuge staff members have many conservation partners in the area who, in turn, are networked throughout the larger region. We hear about many opportunities for land protection or habitat restoration through that broad-based network. Our Northeast Region has field offices and a regional office that integrates the other Service program areas, including those that work with private entities. We have developed outreach materials and make ourselves available to interested organizations and groups to provide more detailed information on the Service and Refuge System missions, refuge goals and objectives, and partnership opportunities.

- ***Recommendation #18:*** Employ monitoring and adaptive management. This recommendation states that we should monitor climate and its effects on wildlife and their habitats and use this information to adjust management techniques and strategies. Given the uncertainty with climate change and its impacts on the environment, relying on traditional methods of management may become less effective.

We agree that an effective and well-planned monitoring program, coupled with an adaptive management approach, will be essential to dealing with the future uncertainty of climate change. We have built both aspects into our CCP. We will develop a detailed step-down inventory and monitoring plan designed to test our assumptions and management effectiveness in light of on-going changes. With that information in hand, we will either adapt our management techniques or reevaluate or refine our objectives as needed.

Cumulative Impacts on Climate Change-Vulnerable Species

For a more generalized consideration of sea level rise and anticipated cumulative impacts to climate-vulnerable species of the mid-Atlantic area, we reviewed the U.S. Climate Change Science Program's report Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region (USCCSP 2009). The findings of this report and how they relate to the refuge and climate change-vulnerable species are summarized below.

Refuge coastal ecosystems consist of a variety of environments, including tidal salt marshes, maritime shrubland and forest, tidal flats, sandy beach, overwash, and dune grassland habitats that will be very vulnerable to cumulative adverse impacts from climate change and sea level rise. Vulnerable species that rely on these habitats include an array of biota ranging from beach dune tiger beetle to commercially important fish and shellfish and from migratory birds to marsh plants and aquatic vegetation.

Artificial shore protection and development currently prevents the natural longshore transport of sand that protects Delaware Bay beach habitats from erosion. Artificial dune stabilization destroys natural beach development and processes that naturally replenish barrier beach island habitats and pace migration of wetlands inland. Three key determinants of future marsh acreage on the refuge will be:

- The capacity of a refuge marsh to raise its surface to match the rate of rising sea level
- The rate of erosion of the bayward boundary of the marsh by overwash and sand transport
- The availability of space for refuge marshes to migrate inland

The cumulative impacts of climate change will result in the following long-term effects on refuge coastal habitats within the next 50 to 100 years that will probably start to become evident within the lifespan of this CCP:

- Significant increase in open water and decrease in tidal salt marsh habitats because there is no available space (beyond refuge boundaries) for these marshlands to migrate inland

- Submersion of our tidal marsh habitats, causing populations of salt marsh-dependent species of fish and birds to be reduced in size

- Loss of tidal marsh areas and brackish impounded areas associated with submerged aquatic plant beds that serve as important nurseries and shelter areas for fish and shellfish, including anadromous river herring species, elvers, striped-bass, white-perch, and blue crab

- Loss of sandy beach, overwash, and dune grassland habitats, adversely impacting rare beetles, horseshoe crabs, diamondback terrapin, and shorebird nesting and foraging habitats

- Loss of interdunal swale habitats adversely impacts rare firefly species and other invertebrates, and breeding shorebirds dependent on these areas

- Degradation and loss of the refuge's isolated marsh islands, which are currently important as bald eagle nesting sites and for other nesting birds that rely on island habitats for protection from predators and human disturbance

- Degradation and loss of most of the refuge's freshwater emergent marsh habitat, rare peat bog communities, and freshwater forest ecosystems, with significant losses of biodiversity

- Potential loss or degradation of freshwater swamps, which are considered globally imperiled and are at very high risk from sea level rise threats; our 1,300 acres of red maple-seaside alder and Atlantic white cedar will not survive permanent salt water inundation

- Loss of tidal flats and emergent marsh areas, rich sources of invertebrate foods for shorebirds and waterfowl, which will gradually become less productive as they revert to open water habitats

- Loss of major ecological processes with the decline and degradation of emergent marsh ecosystems that benefit humans, such as fish and shellfish production, water purification and water storage capacities, delivery of pollination services, and loss of refuge recreational fishing opportunities

- Exacerbation of refuge onsite pollution problems resulting from increased frequency and duration of inundation of upland and wetland habitats that will amplify sources of contamination surrounding the refuge during flooding events

Unlike other estuaries in the mid-Atlantic, the tidal range of the Delaware Bay estuary is greater than the ocean tidal range, generally about two meters. Bay shoreline and tidal marshes appear to be at the low end of their potential elevation range, which increases their vulnerability to sea level rise (Kearney et al. 2002). Recent research indicates that 50 to 60 percent of the bay's tidal marshes have been degraded, primarily because the marsh surface is not rising as fast or keeping up with current rates of sea level rise. Reasons cited for this include channel deepening projects, artificial shoreline stabilization, and consumptive withdrawals of freshwater, which have significantly changed and will continue to thwart sediment supply to Delaware Bay marshes (Sommerfield and Walsh 2005).

Some of the most notable Delaware Bay species that will be the most vulnerable and suffer considerable cumulative adverse impacts from sea level rise and climate change will be shorebirds and horseshoe crabs. A sea level rise modeling study estimated that a 2-foot rise in relative sea level over the next century could reduce shorebird foraging areas in the Delaware Bay by 57 percent or more by 2100 (Galbraith et al. 2002).

As a major refueling stopover area for six species of migratory shorebirds, including most of the Western Hemisphere's population of red knots, shorebirds stand to lose major Delaware Bay invertebrate food resources in tidal flats and nutrient-rich horseshoe crab eggs of sandy beach and foreshore habitats. Human infrastructure along the entire bay coast leaves estuary beaches little to no room to migrate inland as sea level rises. This will cause substantial losses of horseshoe crab spawning habitat likely to occur within the next 50 to 100 years (Galbraith et al. 2002). University of Delaware scientists (Kraft et al. 1992) estimate this loss, along with subsequent wetland drowning, to be greater than 90 percent in Delaware Bay (about 33,000 ha).

The State is purchasing agricultural preservation easements in the coastal zone to conserve shoreline habitats for the future, and a significant portion of undeveloped shoreline habitats are located in Prime Hook and Bombay National Wildlife Refuges. But we will not be able to mitigate the loss of shoreline and barrier beach island habitats in front of our salt marshes as bay water levels flood these sandy habitats, permanently causing cumulative negative impacts to ecosystem functioning of these areas and disruption to critical food webs.

The most abundant beach organisms are microscopic invertebrates that live between sand grains, feeding on bacteria and single-celled protozoa where two billion organisms can occur in a single meter of sand (Bertness 1999). These invertebrates play a critical role in beach food webs as a link between bacteria and larger consumers such as sand diggers, fleas, ghost crabs, and other macroinvertebrates that burrow in sandy sediments or accumulate in wracklines.

Many insects and crustaceans found in deposits of wrack are important food sources for nesting piping plover, American oystercatcher, sandpiper, whimbrel, and other migratory shorebirds (Dugan et al. 2003). With sea level rise, these bird food resources will be irreversibly lost, resulting in declines of many migratory bird species. Methods or plans to mitigate these adverse cumulative impacts to barrier beach island habitats and permanent losses of focal species are currently unknown.

Other cumulative environmental consequences and implications to the long-term irreplaceable loss of refuge salt marsh and impounded wetland habitats will be cumulative adverse impacts to waterfowl, waterbirds, and shorebirds. Particularly at low tide, the areas in our impounded marsh complex that provide forage for herons, egrets, plovers, dunlin, dowitchers, pintails, black ducks, green-winged teal and other waterfowl and shorebirds will be lost.

The incremental disappearance of salt marsh nesting habitats due to habitat fragmentation and conversion to open water would further compound declines for bird species that are already of conservation management concern to federal and state agencies, including American black duck, salt marsh sharp-tailed sparrow, seaside sparrow, coastal plain swamp sparrow, black rail, Forster's tern, American oystercatcher, and black skimmer (Ervin et al. 2006).

Transient estuarine fish and shellfish species that move in and out of salt marsh and impounded wetlands with the tides and take advantage of the abundance of detritus and invertebrate prey will decline and disappear from refuge habitats. Forage fish such as spot and perch will start to disappear, and populations of eels, ghost shrimp, gastropods, ribbed mussels, and blue crabs will decline. These

are all important food sources for fish and migratory birds, and are also the base for a healthy recreational fishery.

The greatest loss to biological diversity and wildlife on refuge lands resulting from cumulative sea level rise and climate change will occur in freshwater forested and emergent wetlands. Many ecologists suggest that freshwater wetlands support the greatest diversity of native flora, invertebrates, amphibians, fish, and bird species of any marsh type and this is very evident in our freshwater impoundment complex.

Freshwater emergent and forested wetlands will be influenced by sea level rise along the entire mid-Atlantic coast. Limited primarily by their requirements for very low-salinity water, they will sustain cumulative adverse impacts from saltwater intrusion. Forested wetlands support a variety of unique wildlife including breeding prothonotary warbler, Acadian flycatcher, yellow-throated vireo, migratory songbirds, bald eagles, and other raptor species. The freshwater impounded wetland complex supports large numbers of migrating and wintering waterfowl and anadromous fish that depend on freshwater to spawn. Herring, shad, and other fish species like striped bass will permanently lose spawning habitats.

The best climate change, sea level rise mitigation solution to adverse cumulative and long-term habitat losses on the refuge would be to allow the migration of salt marsh and freshwater wetland habitats to naturally proceed inland. However, this is not a viable solution for Prime Hook NWR because our CCP has no contingency for future land purchases that go beyond the current land acquisition boundary.

Cumulative Impacts on the Physical Environment

Air Quality

Air quality is generally good around the refuge in winter and spring, with some problems in late summer and fall. We would expect short-term, negligible, localized effects on air quality from the emissions of motor vehicles used by staff and refuge visitors, from refuge equipment such as mowers or heavy equipment used by staff and volunteers, and from prescribed burning. We would mitigate all possible negative impacts from prescribed fire by not conducting burns during periods when the county has non-attainment for national ambient air quality standards during the summer and fall.

We expect none of the refuge activities to contribute to any measurable adverse impacts that would increase ozone levels or other negative air quality parameters. We expect none of the alternatives to cause anything greater than negligible cumulative adverse impacts on air quality locally or regionally. Projected restoration of native upland forest, shrublands, and wetland vegetation should generate beneficial impacts to air quality locally. These beneficial impacts will derive from the refuge's capacity to continue to filter out many air pollutants harmful to humans, wildlife, and the environment. We will also strive to reduce energy consumption with green infrastructure and products associated with refuge activities.

In addition, with the new Service goal of achieving carbon neutrality by 2020, the refuge will be undertaking aggressive efforts to reduce the energy use and carbon footprint of our buildings, facilities, vehicle fleet, and workforce to the maximum extent possible. We will also be exploring ways to offset our residual carbon footprint by increasing carbon sequestration through our habitat management activities, especially aforestation projects. Integrating carbon sequestration awareness into conservation actions for wildlife and other habitat management activities will also have cumulative beneficial impacts for the air quality and humans within the local environment.

Water Quality
None of the alternatives would produce significant adverse cumulative impacts on water quality. We would continue to use best management practices and measures to control erosion and sediments in all ground-disturbing operations to ensure their impacts are minimal.

Alternatives B and C, and to a much lesser extent A, call for increased attention to habitat restoration, passive natural succession, or native vegetation enhancement projects, which would result in improvements in water quality in terms of chemistry, reduced sediment, and mitigation of contaminated run-off from off-refuge sources. Collectively and over time, those actions would improve the ability of refuge upland and wetland systems to process nutrients and store carbon and contribute to other State watershed regulations and initiatives that are geared to improve water quality in the Broadkill River and improve the health of the Delaware Bay.

Management actions would also be adaptive to address climate change and sea level rise cumulative impacts on the physical environment. Restoring and managing more upland forest and riparian habitats on the refuge will improve the health of refuge watercourses and aquatic resources, resulting in greater diversity and functionality of refuge habitats that will also benefit adjacent watersheds and the Delaware Bay.

In slightly varying degrees, all the alternatives emphasize maintaining the biological integrity, diversity, and environmental health of lands within the refuge boundaries, which also contributes to conserving a scenic landscape. Actions taken to ensure the long-term health of freshwater wetlands and forested habitats, preserve and enhance rare native plant and animal communities, and conserve state and federally listed species, will serve as a model for conservation planning use and zoning near the refuge and in the county.

In addition, when the conservation actions on the refuge are combined with actions by State wildlife managers, non-profit organizations, private landowners, local communities, and the State's Livable Delaware Initiative, there will be considerable cumulative progress in stemming and mitigating the urbanization and development changes that detract from good water quality and productive habitats of Delaware's wildlands and the Delmarva Coastal Plain ecosystem.

Soils
The greatest past and present adverse impacts on refuge soils occurred from land clearing activities for agriculture, intensive farming techniques, and development. With the cessation of intensive agricultural practices and return of salt marsh, refuge soils should improve in natural fertility and productivity, as native soil biota recovers in those habitats where native plant and invertebrate communities are restored either by reverting to natural selection (alternative A) or by proactive restoration (alternative B), with invasive plant species treatments as needed for all alternatives. Natural coastal and wetland sediment processes would be returned under alternatives A and B.

We will continue to use best management practices when improving forest stands, maintaining or setting back succession in native grassland and shrubland habitats, mowing, brush-hogging, prescribed burning, or selecting various silvicultural methods to ensure cumulative beneficial impacts for soils.

Under all alternatives, we expect to reclaim areas dominated by non-native crops or invasive species and restore them to native plant communities, which should improve nutrient recycling, restore native soil biota and soil fertility, and return soils to natural productivity regimes. Remediation of drained wetlands used for

croplands and restored hydrology in appropriate areas with hydric soils will also improve functioning of these soils, yielding ecosystem benefits.

Positive consequences and beneficial cumulative impacts of managing soils in native vegetation for the long term are increasing capacity for carbon sequestration from the environment. Biological sequestration can be enhanced in managing natural habitats that increase the natural absorption of atmospheric carbon in soils. The long-term cumulative potential is limited to how the land is used and managed.

Carbon storage potentials of soils with various habitat types have been estimated by the Congressional Budget Office (2007). On pasture and grassland habitats, the equilibrium level of carbon in an acre of soil varies from 73 metric tons of carbon dioxide to 159 tons. Mature never-harvested forests have even higher equilibrium levels per acre of soil varying from 286 to 1,179 metric tons of carbon dioxide and averaging 465 metric tons per acre. In contrast, harvested forests have decreased levels, as the average stand of timber harvested on a 30-year rotation holds the equivalent of 203 metric tons of carbon dioxide per acre at the beginning of the rotation (that is, at the start of regrowth) and 256 metric tons at the end of the rotation.

No new adverse impacts to the refuge's high marsh are anticipated, though adverse impacts to the physical environment may persist where historical (2002 and earlier) open marsh water management excavations have altered salt marsh elevations. In some areas, insufficient soil settling resulted in spoil piles being colonized by invasive *Phragmites*. Other areas that were excessively drained resulted in lowered water tables. These physical environmental conditions resulted in losses of high marsh zones dominated by *Spartina patens*, which were converted to less desirable plants like *Iva* and *Baccharis*. These physical changes to marsh surface elevations may be more prevalent on refuge salt marsh habitats due to soil types that are low in organic content and have higher mineral or sandy consistency that make spreading them out to meet open marsh water management guidelines too difficult to achieve.

