PHASE I AVIAN RISK ASSESSMENT

University of Delaware Wind Turbine Project

Sussex County, Delaware

Report Prepared for:

University of Delaware

January 2010

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Phase I Avian Risk Assessment

University of Delaware Wind Turbine Project

Sussex County, Delaware

Executive Summary

The University of Delaware is proposing to construct a single, utility scale wind turbine at its campus in Lewes, Sussex County. This turbine will likely have a hub height of about 80 m (262 feet) above ground level (agl) and a rotor diameter of about 90 m (295 feet). Thus, the rotor tip would sweep as high as about 125 m (410 feet) agl, and as low as about 35 m (115 feet) agl. The turbine would be mounted on a steel tubular tower and would probably be lit with an L-864 flashing-red light (Federal Aviation Administration [FAA]) mounted on the nacelle at a height of about 82 m (269 feet) agl. The electrical line from the turbine would likely be underground, connecting to an above ground distribution line nearby.

This report details a Phase I Avian Risk Assessment of the University of Delaware Wind Turbine Project (hereafter referred to as the "Project"). Its purpose is to determine the potential for displacement and collision impacts to birds from the construction and operation of the Project. The risk-assessment is informed by: 1) a site visit, 2) a literature search, and 3) written consultations with the U.S. Fish and Wildlife Service (USFWS) and the Delaware Division of Fish and Wildlife (DDFW) regarding special-status species[1] and other wildlife concerns.

The wind turbine would be constructed in flat terrain on what appears to be barren fill bordering a 10-acre (4-ha) patch of disturbed shrubby woodland. An extensive salt marsh of many hundreds of acres is about 200 feet (60 m) from the turbine base. Tidal creeks and rivers are found within 0.5 miles (0.8 km) of the Project site, notably, Canary Creek to the west, the Broadkill River to the north, and the Lewes and Rehoboth Canal to the east. These creeks and rivers connect to Delaware Bay through the Roosevelt Inlet, located about 0.5 miles (0.8 km) north of the site. Cape Henlopen and the Atlantic Ocean are located about 4 miles (6.4 km) east of the site.

The site visit's assessment of habitat and analyses of Breeding Bird Atlas (BBA) and Breeding Bird Survey (BBS) data indicate that no Delaware-endangered species is expected to nest in the vicinity of the proposed turbine, but a number of endangered species may forage near or fly in the vicinity of the turbine. These include Black-crowned Night-Heron, Yellow-crowned Night-Heron, Bald Eagle, Northern Harrier, American Oystercatcher (also *Yellow WatchList*), Common Tern, Forster's Tern, Least Tern (also federally endangered and *Red WatchList*), and Black Skimmer (also *Yellow WatchList*). Species of Greatest Conservation Need (SGCN) foraging or flying near the proposed turbine during the breeding season would be limited to raptors, saltmarsh specialists, and shrubland/edge species. These Black Vulture, Osprey, Red-shouldered

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[1] These would be species listed federally and in Delaware as endangered or threatened, and species featured in the Delaware Wildlife Action Plan (DWAP) as Species of Greatest Conservation Need (SGCN, tiers 1 and 2). We also track *WatchList* species; see the discussion in Section 4.1.

Hawk, Peregrine Falcon, and Barn Owl among raptors; American Black Duck, Clapper Rail (*Yellow WatchList*), Willet, Marsh Wren, Saltmarsh Sparrow (also *Red WatchList*), Seaside Sparrow (also *Red WatchList*), and the coastal race of Swamp Sparrow among saltmarsh specialists; and Willow Flycatcher (also *Yellow WatchList*), Eastern Kingbird, Brown Thrasher, Prairie Warbler (also *Yellow WatchList*), Yellow-breasted Chat, Eastern Towhee, Field Sparrow, and Baltimore Oriole among shrubland/edge species.

Regarding migration, songbirds are expected to migrate nocturnally on broad fronts above the Project site, with most birds flying well above the sweep of wind-turbine rotors. In fall migration, however, fallout events may occasionally concentrate night-migrating songbirds in coastal woodland habitats, including the shrubland near the proposed turbine. Given that the Project site is inland and that coastal woodlands and shrublands are well distributed along the Delaware coastal plain, the limited shrubland at the Project site is not expected to attract particularly large numbers of songbird migrants.

Concentrated raptor migration has been documented in fall at Cape Henlopen, with Sharp-shinned Hawk and Osprey (both SGCN-1) most abundant. The Project site is sufficiently inland from Cape Henlopen and barrier beaches to be off the main raptor migration path, but migrating Osprey, Sharp-shinned Hawks, falcons, and other species may hunt in the vicinity of the proposed turbine.

Delaware Bay is of hemispheric importance as a staging site for Ruddy Turnstone (SGCN-1), Red Knot (SGCN-1 and *Yellow WatchList*), Sanderling (SGCN-1 and *Yellow WatchList*), and Semipalmated Sandpiper (*Yellow WatchList*) in spring migration. They mostly forage for horseshoe crab eggs in Delaware Bay, but they also forage and roost in saltmarshes. Nonetheless, given the location of the proposed turbine adjacent to the saltmarsh zone and slightly inland of Delaware Bay and the Atlantic Ocean, it is likely that relatively small numbers of these shorebirds, or other coastally migrating waterbirds, will fly in the vicinity of the turbine.

Christmas Bird Count (CBC) data indicate that Snow Geese are extremely abundant winter visitors in the Cape Henlopen-Prime Hook region. As they feed in saltmarshes, they will at times frequent the vicinity of the proposed turbine and probably attract endangered Bald Eagle to prey on them. Northern Harrier (Delaware endangered as a breeder) will also frequent adjacent marshes in winter, and the endangered Forster's Tern may occasionally forage there too.

The Project site is located in the Delaware Coastal Zone, which Delaware Audubon has classified as an Important Bird Area (IBA). The Project site is also located between Prime Hook National Wildlife Refuge and Cape Henlopen State Park, which the American Bird Conservancy (ABC) has classified as IBAs. The IBA descriptions emphasize the importance of Delaware Bay to the special-status shorebirds mentioned above that stage there in spring migration, and to a number of special-status breeders. Nonetheless, the Project site is not located immediately on Delaware Bayshore where the shorebirds concentrate, and it lacks habitats that would attract large numbers of special-status breeding birds.

Regarding displacement risk, biologically significant impacts are not indicated for any species likely to inhabit the Project site and vicinity because the likeliest species have large populations that have withstood significant environmental disturbance. Possible exceptions would be endangered species, because they have small populations and generally require less disturbed habitats. However, data sources indicate that no endangered species is likely to nest close enough to the proposed turbine to be displaced by it.