Future salt marsh conservation and management actions will be focused on protecting the few areas of high salt marsh left on the refuge, by not constructing any new open marsh water management systems, maintaining and enhancing tidal flow into existing salt marsh habitats, and controlling invasive plants on spoil piles and other invaded areas within existing open marsh water management systems. Maintenance excavations in existing systems will occur only if there are documented reasons for failures, including considerations of soil types, mosquito production data, and other information as needed. The refuge anticipates that open marsh water management areas requiring clean-out will be largely filled with fine silts and organic material. This material should be spread over the marsh at the appropriate thickness. Open marsh water management excavations must also restore a more natural hydrology and function to the impacted salt marsh areas to reduce cumulative adverse impacts to the physical environment.

Alternatives A and B would permit natural overwash processes along the refuge shoreline to proceed unimpeded. This has cumulative beneficial impacts on sediment accretion and transport of the coastal ecosystem. Long-term maintenance of artificial dunes under alternative C could have long-term and cumulative negative impact of significantly narrowing barrier island shoreline strands. This can ultimately lead to the collapse and disappearance of these ribbons of sand, and significantly increase the vulnerability of back-barrier marshes to sea level rise by limiting accretion of sediments (Coch 2009, Riggs et al. 2009, Levine et al. 2009).

Cumulative Impacts on the Biological Environment

Managing and Protecting Habitat

All of the alternatives would maintain or improve native biological resources on the refuge, in the State of Delaware, and in the Delmarva Coastal Plain and mid-Atlantic ecosystems. The combination of our management actions with those of other conservation partners, organizations, and landowners would result in beneficial cumulative impacts on the biological environment by:

- Improving the protection and management of Federal trust species, State-listed endangered species, and migratory birds
- Using structured decisionmaking and enhancing monitoring to improve wildlife management and conservation actions
- Restoring and conserving native flora, pollinators, and other wildlife
- Protecting and improving upland and wetland habitats that are declining at the state and regional levels or threatened by development
- Controlling invasive plants and animals
- Controlling nuisance or destructive animals
- Improving avian productivity through limited use of predator management
- Revising mosquito integrated pest management strategies to conserve and protect pollinators and non-target invertebrates
- Enhancing and restoring biological integrity, diversity, and environmental health of refuge lands

Certain biological resources that we would manage to control, prevent, or eliminate, such as invasive plants, nutria, mute swans, or resident Canada geese, are not natural components of our managed wildland areas. We do not consider the loss of these biotic elements to be an adverse impact. However, not controlling invasive and nuisance species would create adverse cumulative impacts to the biological environment.

Controlling exotic and invasive plants may involve the use of chemical herbicides. The selective use of herbicides will be based upon an integrated pest management strategy that incorporates pest ecology, the size and distribution of the population, site-specific conditions, known efficacy under similar site conditions. Best management practices will reduce potential effects to non-target species, sensitive habitats, and quality of surface and groundwater. Herbicide applications will be targeted to control discreet pest populations in localized areas. Combinations of two or more herbicides at labeled rates would not likely result in additive or synergistic adverse effects to non-target fish, wildlife, plants, or their habitats. The Forest Service (2005) found that mixtures of herbicides commonly used in land (forest) management likely would not cause either additive or synergistic effects to non-target species based upon a review of scientific literature regarding toxicological effects and interactions of agricultural chemicals (ATSDR 2004). Moreover, combined herbicides with different modes of action may be used more effectively, likely requiring less retreatment over the long term. Herbicides applied on the refuge would be short-lived, resulting from environmental and microbial breakdown to less or non-hazardous degradation products.

Habitat enhancement and restoration under alternatives A and B, and revised mosquito integrated pest management strategies under alternatives B and C, will limit negative cumulative effects on the biological environment by limiting

invertebrate mortality, sustaining and enhancing invertebrate trophic linkages and food webs for wildlife, and potentially increasing avian diversity and abundance within native plant communities. Cumulative beneficial impacts on the refuge's biological environment will also accrue from habitat fragmentation across the refuge.

The phasing out of the cooperative farming program and restoration of cropland acres to native plant communities will have cumulative beneficial impacts for endangered species management and forest interior dwelling birds. Cumulative beneficial impacts to the biological environment will also occur by reducing pesticide use, increasing the refuge's capacity and conservation potential for a greater number of focal bird species, and enhancing native plant resources and associated invertebrate foods that are the foundation for migratory bird and other wildlife nutrition.

Eliminating the cooperative farming program will not detract from waterfowl management or have cumulative negative impacts on waterfowl resources. The cumulative impacts of managing native vegetation in the form of moist-soil crops will continue to increase the carrying capacity of our wetland habitats for migrating and wintering waterfowl, with beneficial cumulative impacts for the biological environment.

Compared to agricultural crops (both row and cover crops), moist-soil crops (annual vegetation with high seed production, such as wild rice and smartweeds) are more efficient to produce each year with less fossil fuel use and a lower carbon footprint on the biological environment as a whole, and provide other cumulative benefits for waterfowl which include:

- Higher nutritional value for waterfowl
- Easier and cheaper to consistently produce high seed yields (800 to 1,800 lbs of moist soil seeds per acre per year)
- Zero negative inputs into ecosystems (no nitrates, phosphates, or pesticides)
- Greater resiliency to wet and dry weather extremes than agricultural crops
- Provide year-round availability of food resources for waterfowl and other wildlife

Mississippi State University scientists have reported that moist-soil seeds such as wild millet, foxtail, and panic grasses may provide even more energy for waterfowl than corn, based on feeding trials with Canada geese (Kross et al. 2007). With or without water, moist-soil plant foods are available for waterfowl consumption. Moist-soil native plants can be consumed by Canada geese as green browse without flooding, or mainly as seeds, roots, and tubers after flooding.

Turning away from single species management (farming cover-crops for Canada geese) and restoring the same land based acres to native vegetation increases our capability to manage for multiple bird species simultaneously. Multiple focal species management of former croplands will have cumulative benefits on the biological environment as a wider array of wildlife (migratory bird species, fish, reptiles, amphibians, invertebrates, and other resident wildlife) will benefit from enhanced biological integrity and diversity of native plant communities.

Although all the alternatives either maintain or increase monitoring and controlling invasive plants and animals, we expect infestations to continue to increase and expand to new areas, especially due to increased cumulative impacts from climate change. Alternatives B also has stronger biological monitoring

components with increased efforts in surveying wildlife species and habitats and research coordination with others.

Additional information will facilitate structured decisionmaking with wide-ranging cumulative benefits for fish and wildlife populations. Building models and using them for conservation and wildlife management, using structured decisionmaking, and enhancing monitoring studies will add to the body of knowledge the Service will collect and share with other conservation partners to influence and improve natural resource decisions with cumulative benefits on the biological environment over a broader landscape.

In general, native habitat management will have considerable cumulative impacts on the biological environment as we expect to increase population numbers of many more breeding and migrating shorebird species, salt marsh passerines, migrating and wintering waterfowl, Delmarva fox squirrels, bald eagles, forest interior dwelling bird species, and breeding and migrating early successional landbird and waterbird species. Native plant management cumulatively benefits the biological environment by increasing and enhancing healthy soil biota, restoring and enhancing native plant resources, increasing resident wildlife populations of mammals, fish, reptiles, and amphibians, and enhancing invertebrate production to sustain and perpetuate migratory bird resources.

Alternatives A and B would also make considerable progress in restoring native habitats that will increase opportunities and capabilities to improve pollinator conservation with cumulative beneficial impacts on native plants and other biological resources both on refuge and off-refuge.

Mosquito Control
Mosquitoes are a wildlife species and a natural component of the ecosystem. We are mandated to conserve, and if possible, enhance habitat for federal trust resources, especially migratory birds, and maintain or restore BIDEH. This implies that we manage for the benefit of all components of a healthy habitat or ecosystem. It is our understanding of ecology, or more appropriately, our inadequate understanding of ecological processes, that makes it imperative that we maintain all the components of the ecosystem. Mosquitoes therefore have intrinsic value.

However, in the interest of public health, some potentially detrimental impacts to the natural environment will continue to be permitted, i.e., use of the larvicides Bti and methoprene for mosquito control. Alternative B, the preferred alternative, makes three substantive decisions regarding current and future mosquito management on the refuge by the State of Delaware: elimination of the use of adulticides except during a documented public health emergency or as directed by the Secretary; permitting the maintenance of existing open marsh water management systems when warranted; and leaving open the potential for additional open marsh water management construction after monitoring, research, and analysis provide sufficient cause to alleviate the refuge's concern regarding open marsh water management's response to rising sea levels and potential impacts on migratory birds of concern.

The elimination of adulticides will restore a measure of BIDEH to the refuge. At a minimum, terrestrial invertebrate mortality, including mosquito mortality, will likely be reduced. Non-target invertebrates will receive an added measure of protection, though mosquitoes (obviously) and non-target species, especially some species of chironomids, will still be vulnerable to larvicide treatments. Reducing impacts to invertebrates should strengthen natural ecological processes that affect refuge resources of concern, especially migratory birds. Direct short-term

impacts from adulticides will be alleviated, and any long term indirect ecological impacts that may have occurred over previous years should be restored. However, it should be understood that there is a considerable lack of studies, local and otherwise, on the long-term ecological effects of repeated larvicide treatments over an extended period of time. Our position is based upon our analysis of current literature, the probability of short-term impacts to the local refuge ecology by adulticides, and current refuge policy. The impacts of larvicides may be lessened further by monitoring and treatment criteria to be specified within the refuge mosquito management plan.

No new open marsh water management excavations have been permitted since 2002. Allowing State maintenance of existing systems, but disallowing any additional open marsh water management at this time should not further impact the marsh. Given sufficient analysis of open marsh water management response to sea level rise and other ecological factors, especially salt marsh passerine and secretive marsh bird impacts, the refuge may consider additional construction in the future. Careful evaluation of refuge policy will be required. Restoration and long-term BIDEH of the salt marsh may ultimately require filling existing open marsh water management configurations, as well as old grid-ditched systems.

Managing Exotic or Nuisance Species
Mute swans and nutria are highly invasive of wetland habitats. The refuge will have a zero tolerance policy for these exotic species. Preventing establishment of viable populations of these animals on the refuge will preserve existing BIDEH.

Beaver and muskrats are native aquatic rodents that are a natural component of the refuge ecosystem. However, on occasion individual animals or small colonies will damage valuable refuge infrastructure, burrow into dikes or cause flooding conditions on neighboring private land. Beaver damming and flooding of refuge managed habitats may impact the refuge's ability to achieve an optimal management regime for Federal trust resources, particularly migratory birds. In addition, beaver have damaged a small stand of swamp cottonwood, the host plant for the globally rare marbled underwing moth (S1, G3). Under these circumstances, the refuge may employ lethal removal of specific individuals to lessen damage. Individual animals will be impacted, but the population as a whole will experience no long-term impacts.

Management of Predation Pressure on Trust Avian Resources
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 birds, eggs, and chicks (Erwin et al. 2001, Greenwood et al. 1990, USDA 2005, USFWS 1996, USFWS 2007, Winter and Wallace 2006). Predation is a natural process and is not normally considered a management issue for the continued productivity and survival of species across a biologically diverse and healthy landscape. However, some habitats have been so fragmented and reduced by human impacts that intervention is considered critical for the continued survival of some species. Some shorebirds, such as 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. Limited predator control has proven effective in improving productivity

Control would be limited to discreet geographic locations inside nesting habitat or within corridors to nesting habitat. The predator population as a whole across the refuge would not be impacted. Locally, predator populations would reestablish themselves shortly after control, and would return to average densities shortly after the nesting season.

Disease Prevention and Service Biological Integrity, Diversity, and Environmental Health Policy
Refuge habitat management actions that increase BIDEH and avian diversity have the potential to provide a buffer against future disease outbreaks. 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 into 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 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).

Public Use
The land use immediately adjacent to the refuge is agricultural and residential. Urban development is changing a formerly rural area as more farms are sold for large scale town house communities and apartments. Within 15 to 20 years, the refuge will have some of the largest expanses of contiguous native forested and wetland habitats accessible to the public in Sussex County. The increased demand for public use may have cumulative impacts on the biological environment.

All alternatives with respect to public use will have cumulative impacts on biological resources because we expect that the demand for all types of wildlife recreation will grow on the refuge as the amount of natural habitats and open space will decrease off-refuge due to increasing development pressures while the amount of refuge space and natural resources remain relatively constant. The management objectives presented in alternatives B and C are our attempts to strike a feasible balance that ensures the refuge remains a destination of choice for both wildlife and people, while also protecting the biological environment for the long term.

Two of the public use programs we offer, hunting and fishing, result in the direct loss of individual wildlife. We describe the site-specific impacts of our hunting and fishing programs earlier in this chapter and in Appendix E, Compatibility Determinations. A detailed cumulative impact analysis on hunting provides further information later in this document.

Fishing seasons and limits are established by the State of Delaware and adopted by the refuge. These restrictions ensure the continued well-being of overall populations of fish. Fishing results in the taking of many individuals within the overall population, but restrictions are designed to safeguard adequate population and recruitment from year to year. Specific refuge regulations address equity and quality of opportunity for anglers, and help safeguard refuge habitat. Disturbance to other fish and wildlife does occur, but this disturbance is generally short-term and adequate habitat occurs in adjacent areas. Loss of

plants or increases in water turbidity from boat motors is minor or temporary, and is generally not concentrated since fishing pressure is well distributed.

Another common concern is the reduction or alteration of prey base important to fish-eating wildlife; however, refuge-specific and State regulations address this concern to ensure that harvest levels do not cumulatively impact native fish resources to the point they are no longer self-sustainable.

Cumulative impacts from research activities are not expected, but could occur if multiple research projects were occurring on the same resources at the same time or if the duration of the research was excessive.

We do not anticipate any significant cumulative effects on biological resources by other wildlife-dependent recreational activities. Impacts caused by these activities can be found earlier in this chapter.

Cumulative Impacts on the Socioeconomic Environment

We expect significant cumulative beneficial impacts on the socioeconomic environment that will result from maintaining and enhancing wildlife populations, improving native wildland habitats, and managing biological integrity, diversity, and environmental health (BIDEH) of refuge lands, which sustain and provide numerous ecosystem services that benefit wildlife and humans.

Ecosystem services provided by refuge habitats include purification of air and water, mitigation of floods and drought, dispersal of seeds, pollination services and natural pest control. Carbon sequestration will contribute to stabilization of climate, increased BIDEH may potentially limit human vector-borne disease, and increased opportunities will enable the public to enjoy biological resources unique in the county, State, and nation. Our proposed alternatives would yield increases in these ecosystem services over time.

It should be understood however, that increased BIDEH will not necessarily equate with reduced nuisance mosquito complaints. Mosquitoes are an integral component of the ecology of coastal wetlands, as are natural mosquito predators. The ability of natural predation pressure to reduce certain species of mosquitoes substantially, if environmental conditions are appropriate, is perhaps limited. The ability of chemical mosquito treatment alone to substantially reduce the threat of periodic pulses of mosquitoes is also limited. Mosquitoes have evolved successfully to overcome mass mortality, regardless of the cause.

The human threshold for mosquito tolerance is largely cultural in origin, and varies considerably across the landscape. It varies largely upon one's frame of reference. Humans who are raised in a relatively urban or suburban landscape generally have 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. The refuge expects that there may be increased local complains from the public regarding nuisance mosquitoes. The refuge does not expect an increased incidence of mosquito-borne disease in the human population.

We expect none of the management actions in the three proposed alternatives to have a significant adverse cumulative impact on the economy of local towns or the county in which the refuge lies. We would expect none of the alternatives to alter the demographic or economic characteristics of the local community. The actions we propose would neither disproportionately affect any communities nor damage or undermine any businesses or community organizations. All of the alternatives would maintain the beauty and aesthetics of the refuge's natural landscape,

enhance biological resources available for consumption, and provide wildlife experiences that promote a pleasurable quality of life for humans.

These varying alternatives will have cumulative impacts, because we expect the demand for nearly all recreation to grow while the amount of refuge space and natural resources stays relatively constant. In alternative A, current uses would continue without much change. Alternative B attempts to strike a reasonable balance to ensure that the refuge remains a destination of choice for both wildlife and people. If successful, that integrated approach may prove more sustainable, with more positive long-term impacts on natural resources on the refuge, and social and economic impacts on the communities beyond. Alternative C strikes a balance between the needs of wildlife and the public while reducing active management of refuge habitats.

Our working relationships with area colleges and universities, private landowners and others should improve in terms of responsiveness to inquiries and speed of joint projects under alternative B. That improvement mainly would result from the increased staffing in key areas such as biology, public use, and maintenance. The overall coordination and communication with the public should improve under alternative B, because a new staff position would deal with public use and public information. Because some may oppose changes in one or more of the alternatives, and some support them, the cumulative impact on the public perception of the refuge and the Service could be negative or positive.

More emphasis on public education, outreach activities, and information in alternative B and C should foster greater understanding and appreciation of resource issues and needs, leading to increased support and funding, which would positively affect fish and wildlife resources on the refuge. The increased outreach of these alternatives could also positively affect land use decisions outside the refuge by local governments and private landowners, and lead to increased fish and wildlife populations over a broader area.

Cumulative Impacts on Cultural Resources

The activities in each alternative have the potential to impact cultural resources, either by direct disturbance during construction of habitat projects and facilities related to public use or administration and operations, or indirectly by exposing artifacts during actions such as managing grassland and prescribed burning. 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.

We expect none of the alternatives to have significant adverse cumulative impacts on cultural resources on the refuge. Depending on the alternative, beneficial effects would vary, because of the changes proposed in habitat management (e.g., allowing some or all of the intensively managed grasslands to transition to shrub and forest habitat), increasing environmental education and interpretation programs, training in cultural resource identification and protection by refuge staff, and increasing field surveys to identify and protect any undiscovered sites.

Cumulative Impact Analysis of Hunting

Cumulative impact is a term that refers to impacts on the environment that result from the incremental impact of a proposed action when added to other past, present and reasonably foreseeable future actions, regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative

impacts can result from individually minor but collectively significant actions taking place over a period of time. Cumulative impacts of hunting on resident wildlife, migratory birds, non-hunted wildlife, endangered species, refuge environment, and other wildlife recreation were analyzed for all three alternatives. Because of the regulatory process of harvest management of migratory birds in place within the Service, the setting of the hunting seasons largely outside the breeding seasons of resident and migratory wildlife, and the ability of individual refuge hunt programs to adapt refuge-specific hunting regulations to changing local conditions, we anticipate no direct or indirect cumulative effects on resident wildlife, migratory birds, non-hunted wildlife, endangered species, refuge environment, and other wildlife recreation from hunting on Prime Hook National Wildlife Refuge.

Anticipated Cumulative Impacts of Alternative A: Current Management (No Action)

Resident Big Game

White-tailed Deer

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 of Sussex County, Delaware (Rogerson 2010). The Delaware Division of Fish and Wildlife has the ability to manage deer populations, in part, through recreational hunting because these animals have a k-selection population strategy. This means that reproductive rates are low, adults invest a tremendous amount of energy bringing young to maturity, and survival rates are relatively high compared to more prolific breeders (such as rabbits). Based on their monitoring programs, the Delaware 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, and are taken into account by the annual monitoring. Their analysis of populations and hunting on populations, habitat, and communities is cumulative.

Delaware deer herd statistics indicate that the deer density in zone 9 is 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 42.6 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 recognized as a problem causing crop damage, reducing some forest understory species, and reducing reforestation seedling survival. Hunting is a viable solution to keep the deer herd and other resident wildlife in balance, resulting in long-term impacts on wildlife habitat.

White-tailed deer hunting is the single most important public use that would affect mammals and other forest-dependent wildlife on the refuge. It serves both as a wildlife-dependent recreational use and a method to reduce and stabilize deer densities. This not only benefits other mammals, but also benefits endangered species management for Delmarva fox squirrels, conserves migratory landbird habitats, and lessen impacts to adjacent agricultural lands. Reducing deer densities is best accomplished by means of the refuge deer hunting program.

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). These changes can lead to adverse impacts on other wildlife species that depend on this vegetation for food or shelter. Several studies have shown that over browsing by deer can decrease tree reproduction, understory vegetation cover, plant density, and plant diversity (Warren 1991). Heavy deer populations in the Great Smokey Mountains National Park in Tennessee caused a reduction in the number of plant species, a loss of hardwood species, and a predominance of conifer species compared to an ecologically similar control area with fewer deer (Bratton 1979).

The alteration and degradation of habitat from overbrowsing deer can have a detrimental effect on deer herd health and may displace other wildlife communities (e.g., neotropical migrant songbirds and small mammals such as the endangered Delmarva fox squirrel) that depend on the understory vegetation habitat destroyed by deer browsing (VDGIF 1999). Deer browsing also affects vegetation that songbirds need for foraging, escape cover, and nesting (DeCalesta 1997). DeCalesta (1997) also found that species richness and abundance of intermediate canopy nesting songbirds was reduced in areas with higher deer densities. Intermediate canopy-nesting birds declined 37 percent in abundance and 27 percent in species diversity at higher deer densities. Five species of birds were found to disappear at densities of 38.1 deer per square mile and another two disappeared at 63.7 deer per square mile. Casey and Hein (1983) found that three species of birds were lost in a research preserve stocked with high densities of ungulates and that the densities of several other species of birds were lower than in adjacent areas with lower deer density. Waller and Alverson (1997) hypothesize that by competing with squirrels and other fruit-eating animals for oak mast, deer may further affect many other species of animals and insects.

Based on a nationwide survey of all states (Krausman 1992), deer were effectively controlled with hunting and habitat manipulation in many areas where they were overpopulated. The remaining overpopulated herds were either not hunted, had an inadequate doe harvest, or an inadequate general harvest. Because the refuge boundary area is open, with numerous tracts and corridors for movement and contact with other herds, it is unlikely that hunting will reduce the population to such low levels as to place it at risk of becoming genetically bottlenecked. Also, no prevention or control of epizootic hemorrhagic disease exists to date except by keeping populations below the carrying capacity of their habitats. 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). Species richness and abundance of shrubs and herbaceous vegetation also has been shown to decline when deer densities reach between 4 to 8 deer/km2 (DeCalesta 1997). At high densities, deer may act as a host reservoir for Lyme disease-bearing ticks (Jones et al. 1998) and reducing the deer population will reduce the potential for Lyme disease transmission. Based on these considerations, it is anticipated that hunting would have a positive impact on deer health and quality and habitat condition.

High densities of deer have also been recognized as vectors for spreading invasive species like Japanese stiltgrass. Deer consume the seed and fruits of many plant species and when excreted, a large percentage of seeds remain viable. In some areas more than 50 percent of seeds eaten represent highly invasive plant species (Williams and Ward 2006). Stiltgrass invasions serve to prevent the shrub layer from returning which decreases or eliminates these forest structural components used by songbirds and interferes with native plant successional dynamics.

Reducing the deer population will also benefit the surrounding human community by reducing damage to agricultural crops and residential landscape vegetation and by reducing deer-vehicle collisions. The average estimated economic impact from deer depredation to high-value agricultural crops from 1994 to 2000 in Delaware was $375,966 (Drake et al. 2005). High-value agricultural crops included fresh market and processed vegetables including, but not limited to, snap beans, sweet corn, leafy vegetables, tomatoes, and peppers. Fruits such as apples and peaches were also included as high-value crops (Drake et al. 2005). The average estimated economic impact from deer depredation to grain crops from 1994 to 2000 in Delaware was $867,937 (Drake et al. 2005). Grain crops included corn (silage and grain), soybeans, wheat, and oats. The average annual vehicle damage from deer-vehicle collisions in Delaware from 1986 to 2000 is estimated at $592,000. This does not include costs of human fatalities associated with deer collisions or costs associated with disposal of deer carcasses.

Hunting resident game species does not have any regional impact on their respective populations due to their restricted home ranges. The refuge contributes negligibly to the State's total harvest for resident game species 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 of deer on the refuge (107) has a negligible impact on the statewide deer population of 31,071 deer (Figure 5-12). Hunting license sales in Delaware have declined from 29,994 in 1975 to 18,746 in 2007 (Rogerson 2010). Based on the decline in the number of hunters and the relatively few 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.

Upland Game or Small Game

Cottontail rabbit is the primary small game species sought on the refuge, and to a much lesser extent, northern bobwhite quail, mourning dove, woodcock, snipe, and ring-necked pheasant. Mourning dove, woodcock, and snipe have been addressed in the migratory bird section of this analysis.

Hunting resident game species such as quail, rabbit, and pheasant 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.

Hunter visits and harvest of upland and small game such as rabbit have been relatively low, and the number of quail taken per year has been 0 to no more than 14 per year on the refuge in recent years (Table 5.9) The refuge does not allow hunting of eastern gray squirrel to minimize conflicts with the endangered Delmarva fox squirrel.

Given the relatively few numbers of animals harvested from the refuge, no cumulative impacts to local, regional, or Statewide populations of small game are anticipated from allowing hunting of these species on the refuge.

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 cumulative impacts to local or State populations (Reynolds, personal communication 2010).

Migratory Birds

Migratory birds are managed on a flyway basis by the Service. The process of surveying populations and setting regulations is, inherently, a cumulative impact analysis. The following paragraphs describe this process.

The Service annually prescribe 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 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, 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 Web site *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 spring 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, U.S. Fish and Wildlife Service, Department of the Interior, MS MBSP-4107-ARLSQ, 1849 C Street, NW, Washington, DC 20240.

Waterfowl at Prime Hook NWR
Impacts to hunting waterfowl are further minimized from State and Federal frameworks by limiting hunting to 4 days per week during the hunting season with a 3:00 pm closure.

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 (Tables 5-7 and 5-8).

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. 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 to 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. 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.

Managing Resident Canada Geese

Canada goose herbivory during the growing season is a relatively new impact upon wetlands. In 2002, a research study conducted at neighboring refuges suggested that higher levels of use by geese may cause a long-term change in wetland community structure (Laskowski et al. 2002). The study measured the impact of foraging by resident Canada geese on biomass and species composition of wetland vegetation at Bombay Hook and Chincoteague National Wildlife Refuges in Delaware and Virginia, respectively. Resident geese reduced the amount of plant biomass that would be available to migrant birds at the end of the growing season. Biomass of several species of vegetation was significantly 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. A single heavy grazing event by Canada geese in the fall, winter, or spring can reduce the yield of winter wheat by 13 to 30 percent (Allen et al. 1985, Flegler et al. 1987). In the mid-Atlantic, the Maryland Department of Natural Resources reported that 23 percent of all complaints were related to agricultural damage by geese and estimated agricultural damage exceeds $200,000 per year (USFWS FEIS, 2005).

To address well-documented concerns regarding the impacts of resident Canada geese on habitats as well as public property, the Service issued new regulations for control of resident geese [vol#71 *Federal Register* page#45964-45993 (2006)]. We expect that the use of resident Canada goose control and management activities, particularly lethal control methods, would increase significantly. Such lethal and nonlethal activities would be expected to significantly decrease the number of injurious resident Canada geese in specific localized areas, thus reducing adverse impacts on vegetation. The long-term viability of goose populations would not be affected, however. Over time, we expect the cumulative impacts to become less evident and significant as goose populations are reduced.

The impact of refuge hunting on resident Canada geese is negligible. For resident Canada geese, hunters averaged 8.8 birds per year from 2001 to 2006 (Table 5-7).

Managing Snow Geese

In the nearly three decades since the original snow goose management plan of 1981, the greater snow goose population, as indexed by the spring survey, has undergone a five-fold increase to over 1 million birds. Various light goose populations in North America have experienced rapid population growth, and have reached levels such 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). Habitat degradation in arctic and sub-arctic areas may be irreversible, and has negatively impacted light goose populations (Abraham and Jefferies 1997) and other bird populations dependent on such habitats (Gratto-Trevor 1994, Rockwell 1999, Rockwell et al. 1997). Natural marsh habitats on some migration and wintering areas have been impacted by light geese (Giroux and Bedard 1987, Giroux et al. 1998, Widjeskog 1977, Smith and Odum 1981, Young 1985). In addition, goose damage to agricultural crops has become a problem (Bedard and Lapointe 1991, Filion et al. 1998, Giroux et al. 1998, Delaware Div. of Fish and Wildlife 2000).

The increasing numbers of light geese are viewed as a continental problem, with real local consequences. A common feeding strategy of snow geese on refuge wetlands is to grub for underground roots and tubers. Primary marsh vegetation species exploited in this fashion are salt marsh cordgrass (*Spartina alterniflora*), salt meadow cordgrass (*S. patens*), Olney's bulrush (*Scirpus americanus*), black needlerush (*Juncus romerianus*), and cattail (*Typha sp*). Grubbing for rhizomes of these species, especially in salt marshes, results in areas denuded of vegetation, typically referred to as eat-outs. Presently, eat-outs occur on four national wildlife refuges within the Northeast Region; Forsythe, Bombay Hook, Prime Hook, and Blackwater.

Snow goose eat-outs in salt marshes tend to revegetate during the subsequent growing season, however, at a reduced vegetative density. Vegetation density at these eat-outs may increase after several years to pre-eat-out levels, if left alone. However, at most NWRs where eat-outs occur within salt marsh habitats, snow geese return each winter to the same areas to feed. This may be a result of the vegetative growth being at an earlier stage of development, being more nutritious, or having a less dense root mat and therefore easier to grub. 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. This material may then be washed away during high or flood tide periods. After several years of successive eat-outs at the same location, a lowering of ground elevation may occur, causing a more permanent impact to the site.

Most agree that salt marsh eat-outs are detrimental to habitat integrity and other wildlife species. This is a result of the radical change of habitat structure from dense vegetation to mudflat. Undoubtedly, this conversion negatively impacts invertebrate communities, species such as rails, and waterfowl that feed on these invertebrates and rely on the dense vegetative structure for cover. However, some refuge staff report increased use of snow goose eat-outs by numerous shorebirds during migration and by some species of waterfowl. This is particularly the case at Prime Hook NWR, Forsythe NWR, and Bombay Hook NWR.

Reducing the acreage in cropland habitats in favor of more native vegetation supports the preferred alternative for snow goose management on refuge lands identified in the final environmental impact statement for snow goose management along the Atlantic Flyway. Reducing the use by snow geese of these upland habitats will also benefit a variety of wildlife species that tend to be absent from agricultural habitats, and will also reduce the numbers of snow geese staying on the refuge. Reducing snow goose numbers on the refuge will also diminish adverse impacts of snow goose herbivory on salt marsh habitats.