Regarding collision risk fatality numbers and species impacted are likely to be similar, on a per turbine per year basis, to those found at Eastern U.S. wind farms. Those fatalities are not likely to be biologically significant because they will be distributed among various species. Collision risk to night-migrating songbirds is likely to be similar to other sites examined because migration occurs on broad fronts at altitudes mostly above the rotor-swept zone; in addition, habitat at the Project site is unlikely to attract large numbers of songbirds in coastal fallout events. Collision risk factors for raptors appear to be minimal, given that raptor abundance is generally low, the Project is removed from coastal migration paths, and the topography of the proposed turbine site does not favor habitual soaring. The Project may incur greater waterbird mortality, particularly among gulls, than inland wind farms because of its coastal location. Among listed species, the Delaware-endangered Bald Eagle may be at minor risk of collision risk, a result of the fact that some eagles may hunt Snow Geese and other waterbirds in the saltmarsh near the turbine.

Because the Project will consist of only one turbine, impacts are likely to be minimal and not biologically significant. The basis for this statement is the information gathered during this study combined with the fact that no wind power project in the U.S. has proven to have significant impacts to birds, with the possible exception of a 5,400 turbine project in California. Thus, it is improbable that the University of Delaware single turbine project will result in significant impacts to birds.

The Delaware Natural History and Endangered Species Program (NHESP) has commented on the Project in a letter dated 31 August 2009 from the Delaware Department of Natural Resources and Environmental Control (DNREC) to the University of Delaware. NHESP is on record as saying that this one-turbine Project is a good opportunity to study the impacts of wind energy on birds and bats. It finds the Project site (which we assume to be Location 1) to have the least potential for environmental impacts than five other proposed sites because it is surrounded by less woodland that would attract night-migrating songbirds, it is likely to result in the fewest impacts to adjacent wetlands, and it is distant from suitable nesting and roosting habitat for beach-nesting birds. NHESP requests a plan to reduce and minimize collisions and other threats to birds prior to construction in the event a major impact occurs. The letter does not define "major impacts." It also recommends that the site be studied both pre- and post-construction to assess impacts fully.

The following recommendations are designed to improve the assessment of, and minimize, avian risk.

Pre-construction Studies

- A seasonal flight-use study may be considered, although the project is so small as to make impacts minimal and, therefore, preconstruction studies cannot predict risk precisely or reliably. Such a study would measure flight use of the site (particularly at altitudes equivalent to the rotor-swept zone) by raptors, waterbirds, and landbirds, paying particular attention to the endangered Bald Eagle and other special-status species.

Construction Guidelines

- Electrical lines within the Project site should be underground. Any new above-ground lines from the site to a substation or transmission line should follow Avian Power Line Interaction Committee (APLIC) guidelines for insulation, spacing, and obstruction marking.
- Permanent meteorology towers, if any are proposed, should be freestanding (i.e., without guy wires) to prevent the potential for avian collisions.
- Size of roads and turbine pads should be minimized to disturb as little habitat as possible. After construction, the area around the turbine should be maintained as mowed lawn to facilitate a mortality study.
- Lighting of turbines and other infrastructure should be minimal to reduce potential for attracting night-migrating songbirds and other species. Federal Aviation Administration (FAA) night-obstruction lighting should only be flashing beacons (L-864 red or white strobe [or LED], or red-flashing L-810) with the longest permissible off cycle. Steady-burning (L-810) red FAA lights should not be used. Sodium vapor lamps and spotlights should not be used at any facility (e.g., lay-down area or substation) at night except when emergency maintenance is needed.

Post-construction Studies

- A mortality study following best practices should be conducted over a two-year period, with the second year contingent on what is found during the first year. In other words, if fatalities in the first year are construed as biologically significant, a second year of study would be conducted.
- Results of the mortality study should be compared with cradle-to-grave (life-cycle) cumulative impacts to birds from other types of power generation now supplying electricity in Delaware. This comparison would facilitate long-term planning with respect to electrical generation and wildlife impacts. The study should seek information from USFWS, DDFW, and environmental organizations regarding existing energy-generation impacts to wildlife in Delaware. If information is not available, these agencies and organizations should consider funding such studies.

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Figure 1. Project location in Delaware. Note location of ACUA wind farm discussed in Section 7.2.

Figure 2. Project location in Sussex County.