The impact of refuge hunting on snow geese is negligible. 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). For snow geese in the late season (late January into March), hunters averaged 16.0 birds per year from 2001 to 2006.

Managing Non-Native Mute Swans
Mute swans are highly invasive of wetland habitats, impact native species of fish and wildlife, damage commercial agricultural crops, and pose a threat to human health and safety. As such, they cause serious nuisance problems and property damage, including economic loss. Because of their consumption of large quantities of submerged aquatic vegetation and their aggressive behavior, mute swans compete directly with many other water birds and fisheries for critical habitats. Due to their strong territorial defense, some pairs will vigorously defend nest and brood sites from intrusion by other wildlife and have attacked humans, causing serious harm. They do provide some aesthetic value for public enjoyment. But, as populations of mute swans have grown in various states and expanded into new areas, there is a need to coordinate management actions among State, Provincial, and Federal wildlife agencies to reduce numbers to desirable levels (AFC 2003).

Consequently, the Atlantic Flyway Council has adopted the Atlantic Flyway mute swan management plan 2003 to 2013. The mute swan is not federally protected under the Migratory Bird Treaty Act, and is listed as an unprotected-invasive species by the State of Delaware. As such, mute swans, their nests, and eggs have been routinely removed from national wildlife refuges, State wildlife management areas and (with landowner permission) from private lands in Delaware since the early 1970s (AFC 2003).

Hunting license sales in Delaware have declined from 29,994 in 1975 to 18,746 in 2007 (Rogerson 2010). Based on the decline in the number of hunters and the relatively low numbers of waterfowl harvested from the refuge in respect to total Statewide, flyway, and national harvests, no cumulative impacts to local, regional, or flyway waterfowl populations are anticipated from allowing hunting waterfowl on the refuge. Impacts to waterfowl using the refuge would be localized to the area being hunted (which can be no more than 40 percent of the refuge) and due to the short temporal nature of these types of disturbance (from day restrictions to hunting at noon), no cumulative indirect impacts from shooting, walking, boats, or vehicles are anticipated.

Other Migratory Birds at Prime Hook NWR
Other migratory birds hunted at Prime Hook NWR include mourning dove, woodcock, and snipe. For 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 (tables 5.9 and 5.10).

Given the low numbers of birds harvested from the refuge, no cumulative impacts to local, regional, flyway, or nationwide populations of other migratory birds are anticipated from allowing hunting of these species on the refuge.

Non-Hunted Wildlife
Non-hunted wildlife would include resident and migratory birds (songbirds, wading birds, shorebirds, etc.); small mammals such as voles, moles, mice, shrews, and bats; reptiles and amphibians such as snakes, turtles, salamanders, frogs and toads; and invertebrates such as butterflies, moths, insects, and spiders. Except for migratory birds and some species of butterflies, moths, and bats, these species have very limited home ranges and hunting could not affect their populations regionally; thus, only local effects will be discussed.

Disturbance to non-hunted migratory birds could have regional, local, and flyway effects. 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 future impacts that could occur if reproduction were reduced by hunting are not relevant 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.

Disturbance of resident birds would increase slightly, but displacement is usually brief, infrequent, and short distance. Disturbance would be unlikely for many small mammals, such as bats, which are inactive during fall and winter when hunting season occurs, and are nocturnal. Hibernation or torpor by cold-blood reptiles and amphibians also limits their activity during the hunting season when temperatures are low, making encounters with reptiles and amphibians infrequent and inconsequential to local populations. Invertebrates are also not active during cold weather and will have few interactions with hunters during the hunting season. The Service anticipates no measurable negative cumulative impacts to resident non-hunted wildlife populations locally, regionally, or globally. The cumulative impact of wildlife and habitat management when considered at the flyway scale may benefit the health of migratory birds by maintaining the diversity and native components of the habitats they use. In summary, hunting has little or no impact on non-hunted wildlife due to temporal and spatial separation due to timing of the season and migration.

Threatened and Endangered Species
Disturbance factors resulting from public use are always considered for all listed species. The Delmarva fox squirrel (Sciurus niger cinereus) and piping plover (Charadrius melodus) are listed as endangered and threatened by the U.S. Fish and Wildlife 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 & Wildlife include American oystercatcher (Haematopus palliates), common tern (Sterna hirundo), Forster's tern (Sterna forsteri), least tern (Sterna antillarum), and bald eagle (Haliaeetus leucocephalus). 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/or their occurrence on the Refuge is outside of the hunting season for deer, upland game, and waterfowl. Impacts on the piping plover, 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 would not likely affect the 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 2007).

Fishing, hunting, and wildlife observation/photography on or near Turkle Pond was an existing activity prior to nesting by bald eagles on the 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.

Anticipated Direct and Indirect Impacts of Proposed Action on Refuge Programs, Facilities, and Cultural Resources

Other Wildlife-Dependent Recreation

The opportunities for recreational sport hunting, a wildlife-dependent priority public use, would be available to the hunters, meeting a demand. Hunting on the refuge would contribute to the State's wildlife management objectives and allow a traditional use to continue.

We may close the refuge to other public uses on certain areas during hunt days, unless we can safely sequester the locations of those uses from the locations of hunting activity. Experience has proven that time and space zoning (i.e., establishment of separate use area, use periods, and restriction on the number of users) is an effective tool in eliminating conflicts between user groups. Currently, we restrict other wildlife-dependent recreation on days when we allow hunting on the refuge. Seasonal closures on Prime Hook Creek minimize conflicts between anglers, wildlife observers, and hunters and minimize disturbance to waterfowl. The headquarters area, which contains the visitor contact station, hiking trails, and fishing opportunities and is open year-round, is closed for limited days to facilitate a deer hunt. Closed areas of the refuge along Slaughter Beach Road, Cods Road, Prime Hook Beach Road, and Broadkill Beach Road are open only to permitted hunters during designated times of the hunting season. For the remainder of the year, these areas are closed to the public.

Refuge Facilities

Facilities most utilized by refuge visitors are roads, parking lots, trails, and boat launching ramps. Maintenance or improvement of these facilities will cause negligible short term impacts to localized soils and waters and may cause some wildlife disturbances and damage to vegetation. The facility maintenance and improvement activities described are periodically conducted to accommodate daily refuge management operations and general public uses such as wildlife observation and photography. These activities will be conducted at times (seasonal or daily) that result in the least amount of disturbance to wildlife. Siltation barriers will be used to minimize soil erosion, and all disturbed sites will be restored as close to pre-disturbance condition as possible. During times when roads are impassible due to flood events or other natural causes, those roads, parking lots, trails, and boat ramps impacted by the event will be closed to vehicular use.

Cultural Resources

With a relatively small number of hunters dispersed across the Refuge during the hunting season, direct or indirect cumulative impacts would be negligible on the refuge's cultural resources based on our observations of past hunting impacts. Refuge lands are vulnerable to looting, despite our best efforts at outreach, education, and law enforcement. 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, continue our outreach, and use law enforcement where necessary.

For compliance with section 106 of the National Historic Preservation Act, the Refuge staff will provide the regional historic preservation officer 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.

Anticipated Impacts of Proposed Hunt on Refuge Environment and Community

The refuge expects no sizeable adverse impacts of the proposed action on the refuge environment, which consists of soils, vegetation, air quality, water quality, and solitude. Some disturbance to surface soils and vegetation would occur in areas used by hunters; however, impacts would be minimal. Hunting would benefit vegetation as it is used to keep many resident wildlife populations in balance with the habitat's carrying capacity.

The refuge expects impacts to air and water quality to be negligible. The effect of these refuge-related activities, as well as other management activities, on overall air and water quality in the region are anticipated to be relatively negligible, compared to the contributions of industrial centers, power plants, and non-refuge vehicle traffic on nearby public roads.

The refuge would work closely with State, Federal, and private partners to minimize impacts to adjacent lands and associated natural resources; however, no indirect or direct impacts are anticipated. The hunts result in a net gain of public hunting opportunities positively affecting the general public, nearby residents, and refuge visitors. The refuge expects a minimal increase in visitation, but any additional use will add some revenue to local communities.

Other Past, Present, Proposed, and Reasonably Foreseeable Actions and Anticipated Impacts

Cumulative effects on the environment result from incremental effects of a proposed action when these are added to other past, present, and reasonably foreseeable future actions. While cumulative effects may result from individually minor actions, they may, viewed as a whole, become substantial over time. Hunting on the refuge has been designed to be sustainable through time given relatively stable conditions.

Due to history of low hunter use and harvest for resident geese and late season snow geese, the refuge has been closed during these seasons but will consider reopening if demand and opportunity exist and conflicts are minimized.

Greater snow geese (*Chen caerulescens atlantica*) have undergone a dramatic increase in recent decades, to current population estimates of over 1 million birds. Natural marsh habitats on some migration and wintering areas have been impacted by the destructive feeding strategies of overabundant light geese (Giroux and Bedard 1987, Giroux et al. 1998, Widjeskog 1977, Smith and Odum 1981, Young 1985). In addition, goose damage to agricultural crops has become a problem (Bedard and Lapointe 1991, Filion et al. 1998, Giroux et al. 1998, Delaware Div. of Fish and Wildlife 2000). Snow geese use the refuge wetland habitats extensively, and are not subjected to any hunting disturbance or mortality on the refuge. Impacts to refuge wetlands and impacts to wetland-dependent wildlife compound over time as long as the population is not adequately controlled at the flyway level through the coordinated efforts of individual agencies.

Similarly, resident Canada geese have been shown to cause changes in wetland community structure (Laskowski et al. 2002). Resident geese can reduce the amount of plant biomass that would be available to migrant birds at the end of the growing season. Direct damage to agricultural resources by resident geese includes 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). Uncontrolled Canada goose populations on the refuge can impact migratory bird populations utilizing the refuge as well as contribute to agricultural losses on lands surrounding the refuge.

The refuge will consider participating in the October antlerless season only if an overabundance of deer arises, as determined the Delaware Division of Fish and Wildlife and concurrence by the refuge (refer to Resident Wildlife Section for impacts of deer overabundance).

If visitation levels expand in the unforeseen future, unanticipated conflicts between user groups may occur. Service experience has proven that time and space zoning (establishment of separate use areas, use periods, and restrictions on the number of users) and limiting visitations are effective tools in eliminating conflicts between user groups.

Anticipate Impacts if Individual Actions are Allowed to Accumulate
National wildlife refuges, including Prime Hook NWR, conduct hunting programs within the framework of State and Federal regulations. Hunting at the refuge is at least as restrictive as the State of Delaware regulations and in some cases more restrictive. By maintaining hunting regulations that are as, or more, restrictive than the State, individual refuges ensure they are maintaining seasons that are supportive of management on a more regional basis. Additionally, the refuge coordinates with the Delaware Division of Fish and Wildlife annually to maintain regulations and programs that are consistent with the State's management programs.

The cumulative impact of hunting on migratory and resident wildlife populations at Prime Hook NWR is negligible. As described in the previous sections, the proportion of the refuge's harvest of waterfowl, deer, and small game is negligible when compared to local, regional, and flyway populations and harvest.

Because of the regulatory process for harvest management of migratory birds in place within the Service, the setting of hunting seasons largely outside the breeding seasons of resident and migratory wildlife, the ability of individual refuge hunt programs to adapt refuge-specific hunting regulations for changing local conditions, and the wide geographic separation of individual refuges, we anticipate no direct or indirect cumulative effects on resident wildlife, migratory birds, and non-hunted wildlife of hunting on Prime Hook NWR.

Anticipated Cumulative Impacts of Alternative B: Service-Preferred Alternative

Resident Big Game
White-tailed Deer
The cumulative impacts of this alternative on white-tailed deer would be similar to those discussed under alternative A. The refuge proposes to open 1,513 additional acres to deer hunting for a total of 5,389 acres. This additional acreage includes an area located north of Prime Hook Beach Road commonly referred to as Oak Island, an area of red maple swamp along Prime Hook Creek and west of the existing headquarters area, an area north of Route 16 referred to as the Millman Tract, and an expansion of the headquarters area. Of these new areas, Oak Island was previously hunted up until 1995 and the Millman Tract was hunted under private ownership up until the Service purchased it in 2001. Prime Hook Creek and its associated red maple swamp will provide additional opportunities and will be limited by access.

Hunter numbers are expected to initially increase based on the opening of these areas and the opportunity for hunters to free roam; however, cumulative impacts are expected to be negligible. The current harvest of deer on the refuge (107) has a miniscule impact on the statewide deer population of 31,071 deer (Table 5.12). Hunting license sales in Delaware have declined from 29,994 in 1975 to

18,746 in 2007 (Rogerson 2010). Based on the decline in the number of hunters and the relatively 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.

Wild Turkey
Under this alternative, the refuge proposes to open 3,472 acres for wild turkey hunting. This additional acreage includes many of the areas for deer hunting under this alternative. Turkey hunting was permitted on the refuge in Unit I west of Slaughter Canal from 1993 up until 1998. 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. Impacts from turkey hunting, which occurs in April and May, are expected to be negligible since only a very small number of hunters, five or fewer will be permitted to hunt.

Upland Game or Small Game
The cumulative impacts of this alternative on small game would be similar to those discussed under alternative A. No expansions of hunting acreage are proposed.

Given the low numbers of animals harvested from the refuge, no cumulative impacts to local, regional, or Statewide populations of small game are anticipated from allowing hunting of these species on the refuge.

Migratory Birds
Migratory birds are managed on a flyway basis by the Service. The process of surveying populations and setting regulations is, inherently, a cumulative impact analysis. The cumulative impacts of this alternative on migratory birds would be similar to those discussed under alternative A.

Waterfowl at Prime Hook NWR
The cumulative impacts of this alternative on waterfowl would be similar to those discussed under alternative A. Under this alternative, the refuge proposes to open 1,732 additional acres for waterfowl hunting for a total of 3,455 acres. This additional acreage includes an area between Slaughter Beach Road and Fowler Beach Road referred to as Unit I, an area located south of Prime Hook Beach Road, Prime Hook Creek, an area along the Broadkill River in Unit IV, and a reconfiguration of the existing waterfowl hunt area in Unit III. Of these new areas, Unit I was already open to dove hunting and Prime Hook Creek was hunted up until 1991.

To minimize waterfowl disturbance, the refuge has designated about 3,000 acres as waterfowl sanctuaries that 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 was established to provide waterfowl with a network of resting and feeding areas and to disperse waterfowl hunting opportunities on the refuge. These sanctuaries lie in the Unit II (approximately 1,800 acres) and the southern half of the Unit III (approximately 970 acres) managed impoundments. 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.

Furthermore, on refuge impoundments in Unit III and Prime Hook Creek, waterfowl hunting will occur three days per week during the hunting season, which is one day less per week than under alternative A. Impacts to waterfowl will also be decreased from current management by changing the end of shooting time from 3:00 pm to noon. These restrictions also apply to the early teal and

resident Canada goose seasons, which will be further limited by lower water levels during that time of year due to drawdown practices.

Hunter numbers are expected to initially increase based on the opening of these areas and the opportunity for hunters to free roam in the regular waterfowl areas; however, cumulative impacts are expected to be negligible. Hunting license sales in Delaware have declined from 29,994 in 1975 to 18,746 in 2007 (Rogerson 2010). Based on the decline in the number of hunters and the relatively low numbers of waterfowl harvested from the refuge with respect to the total Statewide, flyway, and national harvests, no cumulative impacts to local, regional or flyway waterfowl populations are anticipated from allowing hunting of waterfowl on the refuge. Impacts to waterfowl using the refuge would be localized to the area being hunted (which can be no more than 40 percent of the refuge) and, due to the short temporal nature of these types of disturbance (from day restrictions to hunting at noon), no cumulative indirect impacts from shooting, walking, boats, or vehicles are anticipated.

Other Migratory Birds at Prime Hook NWR
The cumulative impacts of this alternative on other migratory birds would be similar to those discussed under alternative A.

Given the low numbers of birds harvested from the refuge, no cumulative impacts to local, regional, flyway, or nationwide populations of other migratory birds are anticipated from allowing hunting of these species on the refuge.

Non-Hunted Wildlife
The cumulative impacts of this alternative on non-hunted wildlife would be similar to those discussed under alternative A. Additionally, spring turkey hunting will negligibly affect non-target wildlife since only a very small number of hunters (no more than five) will be permitted to hunt on the 3,472 designated acres of the refuge.

Threatened and Endangered Species
The cumulative impacts of this alternative on threatened and endangered species would be similar to those discussed under alternative A.

Anticipated Direct and Indirect Impacts of Proposed Action on Refuge Programs, Facilities, and Cultural Resources
Other Wildlife-Dependent Recreation
The opportunities for recreational sport hunting, a wildlife-dependent priority public use, would be available to the hunters, meeting a demand. Hunting on the refuge would contribute to the State's wildlife management objectives and allow a traditional use to continue.

Expanded hunting opportunities are expected to have adverse impacts on a certain segment of the public that does not desire any change in public use programs and regulations, or that may hold differing views on the course of action. In addition, while new visitors become familiar with those changes, violations could increase. Some conflict between wildlife observers, photographers, students, and other refuge users is expected to be short-term and negligible and will be managed through seasonal closures. Negative reactions by some visitors may be caused by the closure of the western end of Prime Hook Creek to all uses (mainly fishing, canoeing, and kayaking) other than hunters from September 1 through the end of the deer and waterfowl hunting seasons; the closure of the eastern end of Prime Hook Creek from September 1 through March 15; and the temporary closure of the general public use area near the refuge headquarters to conduct deer hunts. Under current management, the

westernmost 4 miles of Prime Hook Creek was open year-round to the non-hunting public. Refuge officers would enforce these and other current refuge regulations, where appropriate, and would seek the assistance and cooperation of Delaware Division of Fish and Wildlife in enforcing common regulations to provide a safe environment for refuge visitors and promote activities that are compatible with protecting the resources.

We anticipate some conflict between concurrent hunting programs (e.g., waterfowl, deer, and upland game hunting seasons overlapping). For the majority of the hunting seasons, the Delaware Division of Fish and Wildlife has made efforts to avoid these overlaps in the various hunting programs. As public use levels expand across time, unanticipated conflicts between user groups may occur. The refuge's visitor use programs would be adjusted as needed to eliminate or minimize each conflict and provide quality wildlife-dependent recreational opportunities. The Service's law enforcement efforts will be increased. Conflicts among hunters over desired hunting locations are expected and we will continue to encourage proper hunting ethics.

Refuge Facilities
Minimal infrastructure, which includes the addition of two to three parking areas, enhancement of existing boat ramps, and placement of informational signs, is anticipated in support of this priority public use. There would be some costs associated with these programs in the form of road maintenance, law enforcement, and boat ramp maintenance. These costs should be minimal relative to total refuge operations and maintenance costs and would not diminish resources dedicated to other refuge management programs. Impacts to refuge resources are expected to be negligible.

Cultural Resources
The cumulative impacts of this alternative on cultural resources would be similar to those discussed under alternative A.

Anticipated Impacts of Proposed Hunt on Refuge Environment and Community
In addition to cumulative impacts discussed in alternative A, hunt zones in the proposed waterfowl hunt area in Unit IV along the Broadkill River have the potential to conflict with nearby existing blinds on private lands. We will evaluate this activity and adjust these zones accordingly. Hunters will most likely opt to hunt within the marsh areas of these zones and not along the Broadkill River, which would lessen any direct conflicts with hunters on these nearby private lands. Also, due to an increase in new hunting areas and by allowing hunters to free roam, an increase in violations seems likely until hunters become familiar with the refuge boundaries and regulations. We also anticipate some landowner conflicts with deer hunter trespassing.

The elimination of nearly all hunting permit fees (except for lottery hunts) should be well received by hunters and changes to the hunting program reduce the administrative burden and minimize the amount of staffing resources needed to conduct the hunt by 71 staff days and $17,705 from current management. The benefit to the hunter is a reduction in their cost to hunt.

Other Past, Present, Proposed, and Reasonably Foreseeable Actions and Anticipated Impacts
Cumulative impacts are the same as discussed under alternative A.

Anticipate Impacts if Individual Actions are Allowed to Accumulate
Cumulative impacts are the same as discussed under alternative A.

Anticipated Cumulative Impacts of Alternative C: Historic Habitat Management with Modified Public Use

The cumulative impacts of this alternative would be very similar to and in some cases less than those discussed under alternative B. Cumulative impacts of hunting on the refuge would be the same as alternative B except that the number of hunting days and areas would be reduced and turkey hunting would be closed to reflect a reduction in staff size. More specifically, deer and waterfowl hunting in the regular hunt areas will be restricted to three days per week, the westernmost 4 miles of Prime Hook Creek will be closed to hunting (and would be available to other users throughout the year), and waterfowl hunting along the Broadkill River in Unit IV will be closed. Overall, deer hunting in this alternative is reduced by 480 acres from alternative B, and waterfowl hunting is reduced 582 acres. Cumulative impacts of upland game and webless migratory bird hunting would be the same as under alternative A. The cost of the hunting program would be $1,300 less than the annual hunting program proposed under alternative B.

Relationship Between Short-Term Uses of the Human Environment and the Enhancement of Long-Term Productivity

In this section, we examined the relationship between local, short-term uses of the human environment and maintaining the long-term productivity of the environment. By long-term, we mean that the impact would extend beyond the 15-year period of this CCP.

Under all alternatives, our primary aim is to maintain or enhance the long-term productivity and sustainability of natural resources on the refuge, in the State of Delaware, and in the Delmarva Coastal Plain ecosystem, along with migratory birds, interjurisdictional fish, and other far-ranging wildlife species, across their whole range.

Habitat protection and restoration actions across all alternatives may entail short-term negative impacts to ensure the long-term productivity of the refuge. Many of the cyclic management actions in the alternatives, namely, prescribed burning, controlling invasive plants and animals, proactively managing forests, and restoring native plant communities can have dramatic short-term impacts. These include direct mortality of some plants and animals, displacement of species, and temporary displacement or cessation of certain types of public use.

However, the long-term benefits of those actions generally offset their short-term impacts. Habitat management practices that mimic ecological and sustainable processes optimize the maintenance and enhancement of the biological diversity, integrity, and environmental health of those habitats for the long term. Long-term productivity is especially enhanced when the ecological and sustainable management actions that are proposed in the preferred alternative would best support and improve links between nutrient cycling, ecological processes and ecosystem function.

The nutrient cycling of the refuge's habitats is closely linked to other ecological processes discussed in this document. The dominant presence of wetlands and their distribution in the refuge's landscape strongly influences the transport of nutrients, usually in conjunction with hydrological patterns. Vegetative structural diversity in the forms of dead wood, leaf litter, senesced wetland vegetation, and detritus contributes to terrestrial and aquatic invertebrate resources that maximize sustainable nutrient recycling which in turn enhances the long-term productivity of the refuge's natural resources to people and wildlife.

Diverse and wide-ranging wildlife recreational opportunities for public use should provide the best long-term positive economic impacts to local communities. That mirrors the widely accepted premise that maintaining biological diversity in natural ecosystems helps ensure their long-term resiliency. We would design our proposed public use programs to heavily rely on outreach and environmental education to explain all of our management actions to visitors and the public that would encourage everyone to be better stewards of our natural environment.

In summary, we predict that the alternatives would contribute positively to maintaining and enhancing the long-term productivity of the refuge's natural resources, with sustainable beneficial cumulative and long-term benefits to the environment surrounding the refuge with minimal inconvenience or loss of opportunity for the American public.

Unavoidable Adverse Effects

Unavoidable adverse effects are the effects of those actions that could cause harm to the human environment and cannot be avoided, even with mitigation measures. All the alternatives would result in some minor, localized, unavoidable adverse effects. For example, any new construction, burning of prescribed fires, or control of invasive species would produce minor, short-term, localized adverse effects. However, none of those effects would rise to a significant level. Furthermore, all of those impacts would be mitigated with best management practices, so none of the alternatives would cause significant, unavoidable cumulative impacts.

Some habitat types on the refuge will be adversely affected. In alternative C, increased salinity into Unit II may cause rapid reversion from a freshwater marsh to a saltwater marsh. That would affect the wildlife that depends on freshwater systems. However, it is important to recognize that in virtually all situations where this conversion from freshwater to salt marsh might happen, the original, historic habitat was tidal salt marsh.

Forest habitat is also likely to undergo changes in species composition and structure as we create a more natural forest composition representative of the Delmarva Coastal Plain ecosystem, consisting of mixed hardwood oak-dominated systems. We do not expect significant adverse consequences from treating invasive plant species, improving current forest stand conditions, or conducting proactive reforestation projects.

All these unavoidable adverse effects on the physical and biological environment will be relatively local and more than offset by the long-term benefits of cleaner air, cleaner water, and making rare wildlife species more common across the landscape, while providing quality wildlife-dependent recreation.

As we noted previously, many of the habitat and facility construction projects in the alternatives have a certain level of unavoidable adverse effects, especially during the actual construction. Those effects are mitigated to some degree by the use of practices and precautions that safeguard water quality, avoid sensitive or irreplaceable habitats, or time the actions or include features to avoid or minimize impacts on fish and wildlife. The adverse effects generally are short-term and more than offset by the long-term gains in habitat quality and fish, wildlife, and plant productivity.

All the alternatives, in varying degrees, will have adverse impacts to a certain segment of the public that does not desire any change in current habitat management or public use programs. Some may be concerned about increased visitation to the refuge or others may not like us to open new tracts for public use adjacent to their residences. Some of these impacts on certain individuals or neighbors are unavoidable. Our responsibility is to provide equal opportunities to the American public. We believe we have sought a fair balance in minimizing and mitigating adverse impacts while optimizing wildlife conservation and providing excellent recreational opportunities to the public.

Potential Irreversible and Irretrievable Commitments of Resources

Irreversible commitments of resources are those that cannot be reversed, except perhaps in the extreme long term or under unpredictable circumstances. One example is an action that contributes to a species' extinction. Once extinct, it can never be replaced. By comparison, irretrievable commitments of resources are those that can be reversed, given sufficient time and resources, but represent a loss in production or use for a time. An example of an irretrievable commitment is maintaining grassland areas adjacent to salt marsh habitats for Henslow's sparrow in alternative B. If for some reason, Henslow's sparrow conservation was no longer an objective, those acres would revert gradually to maritime scrub shrub and forest, or we may determine it best to expedite that reversion by planting shrubs and trees. We do not consider small visitor facilities, such as photo blinds and information kiosks, irretrievable commitments of resources. We can dismantle those facilities and restore the sites if resource damage is occurring.

Environmental Justice

President Clinton signed Executive Order no. 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations on February 11, 1994, to focus Federal attention on the environmental and human health conditions of minority and low-income populations, with the goal of achieving environmental protection for all communities.

The order directs Federal agencies to develop environmental justice strategies to aid in identifying and addressing disproportionately high adverse human health or environmental effects of their programs, policies, and activities on minority and low-income populations. The order is also intended to promote nondiscrimination in Federal programs substantially affecting human health and the environment, and to provide minority and low-income communities access to public information and participation in matters relating to human health or the environment.

The United States EPA Office of Environmental Justice defines it as follows:

> "Environmental Justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental law, regulations, and policies. EPA has this goal for all communities and persons across this Nation. It will be achieved when everyone enjoys the same degree of protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work." (*http://www.epa.gov/environmentaljustice*; accessed February 2012)

Overall, we expect none of the alternatives to place disproportionately high, adverse environmental, economic, social, or health effects on minority or low-income persons. Before we make any decisions to make major changes in habitat management or the environment, we always inform all of our publics, equally, and our programs and facilities are open to all who are willing to adhere to the established refuge rules and regulations. We do not discriminate in our responses for technical or practical information on conservation issues or when providing technical assistance in managing private lands.

Table 5-14. Summary Comparing the Effects of Management Alternatives at the Prime Hook NWR

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
General Impacts of Public Use on Refuge Resources of Concern	Direct, indirect, and cumulative impacts affect refuge resources. Direct impacts are those impacts immediately attributable to an action. Indirect impacts are those impacts that are farther in time and in space. Effects that are minor when considered alone, but collectively may be important are known as cumulative impacts. Effects are minimized through restrictions on time and place for public entry such as hours of operation, restriction to designated trails, or seasonal closures. Require a special use permit for groups of 6 or more cyclists or groups of 15 or more pedestrian travelers to minimize wildlife disturbance. Maintenance or improvement of refuge facilities may cause short-term impacts and will be conducted at times that cause the least disturbance to wildlife and their habitats. Illegal activities that may disturb and displace wildlife or trample vegetation include littering, vandalism, ATV use, camping, fires, exceeding the daily bag or creel limit, taking non-target species, or hunting in a closed area. Research activities contribute positively to refuge goals and objectives, but may cause short-term disturbance to wildlife resources.		
Socioeconomic Environment	The general consequences of managing native plant resources to maintain, enhance, and restore elements of biological integrity, diversity, and environmental health (BIDEH) have direct, indirect, and cumulative beneficial effects on people and wildlife. Ecological services derived from refuge wildlands and natural habitat management have the following beneficial impacts on the socioeconomic environment: • Purification of air and water • Mitigation of droughts and flood • Generation and preservation of soils and renewal of their fertility • Detoxification and decomposition • Cycling and movement of nutrients • Dispersal of seeds • Pollination services: pollination of farm crops and native vegetation to sustain native plant diversity in natural habitats and increase yields of farm crops • Carbon sequestration and partial stabilization of climate • Protection of coastal shores from erosion • Moderation of weather extremes and their impacts • Increased avian diversity on refuge lands from managing for BIDEH that generates greater capacity for disease prevention		

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Socioeconomic Environment (cont.)	Continue to make small contributions to local economy, in terms of refuge purchases of goods and services within the local community, refuge personnel salary spending, and spending in the local community by refuge visitors. Contribution to local economy based on 88,000 visitors each year and their expenditures that support refuge activities. Accounting for 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. The hunting program requires 95 staff days and costs $30,955, with a recovery of $12,025. 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 resource may increase. There would be an adverse affect to recreational resources with the loss of wetlands and habitat diversity. Conversion of emergent marsh to large unvegetated open water would result in a diminished capacity of the area to support fish and wildlife populations, which may reduce recreational opportunities. The continued loss of these coastal barrier systems would result in the reduction and eventual loss of natural protective storm buffering.	Forest management activities proposed would have some direct beneficial impact on the socioeconomic environment of the region, as many of these techniques would require the contracted services. Wetlands in many locations play an important role in flood protection. Wetlands can prove a significant and potentially sustainable buffer for wind wave action and storm surge generated by storms. Wetlands protect water quality by trapping sediments and retaining excess nutrients and other pollutants such as heavy metals. A badly degraded wetland can lose its capacity to remove excess sediments, nutrients, and other pollutants, and can lose its habitat value for fish and wildlife. When wetlands lose their value as wildlife and fish habitat, this value is difficult to replace, and the consequent losses to the recreational and commercial industries may be significant. Examples include recreational and commercial fishing, hunting, birding, and photography. Restoring wetlands and reducing the land loss rates may protect nearby recreational infrastructure such as parking areas, roads, piers, and observations towers. Adding five refuge staff would minimally increase benefits for the local economy in jobs, income, and expenditures. Eliminating co-op farming would negligibly affect the agricultural sector in Sussex County, since contribution is relatively small. Enhancing refuge visitor services programs would increase visitation, thereby increasing their expenditures in the local economy and their total economic impact on Sussex County. Accounting for direct, indirect, and induced effects, all refuge activities would generate total economic impacts of $4.7 million in local output, 41 jobs, and $1.29 million in labor income. The hunting program costs $17,890 less and requires 54 fewer staff days than alternative A, with an estimated recovery of $3,832.	Economic impacts would be greater than alternative A and less than alternative B. We would also contribute negligibly to local agricultural sector with a co-op farming program of 600 acres. Numbers of visitors engaged in recreation would be slightly higher than alternative A and lower than alternative B with similar economic impacts on Sussex County. Accounting for 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. The hunting program costs $1,315 less and requires 5 fewer staff days than alternative B, with an estimated recovery of $3,792.
	Regardless of which alternative we select, we would continue to pay refuge revenue sharing each year to Sussex County, and these contributions are relatively small to the county's budget. Regardless of the selected alternative, refuge management jobs, income, and expenditures would negligibly affect the local economy (less than 1 percent of total income and employment in Sussex County), but the expenditures of refuge visitors would continue to add some minor benefits for the local economy.		