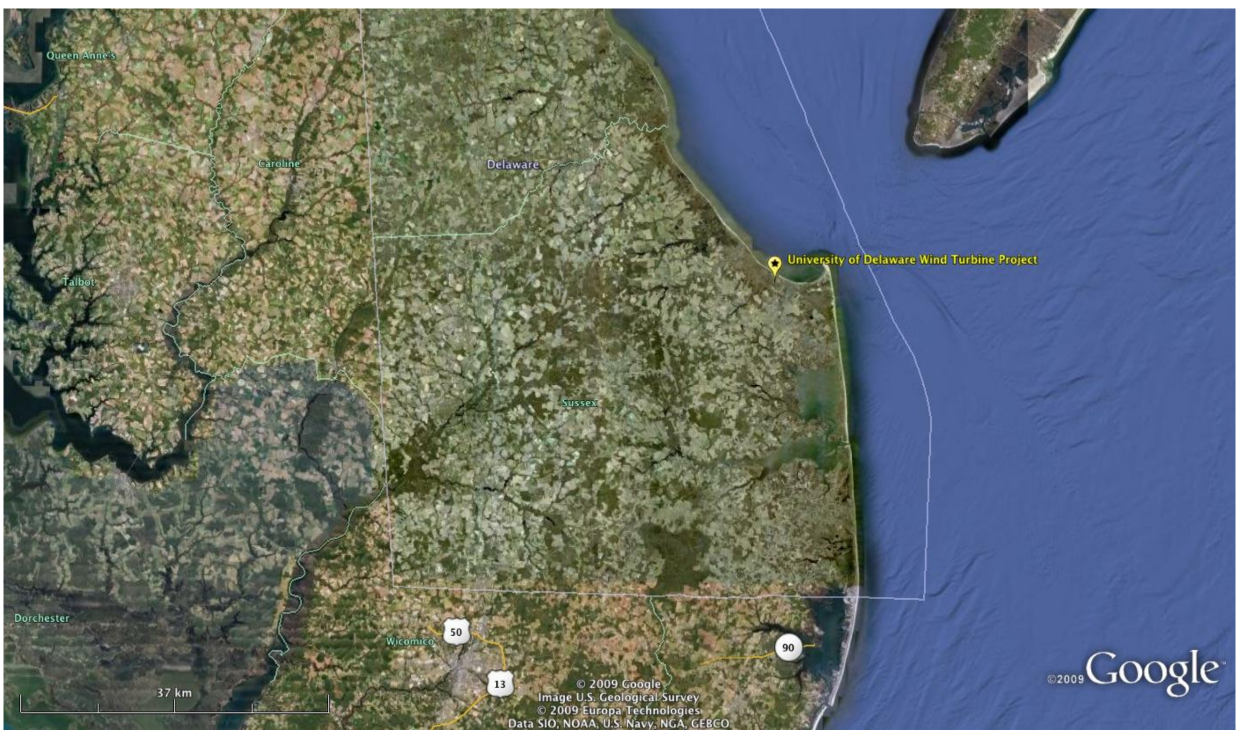
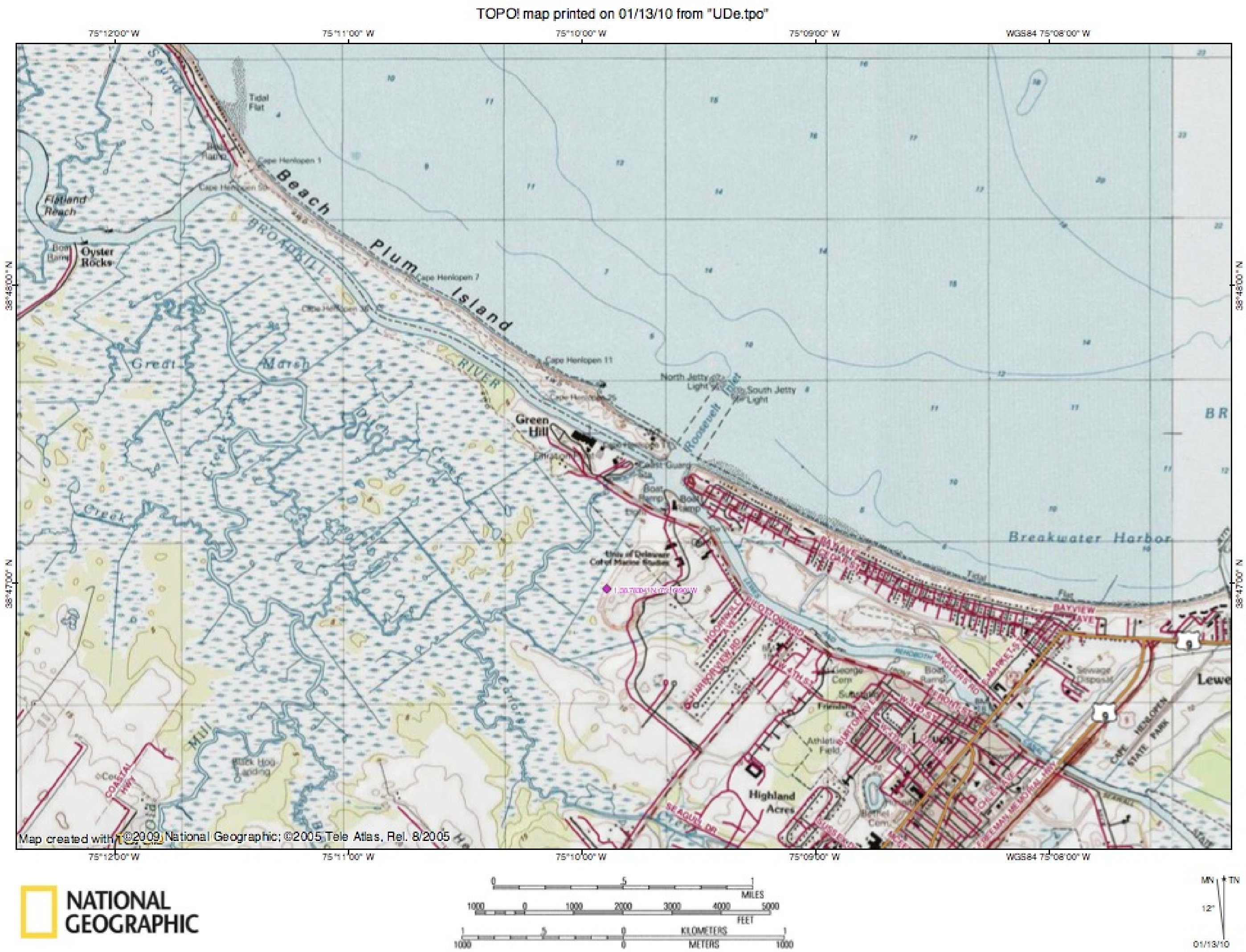


Figure 3. Satellite view of Project site and vicinity.

Figure 4. Topographic map view of Project site.



1.0 Introduction

The University of Delaware is proposing to construct a single wind turbine at its campus in Lewes, Sussex Count (see Figures 1-4). This report details a Phase I Avian Risk Assessment of the University of Delaware Wind Turbine Project (hereafter referred to as the "Project").

The purpose of a Phase I Avian Risk Assessment is to determine potential risk to birds from wind farm construction and operation at a proposed site. Birds are generally at risk of colliding with turbine rotors and of being displaced by construction activities and new, large infrastructure. The Phase I Avian Risk Assessment walks developers, regulators, environmentalists, and other stakeholders through a risk assessment process, including how evaluation of potential impacts may require further study. The process is based on: 1) a site visit, 2) a literature review, and 3) consultations with applicable wildlife agencies. The Phase I also follows relevant guidance for avoiding or minimizing impacts to birds and their habitats as set forth by the U.S. Fish and Wildlife Service (USFWS) in its *Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines* (USFWS 2003).

A field ornithologist skilled in bird identification and habitat evaluation conducts the site visit. This expert tours the site thoroughly by car and on foot recording birds seen or heard and evaluating habitats and topography with special consideration for: 1) federal and state-listed endangered, threatened, and other special-status bird species; and 2) probable avian use during the nesting, spring and fall migration, and winter seasons. The site visit is not intended to be an exhaustive inventory of species presence and use. Nonetheless, it analyzes habitat and topographic features so that a list of species that might conceivably be present at different times of the year can be assembled; thus, potential risk to those birds can be assessed.

The literature review has a number of objectives. One is to profile the seasonal avifauna and determine the likelihood of encountering special-status species. This is accomplished by examining the state's Breeding Bird Atlas (BBA) and Important Bird Area (IBA) program, as well as nearby Breeding Bird Survey (BBS) routes, Christmas Bird Counts (CBCs), hawk watches (available at HawkCount.org), and other relevant databases. Another objective is to reveal what is known about migration patterns, habitat use, and other avian phenomena. Finally, the literature review thoroughly summarizes empirical studies of wind-farm impacts. These empirical findings are the most important tool for assessing risk at prospective wind power facilities.

Consultations are conducted via letter with wildlife agencies – in this case, the USFWS and the Delaware Division of Fish and Wildlife (DDFW) – to request information on listed species at or near the Project site and to document agency concerns. Such consultations sometimes determine the need for additional research (e.g., breeding bird studies, raptor migration studies, etc.) to improve knowledge of avian use for completing the risk assessment.

Based on the process outlined above, this report: 1) summarizes known and likely bird use of the Project site's habitats throughout the year, 2) compares the Project site with wind-energy projects where avian impacts have been determined empirically, 3) determines potential risks that birds may face from the construction and operation of wind turbines at the site, and 4) presents recommendations for additional studies or mitigation, if indicated.

2.0 Project and Site Description

2.1 Project Description

The University of Delaware Wind Turbine Project is proposed for the campus of the University of Delaware in Lewes, Sussex County (Figures 1-4). The University of Delaware proposes to erect one wind turbine. Typically, wind turbines have hub heights of about 80 m (262 feet) above ground level (agl) and rotor diameters of about 90 m (2 feet). Rotor tips would sweep as high as about 125 m (410 feet) agl, and as low as about 35 m (115 feet) agl.