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Cultural & Historical Resources	The refuge contains 14 prehistoric sites and 31 historic sites, which were identified in archaeological, historical, and geomorphological surveys conducted in 1982, 1984, and 2004. The likelihood is moderate to high that we may locate additional areas containing prehistoric or cultural resources.	We would continue to protect all refuge historic and prehistoric sites identified in alternative A and any future actions with the potential to impact cultural resources in moderate to high probability zones will be reviewed and assessed under all provisions of section 106 and Federal historic preservation act requirements (ARPA). This CCP document will be submitted and reviewed by State historic preservation officer for concurrence.	Beneficial impacts similar to alternative B.
	Some risk that refuge visitors may inadvertently or intentionally damage or disturb cultural and historic sites. Known sites would continue to be monitored and protected. Impacts to cultural and historic resources under alternative A have the potential to be less than under alternatives B and C because the passive habitat management approach in alternative A would involve less potential disturbance of culturally significant sites.	Similar to alternative A, but slightly more potential disturbance from habitat management activities, and we will also increase outreach and education to inform visitors and the general public about the refuge's cultural and historic resources.	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
	Regardless of which alternative we select, we would protect known cultural or historic resources. We expect all the alternatives to have minimal adverse impacts on cultural and historic resources on the refuge. For compliance with section 106 of the National Historic Preservation Act, refuge staff will consult with the regional historic preservation officer during the planning stages of new actions. That office will consult as needed with the State historic preservation officer.		
Air Quality	Local long-term benefits in air filtration and carbon sequestration from protecting up to 10,000 acres within approved refuge boundary of wetland, upland, and open water habitats.	Negligible to long-term minor benefits for air filtering and carbon sequestration and slight increases due to proactive reforestation projects and wetland restoration projects. Increased energy-efficient practices with adoption of new practices (solar panel roof replacement for headquarters building, hybrid vehicle fleet)	Beneficial impacts similar to alternative B.
	Local negligible adverse effects from prescribed fire to control invasive plants, and negligible contribution to regional vehicle emissions by visitors.	Local negligible adverse effects from particulate emissions from prescribed fire, given increased grassland and shrubland maintenance and invasive plant control (200 to 1,000 acres/year). Small increase, but still insignificant vehicle emissions resulting from increased visitation.	Adverse impacts are similar to alternate A.
	None of our proposed refuge management activities should adversely affect regional air quality. None would violate EPA standards for criteria air pollutants and each would comply with the Clean Air Act. None would affect visibility due to emission-caused haze at the nearest class 1 airshed. Management actions and public uses at the refuge contribute a negligible increment to regional emissions.		

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Soils	Natural succession to native forested habitats versus proactive forested restoration will likely allow more time to restore and increase below ground biodiversity of soil organism that restore the health of soil resources. In the absence of active salt marsh restoration (dredge spoil) there may be slower or more limited return of vertical accretion than is likely under alternative B. Management actions would have a local long-term minor beneficial impact	Elimination of intensive agricultural practices on 600 acres will reduce soil erosion by wind and water in these areas and restore soil tilth. Restoration to native plant communities on prior farmed areas will rehabilitate damaged soils and restore natural functioning of beneficial soil bacteria and other soil organisms, re-establishing processes of decay and nutrient cycling that restores natural soil fertility levels and productivity of soils. Low intensity and regular prescribed fire in grasslands, shrublands, and understory burns to improve Delmarva fox squirrel forested habitats should improve soils by two ways: establishing native vegetation and by regularly returning nutrients to soils. Restoration of natural soil productivity will increase soil carbon stocks and capacity of soils for carbon sequestration. It is expected that restoring approximately 600 to 800 acres to forested habitats would increase carbon sequestration capacity of these soils within the next 100 year horizon. Salt marsh restoration will improve the quantity and quality of soils and sediment with impounded wetlands. In addition, restoration will reduce wave velocity and promote sediment deposition. Overwash and inlet formation, permitted to occur can contribute to the sediment budget of the wetlands. Management actions would result in local long-term minor to moderate beneficial impacts.	Taking 200 acres out of cropland production and restoring them to native vegetation significantly decreased soil erosion, improved soil conditions, and restored native soil biota with positive impacts for a large number of wildlife species. Periodic low intensity prescribed burning returns nutrients to soils. Use of glyphosate-tolerant corn and soybeans increase the success of conservation tillage, which can decrease soil erosion. The use of cover crops reduces soil erosion and increases soil fertility. Agricultural management actions mpacts can be mitigated with the use best management practices (cover crops and conservation tillage).

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Soils (cont.)	Lands abandoned from intensive agriculture with artificial depletion of nutrients can sometimes degrade ecosystem function, and facilitate the invasion of exotic soil species. Rapid saltwater intrusion could potentially cause subsidence through collapse of organic soils and conversion to open water. 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. There would be few ground disturbing activities and no active forest management to cause adverse soil effects. Best management practices in any refuge improvements would minimize short-term, localized soil impacts and eliminate potential cumulative effects. We would continue to prohibit recreational activities such as mountain biking, ATV's on pedestrian trails, or off-road vehicle travel that would damage soils on the refuge. Hiking trails, boat launch sites, wildlife observation areas, parking areas and other high-use areas would continue to be maintained well to keep soil effects to a minimum. Management action may result in local short-term and long-term moderate adverse impacts.	Impacts of forest management practices through clearing of vegetation and heavy equipment are expected to be negligible with the use of best management practices. The depth of subsidence is greatest marshes impounded form decades with large accumulation of freshwater peat of low bulk density. Rapid introduction of seawater can lead to peat collapse, which can lead to subsidence and may lead to open water environment. The discharge of dredge spoil may result in changes to physical, chemical, and biological characteristics of the substrate. Containment levees or berms may be needed to minimize the effects of dredge spoil as point and nonpoint source of pollution. In addition, timing and the construction of berms/levees may minimize wind and wave energy. Excessive elevation may impede channel formation and undesirable vegetation. Improper sediment grain size may have adverse impacts to piping plovers and/or horseshoe crabs. Minor impacts associated with the following new visitor services' improvements: new trails may require boardwalk pilings for trail access over wetlands or sensitive vegetation communities; expansion of facilities for education and visitor services programs is expected to cause negligible soil impacts. Increase visitation might result in increased trampling along trails, around visitor facilities, and waterfowl blind site areas. Management actions would result in local short-term minor adverse impacts.	Soil erosion may continue where conventional tillage practices increases soil erosion. Soil compaction is associated with field operations, which can increase surface run-off. The restricting tidal flow may have adverse impacts to sediment supply and sedimentation rates of the wetland system. Sedimentation rates are far below sea level rise rates. Impacts from public use would be similar to alternative A, except for deer and waterfowl hunting, which will have impacts greater than alternative A but less than alternative B. Farming and impoundment management will have short and long-term minor to moderate adverse impact to soils
	With all visitor services and recreational activities, habitat management activities and routine maintenance of all Service property and improvements, we will use best management practices in all refuge activities and actions that might affect refuge soils to ensure that we maintain soil productivity, and conserve and protect refuge soil resources.		

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Hydrology and Water Quality	Forested buffers will be created by relying on natural succession to create buffer zones. Continuing to discouraging interference with natural processes of inlet formation, sand migration, and overwash development in Unit I will have beneficial impacts for salt marsh habitats as renewable tidal flows and natural hydrologic patterns that create mini-inlets and expand overwash habitats will be allowed to evolve naturally. With control of pest plants, approved glyphosate herbicides are associated with less surface run-off than other common herbicides. Restore water circulation and access through the maintenance of refuge ditches to enhance water management capabilities. Management actions would have local short-term minor beneficial impacts.	Increasing forested buffers around refuge wetlands and watercourses will improve water quality and help mitigate pesticides and nitrogen run-off from off-refuge sources adjacent to refuge. Properly managed salt marsh restoration will permit natural tidal flows and natural hydrologic patterns that create mini-inlets. This will alleviate water quality problems encountered when sudden saltwater intrusion negatively influences the impoundment vegetation. Ditch maintenance will maintain and enhance water circulation and improve water quality. Proper hydrology must be attainable. Channels are needed to drain and successfully restore the marsh. Construction of tidal channels enhances tidal flooding, increases sedimentation rates, improves drainage, enhances vegetation colonization and species diversity. Vegetated marshes can reduce wave height by 63 percent within 7 meters. Reduced wave velocity may increase sediment deposition and decrease erosion. Restoration may result in decreased storm surges and waves. With the use of dredged material, the construction of berms or levees may protect restoration efforts from wave attack. The removal of Fowler Beach Road or increases in culvert size on other roads may improve tidal flushing and the overall hydrology. Management actions may have local short-term and long-term minor-to-moderate beneficial impacts.	Discouraging interference with natural processes of inlet formation, sand migration, and overwash development in Unit I will have beneficial impacts for salt marsh habitats as renewable tidal flows and natural hydrologic patterns that create mini-inlets and expand overwash habitats will be allowed to evolve naturally. Management actions may have local short-term minor beneficial impacts.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Hydrology and Water Quality (cont.)	Adverse impacts to water quality are minimized with the use of buffer strips, using approved herbicides, and other best management practices. Increased frequency and duration of saltwater incursion into Unit II and ultimately into Unit III will have adverse effects on vegetation communities. These factors could result in a conversion of the wetland to largely open water, at least for the short term. Deeply subsided areas in high wave energy conditions may not vegetate after decades. An increase in tidal flooding frequency and range may create impacts for restored and existing marshes. If *Spartina alterniflora* does not establish an extensive root network in *Spartina* patens marsh areas before it is killed by salinity and flooding the marsh may collapse following mortality. Once the peat collapses, it would be unlikely that *Spartina alterniflora* would colonize Negligible impacts may occur from anglers, hunters, or canoers/kayakers stirring up creek or pond bottom sediments or introducing pollutants into the waterways, but we do not expect even minor impacts that would cause long-term effects. Prohibition of gasoline motors in Turkle and Fleetwood Ponds minimizes impacts Management actions may result in local short-term and long-term minor to moderate adverse impacts.	In salt marsh restoration the discharge of dredge material may lead to high BOD, which can reduce oxygen available to many organisms. An increase in nutrients may also lead to an increase in some species such algae. Dredged material may modify water circulation by obstructing flow, changing velocities, flow direction, and shoreline and substrate erosion rates. These impacts are minimized by confining material to decrease turbidity. Turbidity impacts are local and temporary. Indirect impacts include the possibility of algal blooms, increased dissolved oxygen, agrichemical may increase and decreased water temperatures. The maintenance exiting ditches or creation of new tidal channels to improve water circulation may increase turbidity and BOD locally. This is minimized with time of year restrictions. Hypersalinity is common problem in restoration sites. Proper hydrology is essential to promote rapid recovery and minimize adverse impacts. Catastrophic outcomes may occur once tidal flow is restored. A catastrophic blowout may result in open water with the absence of vegetation for prolonged periods, in the worst case, many decades to more than a century. This can be minimized through careful consideration of restoration design. Potential impacts from recreational users would also increase over alternative A, with expanded hunting, fishing, and wildlife observation opportunities. The use of manual propulsion or electric motors for fishing in the new areas of Goose and Flaxhole Ponds will minimize any effects on water quality. We plan to monitor those sites closely and address any elevated concerns. Management actions may result in local short-term minor adverse impacts.	The movement away from artificial dune restoration in Unit I increases the circulation of salt water into Unit I, which does have implications for Units II and III. Even if Unit II is managed as a freshwater impoundment, increased saltwater intrusion into Unit II will be likely, and will have adverse impacts on the maintenance of freshwater integrity in both Units II and III freshwater impoundments. The maintenance exiting ditches to improve water circulation may increase turbidity and BOD locally. This is minimized with time of year restrictions. Impacts from non-hunting public uses would be similar to alternative A. Impacts from hunting will be greater than alternative A, but less than alternative B. Management actions may result in long-term major impacts.
	None of our proposed refuge management activities would violate Federal or State standards for contributing pollutants to water sources; all three would comply with the Clean Water Act.		