The turbine would be mounted on a steel tubular tower. It would probably be lit with an L-864 flashing red light (approved by the Federal Aviation Administration [FAA]; see guidelines at http://www.windaction.org/documents/7912) mounted on the nacelle at a height of about 82 m (269 feet) agl. The electrical collection line would likely be underground, but the connection to a substation could be above ground.

2.2 Site Description

Satellite imagery viewable through Google Earth Pro, USGS topographic maps viewable through National Geographic's TOPO! mapping software, and various literature sources and Internet sites were consulted in order to understand the Project site's topography, physiography, and land use. This information was checked during a site visit conducted by a field ornithologist on 4 December 2009.

The wind turbine site is located on the Coastal Plain (Hess et al. 2000) at an elevation of about 7 feet (2 m) above mean sea level within 0.5 miles (0.8 km) of Delaware Bay, which i s located to the north. Cape Henlopen and the Atlantic Ocean are located about 4 miles (6.4 km) east of the site. Topography around the site is essentially flat.

The Project site appears to be a manmade upland created by filling saltmarsh. Indeed, it abuts an extensive saltmarsh that extends to the west behind Beach Plum Island, a barrier beach. Tidal creeks and rivers are found within 0.5 miles (0.8 km) of the Project site, notably, Canary Creek to the west, the Broadkill River to the north, and the Lewes and Rehoboth Canal to the east. These creeks and rivers connect to Delaware Bay through the Roosevelt Inlet, located about 0.5 miles (0.8 km) north.

Land use in the vicinity of the Project site is educational (University of Delaware), industrial (filtration plant), and residential (City of Lewes and houses along barrier beach to the east of Roosevelt Inlet). Maps indicate that the Prime Hook National Wildlife Refuge (NWR) approaches within about 2 miles (3.2 km) of the site and includes extensive saltmarshes.

3.0 Results of Site Visit

An experienced field ornithologist visited the Project site on 4 December 2009. He explored the site and vicinity on foot and by car. Photographs in Appendix A show the main habitats and landscape features.

Habitat where the wind turbine would be constructed was dredge spoil/fill. Areas with recent fill were mud with no plant growth. Where there was vegetation, it ranged from dense *Phragmites* and grassy areas to dense shrubby thickets with some larger trees, which were mainly around the perimeter of the site. Extensive saltmarsh was located immediately adjacent to the northwest, west, southwest, and south of the site. Roosevelt Inlet and Delaware Bay were approximately 0.5 miles (0.8 km) north of the site. Canary Creek, a large tidal creek, was located as close as 0.2 miles (0.3 km) west of the site.

Trees and shrubs noted were red cedar (some dense stands), black tupelo, red maple, sassafras, southern red oak, willow oak, hackberry, tulip tree, American holly, black cherry (very common), loblolly pine, pitch pine, persimmon, red mulberry, Osage orange, black willow, wax myrtle/bayberry, winged sumac, marsh elder, and multiflora rose. There were also dense growths of Japanese honeysuckle and greenbriar in some areas.

The site visit took place during late fall migration/early winter and recorded 58 species (see Appendix B for a list). One Delaware endangered species was recorded: Bald Eagle. One Bald Eagle was observed in flight above the site, while three were observed in flight over the adjacent saltmarsh. Two Northern Harriers and one Cooper's Hawk were observed. These species are listed as endangered in Delaware when breeding.

Based on an assessment of available habitat, the following Delaware-endangered species may occur at the Project site or vicinity:

- **Black-crowned Night-Heron:** Could use the site for roosting/nesting, but no old nests noted. It is likely to use the nearby marsh and tidal creeks for foraging.
- **Yellow-crowned Night-Heron:** Could use the site for roosting/nesting, but no old nests noted. It is likely to use the nearby marsh and tidal creeks for foraging.
- **Bald Eagle:** Likely to occur throughout the year, and likely to nest nearby.
- **Northern Harrier:** Could nest in extensive saltmarsh nearby.
- **Cooper's Hawk:** Not likely to nest on site, but could nest in more extensive woods/woodlots south of site.
- **Black Rail (also *Red WatchList*):** Could occur in adjacent saltmarsh.
- **Piping Plover (also federally threatened and *Red WatchList*):** Not likely to occur at site, but known to nest at Cape Henlopen State Park, which is 4 miles (6.4 km) distant.
- **American Oystercatcher:** Could occur in nearby saltmarsh and in flight over site.
- **Upland Sandpiper:** Possible during migration as a fly-over.
- **Common Tern:** Possible as fly-over, and may forage in tidal creeks, saltmarsh, and nearby harbor.
- **Forster's Tern:** Possible as fly-over, and may forage in tidal creeks, saltmarsh, and nearby harbor.

- **Least Tern (also federally endangered and *Red WatchList*):** Possible as fly-over, moving between tidal creeks/marsh, harbor, and Delaware Bay.
- **Black Skimmer (also *Yellow WatchList*):** Could occur along nearby tidal creeks and harbor.
- **Red-headed Woodpecker (also *Yellow WatchList*):** Possible in migration.
- **Sedge Wren:** Possible during migration.
- **Henslow's Sparrow (also *Red WatchList*):** Possible as rare migrant.

4.0 Avian Overview of the University of Delaware Wind Turbine Project Site

The North American Landbird Conservation Plan (Rich et al. 2004) locates the Project site within the New England/Mid-Atlantic Coast Bird Conservation Region (BCR 30). The North American Bird Conservation Initiative (NABCI), describes this BCR as follows (see http://www.nabci-us.org/bcr30.htm):

> This area has the densest human population of any region in the country. Much of what was formerly cleared for agriculture is now either in forest or in residential use. The highest priority birds are in coastal wetland and beach habitats, including the Saltmarsh Sharp-tailed Sparrow and Nelson's Sharp-tailed Sparrow, Seaside Sparrow, Piping Plover, American Oystercatcher, American Black Duck, and Black Rail. The region includes critical migration sites for Red Knot, Ruddy Turnstone, Sanderling, Semipalmated Sandpiper, and Dunlin. Most of the continental population of the endangered Roseate Tern nests on islands off the southern New England states. Other terns and gulls nest in large numbers, and large mixed colonies of herons, egrets, and ibis may form on islands in the Delaware and Chesapeake Bay regions. Estuarine complexes and embayments created behind barrier beaches in this region are extremely important to wintering and migrating waterfowl, including approximately 65 percent of the total wintering American Black Duck population, along with large numbers of Greater Scaup, Tundra Swan, Gadwall, Brant, and Canvasback. Exploitation and pollution of Chesapeake Bay and other coastal zones, and the accompanying loss of submerged aquatic vegetation, have significantly reduced their value to waterfowl.

Curry & Kerlinger has not yet received responses from the USFWS and DDFW to our written inquiries about records of listed species in the Project vicinity. When they are received, they will be found in Appendix D and summarized here. Nonetheless, the Delaware Natural Heritage and Endangered Species Program (NHESP) of the DDFW has commented on the Project in a letter dated 31 August 2009 from the Delaware Department of Natural Resources and Environmental Control (DNREC) to the University of Delaware. In this letter, six proposed turbine locations were evaluated. Location 1 was NHESP's preferred site for the wind turbine. The turbine site would be 600 feet south of this location.

The NHESP acknowledged that a small-scale (one-turbine) project presents an opportunity to study the impacts of land-based, coastal wind turbines on birds and bats in Delaware. It did not have any significant concerns for migratory shorebird impacts, but some proposed turbine locations (not Location 1) were discouraged because they were near nesting sites of Delaware-endangered Least Terns (also *Red WatchList*) and American Oystercatchers. Regarding night-migrating songbirds, the NHESP acknowledged that mortality from a single turbine was not likely to have any population-level effect. Moreover, it found that migrant songbirds were unlikely to concentrate around proposed turbine sites because there was little woodland habitat to attract them. Migratory raptors were a concern, however, because the coastline serves as a leading line for several species, particularly falcons and Osprey. Negative population impacts to waterfowl populations were deemed unlikely.

In the recommendations section of the above letter, NHESP reiterated that the Project is a good opportunity to study the impacts of wind energy on birds and bats. Its preferred site would be Location 1, which is surrounded by less woodland that would attract night-migrating songbirds, would most likely result in the fewest impacts to adjacent wetlands, and is distant from suitable nesting and roosting habitat for beach-nesting birds. NHESP did point out, however, that a plan to reduce and minimize collisions and other threats be developed prior to construction in the event a major impact occurs. It also recommended that the site be studied both pre and post-construction to assess impacts fully.

A seasonal look at the avifauna likely to occur at the University of Delaware site follows.

4.1 Breeding Birds

Table 4.1-1 summarizes the DDFW and USFWS lists of endangered and threatened species. Given their high conservation status, these species have been given particular attention in assessing avian risk at the Project site. Based on the site visit and other data sources (see below), Table 4.1-1 also grades the suitability of Project site's habitats for nesting.

DDFW has also approved the *Delaware Wildlife Action Plan, 2007-2017* (Allen et al. 2006; http://www.dnrec.state.de.us/nhp/information/dewaptoc.shtml). In addition to the 24 endangered species listed above, the Delaware Wildlife Action Plan (DWAP) lists an additional 123 avian species as Species of Greatest Conservation Need (SGCN), of which 24 are assigned to Tier 1 and 99 are assigned to Tier 2, with Tier 1 indicating a greater conservation priority. Where these species are encountered in data sources, they are indicated as SGCN-1 and SGCN-2.

In addition, some Delaware endangered and SGCN species are also included in the recently published *2007 WatchList for United States Birds* (Butcher et al. 2007). Developed collaboratively by Audubon and the American Bird Conservancy (ABC), the *WatchList* highlights all the highest priority birds for conservation in the United States. It is based on the species assessment methodology that Partners in Flight (PIF; see Rich et al. 2004) has employed to rate the conservation status of landbirds. Audubon and ABC have taken PIF's standards and applied them to the other bird groups.

The *WatchList* is divided into two categories: 1) *Red WatchList: Highest National Concern* (59 species, including Black Rail, Piping Plover, Least Tern, and Henslow's Sparrow on the Delaware endangered list) and 2) *Yellow WatchList: Declining or Rare Species* (119 species, including Black Skimmer, Short-eared Owl, Red-headed Woodpecker, Cerulean Warbler, and Swainson's Warbler on the Delaware endangered list). Some SGCN species are also on the *WatchList*, as are some non-SGCN species. *WatchList* species will be indicated when they are encountered in the data sources checked for this report.

Table. 4.1-1. Habitat suitability for nesting by Delaware endangered species

Delaware Endangered[1]	Recorded in BBA?	Recorded in BBS?	Habitat Suitability for Nesting?[2]
Pied-billed Grebe	Yes	Yes	NS
Black-crowned Night-Heron		Yes	MS?
Yellow-crowned Night-Heron			MS?
Bald Eagle	Yes	Yes	NS
Northern Harrier	Yes	Yes	NS
Cooper's Hawk	Yes	Yes	NS
Black Rail (*Red WatchList*)	Yes		NS
Piping Plover (US-T, *Red WatchList*)	Yes		NS
American Oystercatcher	Yes		NS
Upland Sandpiper			NS
Common Tern	Yes		NS
Forster's Tern		Yes	NS
Least Tern (US-E, *Red WatchList*)	Yes	Yes	NS
Black Skimmer (*Yellow WatchList*)	Yes	Yes	NS
Short-eared Owl (*Yellow WatchList*)			NS
Red-headed Woodpecker (*Yellow WatchList*)	Yes		NS
Loggerhead Shrike			NS
Brown Creeper			NS
Sedge Wren			NS
Northern Parula	Yes	Yes	NS
Cerulean Warbler (*Yellow WatchList*)			NS
Swainson's Warbler (*Yellow WatchList*)			NS
Hooded Warbler		Yes	NS
Henslow's Sparrow (*Red WatchList*)			NS

[1] From Delaware Wildlife Action Plan, 2007-2017 (Allen et al. 2006); *WatchList* species from Butcher et al. 2007; see Section 4.1 discussion.

[2] S = Suitable habitat for nesting occurs at site for this species, MS = Marginally Suitable, NS = Not Suitable, ? = uncertainty in evaluation.

In the following sections, two data sources will be examined to determine the likely breeding bird community in and around the Project site. One is the Delaware Breeding Bird Atlas (BBA, 1983-1987), because it covered the Project site and surrounding region. It will be checked for the occurrence of special-status species (endangered, SGCN, and *WatchList*). The other source is the last ten years of data from a nearby route of the Breeding Bird Survey (BBS) of the U.S. Geological Survey (USGS). That route will be analyzed in detail in order to profile the breeding bird community.

4.1.1 Breeding Bird Atlas (BBA) Analysis

A Breeding Bird Atlas (BBA) is a survey that reveals the distribution of breeding birds in a country, state, or region. Delaware's first BBA was conducted in 1983-1987, with the results reported in *Birds of Delaware* (Hess et al. 2000). A second BBA was initiated in 2008, with completion scheduled for 2011[2].

As explained by Hess et al. (2000), atlas organizers used the 7.5-minute quadrangle series of the U.S. Geological Survey (USGS) topographic maps to section the state into sampling units. Each quadrangle was divided into six equal blocks, each 25 km^2 (9.6 mi^2). Mainly volunteer participants relied on topographic maps to orient themselves and survey as much of their assigned blocks as possible to record evidence of breeding for the birds they saw. Evidence of breeding was assessed as *Possible* (i.e., a species is simply observed in possible nesting habitat), *Probable* (i.e., a species exhibits certain behaviors that indicate breeding, such as territoriality, courtship and display, or nest building), or *Confirmed* (i.e., a species is observed nesting or engaged in behaviors associated with nesting, such as distraction display, carrying a fecal sac, carrying food for young, feeding young, etc.).