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Vegetation	Allowing natural succession to occur in refuge uplands will take longer to achieve habitat management objectives and reduce quality of many forest stand conditions. Salt marsh restoration would have a moderate long-term beneficial impact marsh vegetation. Even though salt marshes are less diverse, they are most productive. Tidal flows established from inlets would continue to introduce new sediments that could aid in the natural return of the unit to salt marsh. Management actions would result in long-term moderate beneficial impacts.	Same as A, but with additional long-term benefits from protecting and pro-actively managing 10,132 acres within the approved Refuge boundary using forest management activities. These forest management actions would improve forest conditions of existing upland forest stands, create new forested acres and riparian buffers, and restore areas in non-native vegetation to native plant communities, thus reducing habitat fragmentation, promoting habitat connectivity, and increasing the refuge's carbon sequestration capacity. Increase acreage of upland forested habitat and early successional habitats. Restoration will promote habitat connectivity and reduce fragmentation. Various forest management techniques are aimed at stand improvement and will directly impact the composition of vegetation. These silvicultural treatments provide benefits regarding regeneration and stand replacement, species composition and diversity, forest health, and long-term sustainability of forest habitats. Prescribed burning can improve natural regeneration, especially oak species. Fire can also be used in hazard fuel reductions. Weed control would increase survivability, growth, and production of desired species. Only approved herbicides would be used. Salt marsh restoration would have a moderate-to-major long-term beneficial impact marsh vegetation. Even though salt marshes are less diverse, they are among the most productive. The placement of dredged materialmay provide a substrate for emergent vegetation allowing open water areas to function as marshes and reduce wave fetch. The salt marsh restoration efforts will focus on tidal range and sedimentary delivery rates to grow and expand salt marsh vegetation. Management actions would result in long-term moderate to major beneficial impacts.	Management of impounded wetlands would have moderate beneficial impact to freshwater vegetation. Water levels and timing of drawdowns determine composition and production of moist soil plants. Other factors influencing composition include soil types, temperatures salinities, and soil moisture. Management actions would result in short-term moderate beneficial impacts

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Vegetation (cont.)	Allowing deer hunting would ensure that deer overbrowsing does not result in extensive damage to vegetation. Vegetation trampling from hunting is negligible. Allowing natural conversion to occur instead of using proactive restoration may reduce quality of salt marsh conditions or result in more open water. Some portions may 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 Direct loss of vegetated habitat would continue to occur as plants are physically removed by erosion from marine processes, increased water velocities, and increase herbivory pressures. Other visitor services programs would produce some effects on refuge vegetation. We would continue to maintain or improve infrastructure, such as roads and trails, which would involve the occasional trimming or felling of trees. Some trampling may result from visitors walking off-trail. Impacts would generally occur within areas already disturbed and confined to existing infrastructure footprints. We would continue to educate visitors about invasive plants to prevent the spread of seeds to new areas. Management actions would have short-term and long-term moderate-to-major adverse impacts.	Allowing deer hunting would ensure that deer overbrowsing does not result in extensive damage to vegetation. Vegetation trampling may increase, but will have minimal impacts from hunters in free roam hunting areas or areas adjacent to waterfowl blind sites. Direct impacts of management activities would be the temporary removal of vegetation through bush-hogging, mowing, burning, or applying herbicides. The impacts would be short term. Minor adverse impacts to upland forest communities may result if natural regeneration does not result in desirable species composition. Fire, as a management tool, will have negligible adverse impact on vegetation. Saltwater intrusion will significantly reduce the moist-soil (freshwater vegetation) acreage. In addition, forested wetlands may be adversely impacted. If raising marsh elevations are not successful, some additional portions of the unit may 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. Impacts from public use would increase from alternative A. Minimal impacts are expected from the construction of new trails or expansion of existing facilities. New trails would be built on existing roads or presently maintained interior access routes to the extent possible. Management actions would result in negligible to minor short-term adverse impacts.	Hunting is expected to cause more impacts to vegetation than in alternative A, but less than alternative B. All other recreation is expected to cause adverse impacts similar to alternative A. Management actions would have local long-term minor-to-moderate adverse impact.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Federal & State Endangered Species	Natural succession processes will take longer to achieve DFS habitat management objectives. Protection and maintenance actions conserve and enhance overwash inlet areas, mudflats sand flats and shorelines provide local short-term minor beneficial impacts. Management actions would result in short-term local minor beneficial impacts.	Afforestation will increase DFS habitat acres and enhance refuge population size to ensure long-term viability of DFS and refuge population. Forest management (TSI, silvicultural practices, and prescribed burning) will enhance the quality and quantity of the DFS habitat. Protection and maintenance actions conserve and enhance overwash inlet areas, mudflats sand flats and shorelines provide local short-term minor beneficial impacts. Seasonal closures of designated beach and overwash areas from March 1 through September 1. The deposition of dredged material on beaches can improve quality and availability of plover habitat, if it is clean sand of appropriate grain size. Management actions would result in short-term local minor beneficial impacts.	Seasonal closures of designated beach and overwash areas from March 1 through September 1. Management actions would result in local short-term minor to moderate adverse impacts.
	Management actions would have local short-term adverse impacts to endangered species but are minimized through seasonal closures and section 7 consultations. The continued loss of coastal wetlands would cause habitat loss and a decrease food supply for piping plovers. Management actions would result in local minor-to-moderate adverse impacts.	Impacts to endangered and sensitive plants and animals are expected to be greater than Alternative A, but are minimized through actions discussed in alternative A. Disturbance to endangered or sensitive plants and animals are minimized by following bald eagle management guidelines and completing section 7 consultations. Prohibiting dog walking minimizes or eliminates adverse impacts from dogs. If sediment quality standards and time in year restrictions are utilized, they can minimize any adverse impacts of the use of dredged material. Management actions would result in local short-term minor-to-moderate adverse impacts	Potential impacts from non-hunting public uses are similar to alternative A. Hunting is expected to cause more impacts to endangered species than in alternative A, but less than alternative B.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Waterfowl	Passive conversion of freshwater impounded habitats to salt marsh will decrease the effective land-base of moist-soil seed yields and refugewide annual moist-soil production available for migrating and wintering waterfowl.	Eliminating adulticides may have indirect beneficial impacts by providing a food resource. Eventual salt marsh restoration will reduce freshwater impounded habitats, which will decrease the effective land-base of moist-soil seed yields and refugewide annual moist-soil production available for migrating and wintering waterfowl. However, restored salt marsh will provide alternate waterfowl habitat in its place, especially for American black duck. The increased usage of sanctuaries will also benefit waterfowl. Management actions would result in local minor-to-moderate beneficial impacts.	Maintaining the freshwater impoundment systems maximizes production of moist-soil plants on 4,200 acres for waterfowl foraging foods. The use of sanctuaries and moist-soil management coupled with water level management increases the carrying capacity of refuge wetland habitats to sustain high numbers of migrating and wintering waterfowl 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 involves the use, as approved, of glyphosate-tolerant corn and soybeans. This is considered more environmentally friendly than other herbicide technologies employed by farmers. Management actions would result in local short-term moderate beneficial impacts.
Shorebirds	There will be benefits from managing, enhancing and protecting barrier beach island and coastal salt marsh habitats, created through natural overwash processes, for piping plover and breeding American oystercatcher, least and common terns and migrating and wintering shorebird species. During the transitional phases to salt marsh may, for the short term increase, habitat availability for other breeding and migrating shorebirds. Management actions would result in local short-term and long-term minor-to-moderate adverse impacts.	Eliminating adulticides may have indirect beneficial impacts by providing a food resource. Proactive predator control would likely increase the productivity and numbers of State and federally endangered shorebird species that attempt to breed in available areas. Improved protection of beach habitats would also provide improved foraging and resting opportunities for spring and summer migrating shorebird species using these habitats. Through salt marsh restoration, there will be benefits from managing, enhancing and protecting barrier beach island and coastal salt marsh habitats, created through natural overwash processes, for piping plover and breeding American oystercatcher, least and common terns and migrating and wintering shorebird species. During the transitional phases to salt marsh may, for the short term increase, habitat availability for other breeding and migrating shorebirds. Management actions would result in local short-term and long-term minor-to-moderate beneficial impacts.	Moist-soil management assists with meeting the needs of shorebirds by providing protein rich foods during egg-laying, migration, and molt. Management actions would have local minor-to-moderate beneficial impacts Eliminating adulticides may have indirect beneficial impacts by providing a food resource. Same as alternative B.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Shorebirds (cont.)	Use of mosquito adulticides and larvicides on barrier beach island habitats increases disturbance and potentially has indirect adverse impacts on shorebird condition and survival through direct impacts on invertebrate food resources during critical breeding and migration periods. No predator control and lack of proactive habitat protection on barrier beach island habitats during critical breeding and migrational shorebird periods in the spring, summer, and fall reduces availability of quality habitats for shorebird use. The absence of proactive restoration, such as is proposed in alternative B, may result in a higher ratio of open water in impounded wetland areas under alternative C. The potential for visitors to directly disrupt birds that are resting or foraging near water or disturb their nests can occur. Seasonal area closures, particularly along sensitive beach areas, and requiring dogs on leashes minimize disturbance. Management actions would result in local short-term and long-term minor adverse impacts.	Elimination of adulticides and other mosquito chemical use restrictions in freshwater wetland habitats and along beach strand habitats would reduce disturbance and mitigate adverse impacts on non-target insect food resources and aquatic food webs along barrier beach island and impoundment habitats. 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. Impacts to shorebirds are expected to increase from alternative A, with an expansion of public use opportunities. Impacts are expected to be minimal. Seasonal closures in sensitive areas and eliminating dog walking on the refuge will minimize disturbance. Management actions would result in local short-term and long-term minor adverse impacts.	Hunting is expected to cause more impacts to shorebirds than in alternative A, but less than alternative B. All other recreation is expected to cause similar adverse impacts as in alternative A. Management actions would result in local long-term minor-to-moderate adverse impacts.
Landbirds	Improved forest interior conditions may develop passively over a long time, rather than as a result of active silvicultural management. To the extent there is an increase in salt marsh acreage through passive return of tidal flow 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. Management actions would provide local short-term minor impacts.	In addition to alternative A, phasing out an additional 600 acres of farming acres has the continued and long-term beneficial impacts for area-sensitive landbirds. Benefits include greatly improved forest interior conditions for breeding forest landbirds through silvicultural management of refuge upland/wetland habitats. Adding more acres of grassland (~ 164) and early successional shrubland acreage (~ 234 acres) will benefit early successional-dependent landbird species. Proactive habitat management and restoration actions will increase landbird breeding potential and improve migrational and wintering foraging habitats with long term benefits of contributing to State and regional landbird population objectives. Direct beneficial impacts on targeted breeding landbirds, proactive habitat management of upland and wetland forests, maritime shrub, maritime forest, and early successional shrub and grassland habitats, and the maintenance and enhancement of biological integrity, diversity, and environmental health of salt marsh habitats, will also have direct beneficial impacts on other landbird species migrating to and wintering on the refuge. In addition, forested landbirds would also benefit by the expansion of the widths of forested riparian and wetland buffer zones and reap direct and long-term benefits from forest stand improvement on 775 acres.	Protection and conservation of existing 775 acres of mature mixed hardwood forested areas, 1,238 acres of forested wetland areas, and 2,200 acres of salt marsh habitats are beneficial to breeding, migrating, and wintering landbirds. However, fields managed through farming do not provide valuable landbird habitat. Protection and conservation of existing salt marsh are beneficial to sensitive salt marsh obligate passerines.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Landbirds (cont.)		An increase in salt marsh acreage through restoration would benefit high priority tidal creek and saltmarsh-dependent species, such as saltmarsh sharp-tailed sparrows, seaside sparrows, and willet. Forest management actions to increase patch sizes with a greater diversity of species composition and structure of existing forest stands, reducing forest fragmentation by reforestation of certain areas, and improving forest health and biological integrity of existing forest stands will have beneficial long-term impacts on focal forest management bird species. The use of dredged material for active restoration would restore open water habitat to wetlands, providing a more diverse and stable habitat. Important stopover habitat would be created or restored for migratory birds. Management actions would result in local minor-to-moderate beneficial impacts.	