The Project site is situated in the Lewes SE block, which is surrounded by six blocks. Table 4.1.1-1 has been prepared to summarize the occurrence of endangered, SGCN, and *WatchList* species in the one overlapping and six surrounding blocks. Data are from the 1983-1987 BBA (Hess et al. 2000), because results of the 2008-2011 BBA are still preliminary. For example, in 1983-1987, 76 species were recorded in the Lewes SE block, while so far in the 2008-2011 BBA only 46 species have been recorded.

As may be seen in Table 4.1.1-1, twelve Delaware-endangered species were recorded in surrounding blocks, but none was recorded in the overlapping block. The lack of endangered species records in the overlapping block has continued so far in the 2008-2011 BBA (data accessed 7 January 2010).

Confirmed breeding for Piping Plover, Common Tern, Least Tern, and Black Skimmer and possible breeding for Northern Harrier and American Oystercatcher were from the block that covers Cape Henlopen, which is located 4 miles (6.4 km) east of the Project site. In a block to the northwest of the Project site, Piping Plover was also recorded as a possible breeder (probably from the beaches on Beach Plum Island), Northern Harrier was recorded as a probable breeder (likely in saltmarsh), and Black Rail was recorded as a probable breeder (likely from salt hay marsh). Possible breeding for Pied-billed Grebe was recorded from the three surrounding blocks to the west of the Project site.

Confirmed breeding for Bald Eagle and possible breeding for Cooper's Hawk were recorded in the block to the southwest of the Project site, where Red-headed Woodpecker was also recorded as a probable breeder. The woodpecker was confirmed as a breeder in the adjacent block to the

[2] For preliminary results, visit http://www.pwrc.usgs.gov/bba/index.cfm?fa=explore.ProjectHome&BBA_ID=DE2008.

north (i.e., the block west of the Project site). A possible breeding record for Northern Parula was from the block to the south of the Project site.

Table 4.1.1-1. Special-status species recorded in overlapping and surrounding BBA blocks, 1983-1987[1]

Delaware Endangered[2]	**Status in Overlapping Block**	**# of 6 Surrounding Blocks in Which Recorded**	**Highest Status in Surrounding Blocks**
Pied-billed Grebe		3	Possible
Bald Eagle		1	Confirmed
Northern Harrier		2	Probable
Cooper's Hawk		1	Possible
Black Rail (*Red WatchList*)		1	Probable
Piping Plover (US-T, *Red WatchList*)		2	Confirmed
American Oystercatcher		1	Possible
Common Tern		1	Confirmed
Least Tern (US-E, *Red WatchList*)		1	Confirmed
Black Skimmer (*Yellow WatchList*)		1	Confirmed
Red-headed Woodpecker (*Yellow WatchList*)		2	Confirmed
Northern Parula		1	Possible
SGCN (Tier 1)[2]			
American Black Duck	Confirmed	4	Confirmed
Osprey	Confirmed	3	Confirmed
Spotted Sandpiper		2	Possible
American Woodcock	Probable	5	Confirmed
Common Nighthawk	Confirmed	3	Confirmed
Wood Thrush (*Yellow WatchList*)	Probable	6	Confirmed
Prairie Warbler (*Yellow WatchList*)	Possible	5	Probable
Saltmarsh Sparrow (*Red WatchList*)	Possible	1	Confirmed
Seaside Sparrow (*Red WatchList*)	Probable	3	Confirmed
Swamp Sparrow (coastal plain race)	Probable	2	Confirmed
SGCN (Tier 2)[2]			
Mallard	Possible	6	Confirmed
Northern Bobwhite	Confirmed	6	Confirmed
American Bittern	Possible	1	Possible
Least Bittern		1	Confirmed
Red-shouldered Hawk		1	Possible
Peregrine Falcon		1	Probable
King Rail (*Yellow WatchList*)		2	Probable
Willet	Confirmed	4	Confirmed
Barn Owl		1	Confirmed
Barred Owl		1	Possible
Whip-poor-will	Possible	6	Probable
Chimney Swift	Confirmed	6	Probable
Northern Flicker	Confirmed	6	Confirmed
Willow Flycatcher (*Yellow WatchList*)		1	Confirmed

Delaware Endangered[2]	**Status in Overlapping Block**	**# of 6 Surrounding Blocks in Which Recorded**	**Highest Status in Surrounding Blocks**
Great Crested Flycatcher	Confirmed	6	Confirmed
Eastern Kingbird	Probable	6	Confirmed
Yellow-throated Vireo		1	Probable
Brown-headed Nuthatch		1	Confirmed
Marsh Wren	Probable	4	Confirmed
Brown Thrasher	Confirmed	6	Confirmed
Yellow-throated Warbler		1	Possible
Prothonotary Warbler (*Yellow WatchList*)		3	Confirmed
Worm-eating Warbler		1	Probable
Louisiana Waterthrush		3	Probable
Kentucky Warbler (*Yellow WatchList*)		3	Probable
Yellow-breasted Chat	Possible	5	Probable
Scarlet Tanager	Confirmed	4	Confirmed
Eastern Towhee	Possible	6	Confirmed
Field Sparrow	Confirmed	5	Confirmed
Grasshopper Sparrow		1	Probable
Baltimore Oriole		2	Confirmed
***WatchList* not listed in Delaware**[2]			
Clapper Rail (*Yellow WatchList*)	Confirmed	3	Confirmed

[1] Data from Hess et al. 2000.

[2] Special-status species are discussed in Section 4.1.

Regarding SGCN and other special-status species, we look at birds of saltmarsh and shrubland/edge habitats, as they are most likely to occur in the vicinity of the proposed wind turbine. Saltmarsh-related species were American Black Duck, Clapper Rail, Willet, Marsh Wren, Saltmarsh Sparrow, Seaside Sparrow, and the coastal race of Swamp Sparrow. Shrubland/edge birds included Willow Flycatcher, Eastern Kingbird, Brown Thrasher, Prairie Warbler, Yellow-breasted Chat, Eastern Towhee, Field Sparrow, and Baltimore Oriole.

SGCN raptors recorded were Osprey, Red-shouldered Hawk, Peregrine Falcon, Barn Owl, and Barred Owl; they could conceivably occur in the vicinity of the proposed turbine. Indeed, a Red-shouldered Hawk was recorded at the site during the site visit. Aerial-foraging birds that could fly over the Project site were Common Nighthawk and Chimney Swift.

4.1.2 Breeding Bird Survey (BBS) Analysis

Now overseen by the Patuxent Wildlife Research Center of the U.S. Geological Survey (USGS), the North American Breeding Bird Survey (BBS) is an avian monitoring program that tracks the status and trends of North American bird populations. Each year during the height of the breeding season (normally June), mainly volunteer participants skilled in bird identification collect bird population data along roadside survey routes. Each survey route is 24.5 miles (39.4 km) long with stops at 0.5 mile (0.8 km) intervals, for a total of 50 stops. At each stop, a threeminute point count is conducted. The total survey time over the entire route, therefore, is 2.5 hours. At each point count, every bird seen within a 0.25 mile (0.4 km) radius or heard is recorded. Surveys start one-half hour before local sunrise and take about five hours to complete.

We have chosen to analyze the Harrington BBS route (21003) because it accesses coastal habitats similar to those in the vicinity of the Project site. It approaches within 7 miles (11.3 km) of the Project site. Appendix E lists in taxonomic and abundance orders the birds recorded on that route during the last ten years (2000-2009). Average abundance was calculated by dividing the average number of individuals per year by the survey time of 2.5 hours. This measure indicates which birds are likeliest to be found in habitats at the Project site.

A total of 125 species was recorded on the Harrington route over the last ten years. Of them, 74 were recorded above 1.00 bird/hr and may be considered common to abundant. They are listed in abundance order in Table 4.1.2-1. Together, individuals of these 74 species made up 98% of all individuals recorded on the BBS route. The other 51 species recorded (see Appendix E) were uncommon to rare.

Of the species included in Table 4.1.2-1, 18 averaged above 10 birds/hour and may be considered abundant. Most would be expected to occur in the Project vicinity. Horned Lark, however, is unlikely; Hess et al. (2000) describe its habitat as open fields in agricultural areas.

Of the common species (1-10 birds/hour), saltmarsh and shrubland/edge species may be expected in the Project vicinity, but woodland birds (e.g., Wood Thrush, Ovenbird, etc.) would not. Of the obligate grassland birds, Grasshopper Sparrow is not described as nesting in higher parts of tidal marshes, but Eastern Meadowlark is (Hess et al. 2000).

Table 4.1.2-2 highlights the special-status species recorded in the last ten years on the Harrington route. In addition to average abundance, it shows the percent of years in which a species was recorded and the range in individuals recorded.

Among endangered species, only Forster's Tern was recorded as common (i.e., >1.00 birds/hour), with small numbers found nearly every year. All others were uncommon to rare.

Of the SGCN species, the same suite of saltmarsh and shrubland/edge species was encountered as in the BBA. Common to abundant saltmarsh specialists were Willet (9.92 birds/hour) and Seaside Sparrow (5.64). Both were found all years in relatively large numbers.

Table 4.1.2-1. Most abundant birds on 2000-2009 Harrington BBS route (21003)[1]

Abundance Sort[1]	Avg. birds/hr
Common Grackle	109.08
European Starling	58.08
Red-winged Blackbird	45.72
American Robin	40.04
Laughing Gull	34.96
House Sparrow	30.12
Purple Martin	29.04
Mourning Dove	28.52
Barn Swallow	24.68
Turkey Vulture	19.52
Northern Cardinal	17.56
Northern Mockingbird	16.40
Indigo Bunting	15.24
Ring-billed Gull	15.04
American Crow	15.00
Carolina Wren	14.48
Song Sparrow	14.44
Horned Lark	10.12
Willet (SGCN-2)	9.92
House Finch	9.88
American Goldfinch	9.88
Blue Grosbeak	9.60
Canada Goose	9.20
Rock Pigeon	8.68
Common Yellowthroat	8.48
Red-eyed Vireo	8.04
Chimney Swift (SGCN-2)	7.76
Tufted Titmouse	7.44
Chipping Sparrow	7.28
Brown-headed Cowbird	7.17
Red-bellied Woodpecker	5.80
Seaside Sparrow (SGCN-1, *Red WatchList*)	5.64
Fish Crow	5.44
Cedar Waxwing	5.44
Great Crested Flycatcher (SGCN-2)	5.24
Wood Thrush (SGCN-1, *Yellow WatchList*)	4.76
Boat-tailed Grackle	3.96
Blue Jay	3.76
Eastern Wood-Pewee	3.72
Double-crested Cormorant (SGCN-2)	3.60
Orchard Oriole	3.60
Herring Gull	3.40
Tree Swallow	3.32
Gray Catbird	3.16
Great Blue Heron (SGCN-2)	3.00
Acadian Flycatcher	2.76

Abundance Sort[1]	**Avg. birds/hr**
Northern Bobwhite (SGCN-2)	2.60
Killdeer	2.36
Black Vulture (SGCN-2)	2.12
Mallard (SGCN-2)	2.04
Eastern Bluebird	2.00
Swamp Sparrow (SGCN-1)	2.00
Carolina Chickadee	1.92
Eastern Kingbird (SGCN-2)	1.88
Marsh Wren (SGCN-2)	1.88
Ovenbird	1.80
Scarlet Tanager (SGCN-2)	1.76
Eastern Meadowlark	1.76
White-eyed Vireo	1.60
Snowy Egret (SGCN-2)	1.48
Yellow Warbler	1.40
Green Heron	1.36
Blue-gray Gnatcatcher	1.32
Prothonotary Warbler (SGCN-2, *Yellow WatchList*)	1.32
Bank Swallow (SGCN-2)	1.28
Downy Woodpecker	1.24
Field Sparrow (SGCN-2)	1.20
Clapper Rail (*Yellow WatchList)*	1.16
Northern Flicker (SGCN-2)	1.12
Brown Thrasher (SGCN-2)	1.12
Red-tailed Hawk	1.08
unid. Crow	1.08
Grasshopper Sparrow (SGCN-2)	1.08
Forster's Tern (DE-E)	**1.04**
House Wren	1.04

[1] Recorded at 1.00 birds/hour or greater.

[2] Delaware-endagered species are indicated in boldface; see Table 4.1-1. Species of Greatest Conservation Need (SGCN) and *WatchList* species are noted; see discussion in Section 4.1.

Table 4.1.2-2. Special-status species recorded on 2000-2009 Harrington BBS route (21003)[1]