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Landbirds (cont.)	Possible loss of forested wetland acreage with increasing saltwater intrusion into forested wetland habitats in Unit III, and adverse impacts to wetland-dependent birding landbirds. Visitor activities and facility improvements have the potential to disturb birds. Off-trail visitor use has the greatest potential to impact nesting birds, but the extent of disturbance depends on vegetation density and visibility, and on species-specific responses to human presence. To minimize that impact, visitors are limited to trails. Maintenance or construction activities would displace birds temporarily, but we would avoid sensitive areas during the nesting season Upland bird hunting results in the direct removal of individuals, but annual seasons and harvest are set by the Delaware Division of Fish and Wildlife and would not jeopardize population viability. Hunting is negligible to non-hunted migratory birds because the hunting season does not coincide with the nesting season. Hunting, especially when dogs are present, results in the direct, short-term disturbance of resident upland birds and other wildlife. Management actions would provide local long-term minor-to-moderate impacts.	Temporary adverse impacts, particularly on migrating and wintering landbird species would result from setting back succession and maintaining grassland and shrubland habitats. Forest interior birds that require an open understory may be negatively impacted by selective harvesting practices. 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. 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. Indirect impacts from visitor activities would increase from those activities described under alternative A. Impacts will be minimized by requiring visitors to stay on designated new trails. Increased hunting opportunities, particularly with turkey hunting during April and May, will increase disturbance to nesting landbirds; however impacts are expected to be minimal due to the small number of permitted hunters. Turkey hunting results in the direct removal of individuals, but annual seasons and harvest are set by the Delaware Division of Fish and Wildlife and would not jeopardize population viability. Refuge and State staff would assess turkey populations on the refuge to determine if a huntable population exists. Management actions would result in local short-term minor adverse impacts.	Loss of 600 acres of potential native forest or early successional habitats to cooperative farming that would be unavailable for focal breeding grassland, shrubland-dependent, or forest-interior dwelling landbird species and migrating and wintering landbirds. 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. Potential impacts from non-hunting public uses are similar to alternative A. Hunting is expected to cause more impacts to landbirds than in alternative A, but less than alternative B. Management actions would provide local long-term minor-to-moderate adverse impacts.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Secretive Marsh and Waterbirds	Increase in foraging areas with the increase in open water, although increased water depth may decrease food availability.	Breeding birds would be more severely impacted than migrating and wintering birds. Clapper rail and willets would benefit from salt marsh restoration. Reestablished tidal flow would provide food resources for waterbirds. Seasonal or area closures reduce disturbance. Management actions would result in long- term local minor beneficial impacts.	Using water level management techniques to create appropriate habitat structural conditions and enhance the annual production of invertebrates and fish, benefit focal breeding secretive marsh bird species. Quality foraging wetland habitats also benefit migrating and wintering secretive marsh and waterbird species. Management actions would result in short-term local minor beneficial impacts. Management actions would result in local minor beneficial impacts.
	The potential for anglers and wildlife observers to directly disrupt birds that are resting or foraging near water, disturb their nests, and leave debris that they can ingest or entangle themselves can occur. Seasonal or area closures minimize disturbance impacts. Management actions would have local minor-to-moderate adverse impacts.	Salt marsh restoration would adverse impact freshwater species such as bitterns and sora. Impacts for fishing, wildlife observation, and photography would increase from alternative A. Impacts are expected to be negligible. We would restrict access to designated areas, provide seasonal closures, and increase outreach and education. Management actions would result in short-term local adverse impacts.	Management actions would provide unfavorable habitat for salt marsh species such as clapper rail and willet. Potential impacts from non-hunting public uses are similar to alternative A. Impacts for fishing, wildlife observation/ photography would increase from alternative A. Impacts are expected to be negligible. We would restrict access to designated areas, provide seasonal closures, and increase outreach and education. Management actions may result in local long-term adverse impacts with the increase in open water.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Fisheries	Loss of Unit II and Unit III freshwater habitats as they convert to salt marsh will increase refuge marine invertebrates needed to sustain more salt marsh fishery resources and decrease refuge freshwater fisheries resources. Management actions would result in local long-term minor-to-moderate beneficial impacts.	Same as alternative A, plus improve and expand water quality monitoring and habitat management actions to increase water circulation and water level management capability within freshwater impounded habitats. These actions improve foraging and breeding habitats for focal fish species that include river herring (alewife and blueback herring), elvers, and striped bass, and benefit other recreational fish species. Salt marshes provide critical nursery habitat for fish and shellfish. Increased tidal flushing into impounded areas may increase water-column aeration, reduce summertime oxygen stress, and promote survival of all aquatic animals including the migratory river herring. The return of tidal flow and creation of creeks during the restoration of salt marshes in the Delaware Bay provided an immediate, dramatic increase in fish species diversity and abundance, particularly by resident and transient young-of-year fish species that once again have access to the marsh area. The movement, habitat use, and diet composition of striped bass in restored salt marshes were similar to reference salt marshes, signifying the importance these restored sites in the management of commercially important large predators in the Delaware Bay. Changes in mosquito IPM practices and strategies, with elimination of adulticide and prescribing additional thresholds for larvicide use, will improve the BIDEH of fisheries resources by providing additional protection to aquatic adult and larval insect species and other non-target invertebrates that are critical to maintaining healthy food webs for fish. Management actions would result in short-term minor-to-moderate beneficial impacts and long-term moderate local and regional beneficial impacts.	Continue refuge fisheries management by maintaining fish weir passages in Units II and III water control structures, which allow unimpeded passage of river herring and other anadromous fish species. Conduct area and seasonal closures and ditch cleaning in impoundments with direct benefits of improving oxygen content, water circulation, and water quality, as needed, to conserve priority fish resources of concern. Upstream freshwater systems provide spawning habitat for anadromous fish such as adult alosids (shad and river herring), for semi-anadromous fish such as white perch, and as nursery habitat for juvenile fish Management action would result in local long-term minor-to-moderate beneficial impacts.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Fisheries (cont.)	Use of mosquito adulticides and larvicides has potentially adverse indirect impacts on fisheries resources because they are toxic to the aquatic invertebrates that sustain robust food webs. An open-water, shallow habitat (extension of the Delaware Bay), would have local long-term minor-to-moderate adverse impacts to the fisheries component of the BIDEH on the refuge. The inability of emergent wetland species to colonize due to lack of substrate and excessive water depths therefore, would not provide the necessary cover utilized by fisheries resources. Loss of freshwater marsh habitat would result in a decline in abundance of freshwater fish species. Adverse impacts of the refuge fishing program include deliberate introductions of non-native fish, and accidental introductions of invasive plants, pathogens, and exotic, invasive invertebrates. We will continue enforcement, outreach, and education to explain the impacts of those introductions. State regulations for fishing would be adhered to, which establish species and harvest limits to insure no cumulative impact on any fish populations. Management actions would result in local long-term minor adverse impacts.	Salt water intrusion into freshwater marshes may result in direct mortality or stress on freshwater fish species due to increased salinity. During the marsh restoration process, short-term minor adverse impacts may occur when a thin layer of silt is applied to the marsh surface, potentially causing an increase in the suspension of sediments and affecting the BOD on fisheries resources. Short-term minor to moderate direct adverse impacts to certain fish species may occur in restored marshes if these fish become restricted to areas of low dissolved oxygen and elevated temperatures. Fishing impacts will increase from those described under alternative A, and new opportunities in Goose and Flaxhole Ponds and night fishing at Fowler Beach would create the potential for those direct and indirect impacts to fisheries in the new areas. We will continue to work with DEDFW on outreach, education, and law enforcement. Requiring catch and release regulations and the mandatory use of barbless hooks in Turkle Pond, Fleetwood Pond, Goose Pond, Flaxhole Pond, and Prime Hook Creek will decrease fish injury and mortality. Increased deer and waterfowl hunting on Prime Hook Creek and Unit III impoundments will cause increased suspension of bottom sediments from boat motors. Management actions would result in short-term minor-to-moderate adverse impacts.	Diking and drainage of impounded freshwater marshes may degrade water quality, release acidity and metals, cause summertime oxygen depletions and fish kills, and thereby further reduced finfish populations Potential impacts from fishing are similar to alternative A. Hunting is expected to cause more impacts to fisheries than in alternative A, but less than alternative B. Management actions would result in a local long-term minor-to-moderate adverse impacts.
Mammals	Passive reforestation will increase DFS habitat and help sustain population viability for the long term. Increased forest cover also benefits bat species that gain increased roosting and brood rearing habitats. Along riparian buffer zones, increased forest cover benefits otter, mink, weasel, and beaver. Grassland and shrubland that develop naturally have direct benefits for many mammal species. Management actions would result in short-term and long-term minor-to-moderate direct beneficial impacts.	Same as alternative A, plus afforestation projects will increase DFS habitat and help sustain population viability for the long term. Increased forest cover also benefits bat species that gain increased roosting and brood rearing habitats. Along riparian buffer zones, increased forest cover benefits otter, mink, weasel, and beaver. Grassland and shrubland maintenance and enhancement has direct benefits for voles, moles, shrews, mice, rabbits, groundhogs, and deer. Carnivores and omnivores such as fox, skunk, mink, long-tailed weasel, coyote, opossum, and raccoon will thrive in ecotone areas between field and forest. Management actions would result in short-term and long-term minor-to-moderate direct beneficial impacts.	Continue strategies and management actions to conserve and maintain biological integrity, diversity, and environmental health of refuge habitats that have direct benefits for mammal population on the refuge. Controlling invasive and nuisance species, restoring native plant communities where appropriate, and improving habitat conditions for the endangered DFS, are conservation actions that have short-term, long-term and cumulative impacts benefiting mammalian populations on the refuge. Management actions would result in indirect long-term minor-to-moderate beneficial impacts.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Mammals (cont.)	Deer or small game hunting results in the direct removal of individuals, but annual seasons and harvest are set by the Delaware Division of Fish and Wildlife and would not jeopardize population viability. Hunting benefits the health of the remaining individuals, and benefits species negatively affected by deer overbrowsing. Hunting for deer or small game, especially when dogs are present, results in direct, short-term disturbance of other resident mammals. The presence of humans will disturb most mammals, which typically results in a temporary displacement without long-term effects on individuals and populations. Management actions would contribute negligible short-term, site-specific, local, and regional, adverse impacts on hunted and non-hunted species.	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 mammals from suitable nesting and brood rearing habitat. The removal of a few individual mammals from such localized areas would have a negligible adverse impact on the population as a whole. Maintenance activities such as brush-hogging and burning prescribed fires carry a direct risk to some individuals among small mammals, but the adverse impacts are short-term and negligible. Negligible to indirect adverse minor impacts are expected due to the removal of protective cover, which exposes small rodents and rabbits to predation or cold if in the winter. Indirect impacts from visitor activities would increase from those activities described under alternative A. Impacts would be minimized by requiring visitors to stay on designated new and existing trails. Direct hunting impacts would be similar to alternative A for small game; however, the deer harvest is expected in increase. Increased hunting opportunities, particularly with turkey hunting during April and May, will increase disturbance to mammals; however, impacts are expected to be minimal due to the small number of permitted turkey hunters. Management actions in alternative B would result in negligible to short-term indirect minor adverse impacts.	Impacts to mammals from hunting will be similar to alternative B and impacts from other public use will be similar to alternative A.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Amphibians and Reptiles	This alternative provides the habitat improvements beneficial for herpetiles, through passive conversion of upland fields to natural vegetation: • Maintaining, enhancing, and restoring native forest cover • Maintaining and protecting downed woody debris in forest floor • Decreasing forest fragmentation and creating connecting corridors • Enhancing connectivity between upland and wetland areas • Restoring natural surface and ground water hydrology in prior converted wetlands	This alternative provides the most habitat improvements beneficial for herpetiles through active restoration: • Maintaining, enhancing, and restoring native forest cover • Maintaining and protecting downed woody debris in forest floor • Decreasing forest fragmentation and creating connecting corridors • Enhancing connectivity between upland and wetland areas • Restoring natural surface and ground water hydrology in prior converted wetlands Elimination of adulticides and improved mosquito IPM strategies should provide direct benefits on wetlands and on reptiles and amphibians. The refuge will maintain connectivity between wetlands and upland forest habitats that serve as travel corridors for herpetiles. In impounded wetlands, newly restored brackish/saline wetland habitat will likely be colonized by the State-listed northern diamondback terrapin. Management actions would result in local, long-term minor-to-moderate beneficial impacts.	Protecting or improving conditions of existing mixed hardwood communities for DFS, wetland forest habitats, and freshwater marsh areas, also provides habitat for numerous amphibian and reptile species of interest. Shallow lotic areas and vernal pool habitats shaded by canopy trees are crucial breeding sites from February to late summer and for over-wintering amphibians. Maintenance of grassland and shrubland habitats provides direct benefits for reptiles and to a lesser extent for amphibians. Management of Unit II and Unit III wetlands as freshwater impoundments would have a moderate beneficial impact on a number of amphibian species that prefer freshwater wetlands. Management actions would result in short-term local minor-to-moderate beneficial impacts. Elimination of adulticides and improved mosquito IPM strategies should provide direct benefits on wetlands and on reptiles and amphibians.
	Use of mosquito adulticide and larvicides will have direct adverse impacts on aquatic and terrestrial invertebrates (including mosquitoes) and non-target insects, posing indirect adverse impacts for reptiles and amphibians. High salinities from saltwater intrusion render the wetlands inhabitable to most herpetiles. Visitor activities and improvements have the potential to disturb amphibians and reptiles. Roads and trails may create barriers or hazards to movement. Use of roads and trails by visitors may disturb species along those corridors. Those impacts are localized, concentrated in size and distribution, and relatively insignificant when considering the extent of all refuge land. Management actions would result in long-term local minor-to-moderate adverse impacts.	Salt marsh restoration may have minor-to-moderate adverse impacts on individual reptiles and amphibians (mortality) if they are not capable of emigrating upstream to areas with reduced salinities. Indirect impacts from visitor activities would increase from those activities described under alternative A. Impacts will be minimized by requiring visitors to stay on new and existing trails. Impacts from hunters are expected to be negligible because colder weather during the hunting season limits the activity of amphibians and reptiles. Management actions would result in local minor-to-moderate beneficial impacts.	Freshwater impoundments provide suitable habitat for many herpetiles, amphibians in particular. The refuge farming program may result in moderate local long-term adverse impacts. The use of such herbicides has been associated with adverse impacts on amphibians. Potential impacts to amphibians and reptiles from public uses will be greater than alternative A, but less than alternative B. Impacts are expected to be negligible.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Invertebrates	In the absence of proactive restoration of salt marsh habitat, the benefits of salt marsh for certain invertebrates will not be realized as quickly or possibly to the same extent as under alternative B. Management actions will have moderate local, long-term beneficial impacts.	Increased restoration and maintenance of grassland, shrubland, and forested habitats will significantly increase refuge coverage of native plants for pollinating, herbivorous, and predatory invertebrates that provide ecological services and provide principle nutrition and food resources for migratory birds, fish, reptiles, amphibians, and mammalian species. An important direct benefit for refuge invertebrate populations is the removal of the cooperative farming program and conversion to native plant communities. Beach overwash processes would be permitted to occur unimpeded in alternative B, having a beneficial impact on invertebrates that utilize the intertidal area. Surf zones and tidal inlets are important nursery and foraging areas for fishes and waterbirds because of high densities of invertebrates. Restoration of salt marsh in impounded wetlands will benefit invertebrate species that favor salt marsh though the shift in invertebrate species composition may lag behind the shift in vegetation communities by a decade or more. Eliminating adulticides, and modifying mosquito IPM strategies and actions to further support the limiting of direct mortality to refuge insect populations, will benefit pollinator insect species, rare insects, and other non-target invertebrates, thereby providing a larger, potentially more diverse food base for migrating and breeding shorebirds, landbirds, secret marsh birds, waterfowl and other wildlife. Management actions would, overall, result in moderate local, long-term beneficial impacts.	Continued water level management will maintain and enhance annual invertebrate production (especially benthic macroinvertebrates). Continued habitat management of native plant communities will benefit the invertebrates dependent on those communities. These benefits to invertebrates will benefit the migratory birds, fish, and other resident wildlife, which depend on invertebrate food resources. Management actions would result in local minor beneficial impacts.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Invertebrates (cont.)	Use of mosquito adulticide and larvicides will have direct adverse impacts on aquatic and terrestrial invertebrates, including mosquitoes and non-target insects, posing potential long-term indirect adverse impacts to the ecological systems that support the refuge at lower trophic levels Management actions will result in minor local short-term adverse impacts.	Prescribed fire can have adverse impacts on invertebrates. The difference between causing beneficial or adverse impacts to invertebrates from mowing as a habitat management strategy is based on timing, scale, and techniques used. To minimize adverse impacts from mowing and allow sufficient space and time for pollinator populations to recover, mowing a mosaic of patches over several years is better than mowing all habitats at the same time, and no single areas should be mowed or burned more than once a year. It is expected that due to the sheer volume of invertebrates, populations adversely impacted by any shoreline or wetland sediment manipulation would recolonize and recover quickly. Continued use of Bti and methoprene on the refuge will result in the intended temporary reduction in larval mosquito density, and a subsequent temporary local reduction in gross numbers of adult mosquitoes and potential shift in mosquito diversity. There may be a temporary adverse impact on both aquatic non-target invertebrate density and diversity, as well as adult non-target invertebrate density and diversity, e.g., chironomids, dragonflies. The Service recognizes that spray drift will likely enter the refuge from the three neighboring barrier island communities during mosquito control on those lands. Since the State employs best management practices, and follows the EPA approved label, the Service expects impacts to refuge resources to be negligible. Management actions would result in local short-term adverse impacts.	The State of No direct impacts of glyphosate resistance transgenes in plant material have been found on insects. Management actions would result local short-term and long-term minor-to-moderate adverse impacts. Delaware will still be permitted the limited use the larvicides Bti and methoprene, thus would still result in the adverse impacts to invertebrates.

Resources	Alternative A Current Management	Alternative B Service-Preferred Alternative	Alternative C Historic Management
Public Use and Access	We would continue to maintain the existing programs for all six priority public uses. Demand would continue to be satisfied for all but interpretation and environmental education. No major conflicts among visitors engaged in respective wildlife dependent uses or programs. Implementing public access closures, for either wildlife protection (some seasonal/temporary) or to reduce user conflicts, would continue and may inconvenience some visitors Impacts and opportunities associated with hunting would not change.	There would be enhanced interpretation and environmental education opportunities and therefore impacts under alternative B with the proposed expansion of the existing visitor contact station and refuge office, which would help the refuge satisfy demand. Plans to open previously closed refuge units to certain activities, such as hunting and wildlife observation, will increase visitor use, as well as the opportunity to conduct outreach and raise appreciation of the refuge and Refuge System. Increased visitation coupled with expanded programs might increase likelihood of conflicts among visitors, especially if certain activities require closing off areas of the refuge to others. Increased outreach and enforcement presence over time would also reduce violations. Area closures to protect wildlife would continue to inconvenience some visitors. Expanded opportunities and new approaches to the hunting program (blind sites, preseason drawings, etc.) will provide quality hunting experiences, while reaching a different public.	Impacts for environmental education and interpretation would be increased from alternative B. Fishing, wildlife observation, and photography opportunities are similar to alternative A. Hunting opportunities for deer and waterfowl are the same as alternative B, except the number of days and areas are decreased. Turkey hunting is closed and upland game and webless migratory bird hunting are the same as under alternative A.
	Under all alternatives, we would continue to provide compatible wildlife-dependent activities that can be supported with respective staff and budget projections. We would maintain our infrastructure to support those activities and provide safe access. We would continue to conduct outreach to visitors and the local communities to instill an appreciation of the Refuge System and the refuge, its resources, and our priorities for management.		