Conservation Priority and Taxonomic Sort[1]	Avg. birds/hr	% years recorded	Range # individuals
Pied-billed Grebe (DE-E)	**0.04**	10%	1
Black-crowned Night-Heron (DE-E)	**0.08**	10%	2
Bald Eagle (DE-E)	**0.16**	40%	1
Northern Harrier (DE-E)	**0.08**	20%	1
Cooper's Hawk (DE-E)	**0.12**	30%	1
Forster's Tern (DE-E)	**1.04**	80%	2-4
Least Tern (DE-E, Red WatchList)	**0.12**	10%	3
Black Skimmer (DE-E, Yellow WatchList)	**0.24**	20%	2-4
Northern Parula (DE-E)	**0.04**	10%	1
Hooded Warbler (DE-E)	**0.04**	10%	1
American Black Duck (SGCN-1)	0.40	90%	3-11
Osprey (SGCN-1)	0.92	90%	1-5
Common Nighthawk (SGCN-1)	0.08	20%	1
Wood Thrush (SGCN-1, *Yellow WatchList*)	4.76	100%	7-19
American Redstart (SGCN-1)	0.20	50%	1
Saltmarsh Sparrow (SGCN-1, *Red WatchList*)	0.04	10%	1
Seaside Sparrow (SGCN-1, *Red WatchList*)	5.64	100%	7-22
Swamp Sparrow (SGCN-1)	2.00	100%	1-10
Mallard (SGCN-2)	2.04	90%	4-11
Northern Bobwhite (SGCN-2)	2.60	100%	1-29
Double-crested Cormorant (SGCN-2)	3.60	100%	1-53
Least Bittern (SGCN-2)	0.04	10%	1
Great Blue Heron (SGCN-2)	3.00	100%	3-15
Great Egret (SGCN-2)	0.08	20%	1
Snowy Egret (SGCN-2)	1.48	100%	1-9
Tricolored Heron (SGCN-2)	0.04	10%	1
Cattle Egret (SGCN-2)	0.04	10%	1
Glossy Ibis (SGCN-2)	0.40	20%	3-7
Black Vulture (SGCN-2)	2.12	100%	1-13
Red-shouldered Hawk (SGCN-2)	0.04	10%	1
Black-necked Stilt (SGCN-2)	0.32	50%	1-3
Willet (SGCN-2)	9.92	100%	18-32
Barred Owl (SGCN-2)	0.04	10%	1
Whip-poor-will (SGCN-2)	0.04	10%	1
Chimney Swift (SGCN-2)	7.76	100%	11-35
Northern Flicker (SGCN-2)	1.12	100%	1-4
Willow Flycatcher (SGCN-2, *Yellow WatchList*)	0.56	60%	1-5
Great Crested Flycatcher (SGCN-2)	5.24	100%	8-28
Eastern Kingbird (SGCN-2)	1.88	90%	2-8
Yellow-throated Vireo (SGCN-2)	0.08	20%	1
Bank Swallow (SGCN-2)	1.28	100%	1-7
Marsh Wren (SGCN-2)	1.88	100%	3-8
Brown Thrasher (SGCN-2)	1.12	100%	1-7

Conservation Priority and Taxonomic Sort[1]	**Avg. birds/hr**	**% years recorded**	**Range # individuals**
Yellow-throated Warbler (SGCN-2)	0.40	80%	1-2
Prothonotary Warbler (SGCN-2, *Yellow WatchList*)	1.32	90%	2-6
Worm-eating Warbler (SGCN-2)	0.08	20%	1
Louisiana Waterthrush (SGCN-2)	0.12	30%	1
Kentucky Warbler (SGCN-2, *Yellow WatchList*)	0.40	70%	1-3
Yellow-breasted Chat (SGCN-2)	0.72	100%	1-4
Scarlet Tanager (SGCN-2)	1.76	100%	2-9
Eastern Towhee (SGCN-2)	0.72	80%	1-4
Field Sparrow (SGCN-2)	1.20	100%	1-4
Grasshopper Sparrow (SGCN-2)	1.08	100%	1-7
Baltimore Oriole (SGCN-2)	0.20	50%	1
Clapper Rail (*Yellow WatchList)*	1.16	90%	1-6

[1] Delaware-endangered species are indicated in boldface; see Table 4.1-1. Species of Greatest Conservation Concern (SGCN) and *WatchList* species are noted; see discussion in Section 4.1.

4.1.3 Breeding Birds, Conclusions

Based on the site visit's assessment of habitat and on analyses of Breeding Bird Atlas (BBA) and Breeding Bird Survey (BBS) data, no Delaware-endangered species is expected to nest in the vicinity of the proposed turbine, but a number of endangered species may occasionally forage near or fly in the vicinity of the turbine. These would include Black-crowned Night-Heron, Yellow-crowned Night-Heron, Bald Eagle, Northern Harrier, American Oystercatcher (also *Yellow WatchList*), Common Tern, Forster's Tern, Least Tern (also federally endangered and *Red WatchList*), and possibly Black Skimmer (also *Yellow WatchList*). Species of Greatest Conservation Need (SGCN) foraging or flying near the proposed turbine would be limited to raptors, saltmarsh specialists, and shrubland/edge species. These may include Black Vulture, Osprey, Red-shouldered Hawk, Peregrine Falcon, and Barn Owl among raptors; American Black Duck, Clapper Rail (*Yellow WatchList*), Willet, Marsh Wren, Saltmarsh Sparrow (also *Red WatchList*), Seaside Sparrow (also *Red WatchList*), and the coastal race of Swamp Sparrow among saltmarsh specialists; and Willow Flycatcher (also *Yellow WatchList*), Eastern Kingbird, Brown Thrasher, Prairie Warbler (also *Yellow WatchList*), Yellow-breasted Chat, Eastern Towhee, Field Sparrow, and Baltimore Oriole among shrubland/edge species.

4.2 Migratory Birds

This section sheds light on how migratory birds are likely to use the Project site's airspace and habitats. Bird migration is a complex phenomenon; therefore, this report examines the major migratory bird groups separately: night-migrating songbirds, raptors, and waterbirds (waterfowl, shorebirds, and others).

4.2.1 Nocturnal Songbird Migration

Most songbirds and allies migrate at night. In North America, they include cuckoos, woodpeckers, flycatchers, vireos, nuthatches, wrens, kinglets, gnatcatchers, thrushes, catbirds, thrashers, warblers, tanagers, and sparrows (Kerlinger 1995). Based on population estimates provided by Rich et al. (2004), hundreds of millions of birds are aloft at night over North America during the fall and spring migration seasons. Studies with radar, ceilometer, and direct observation have shown that nocturnal migration begins thirty minutes to an hour after sunset and peaks soon thereafter until after midnight. Most birds land by sunrise (Kerlinger 1995).

Nocturnal migration generally fits a broad-front pattern. To paraphrase Berthold (2001), individual birds originating from geographically broad breeding or wintering ranges migrate roughly parallel to each other (on broad fronts, like weather systems), crossing major landforms with little deviation in direction. This has been graphically demonstrated in the Appalachians, where radar studies (Cooper et al. 2004, Kerlinger 2005) found that fall migrants cross ridges at oblique angles and at high altitudes, thus refuting a ridge-following hypothesis. Nocturnal migration has also been found to occur in waves associated with meteorological phenomena. For example, fall migration is concentrated after the passage of cold fronts, which provide tail winds (Kerlinger 1995).

Along the Atlantic coast, radar studies demonstrate broad-front migration over the ocean. In Nova Scotia, Richardson (1978) documented migrants moving offshore at right and acute angles to the coast irrespective of wind direction. From Cape Cod, Drury and Nisbet (1964) and Nisbet and Drury (1967) found that migrants maintained constant headings over the water by apparently making corrections for displacement by crosswinds.

Broad-front nocturnal migration may occasionally concentrate at ecological barriers, such as coasts or lakeshores. In coastal Louisiana, inclement weather during spring migration was found to precipitate spectacular fallout events involving trans-Gulf of Mexico migrants in coastal woodland patches, but in fair weather, songbirds continued their flight hundreds of miles inland (Gauthreaux 1971). Away from ecological barriers, nocturnal migrants disperse themselves across the landscape to rest and feed in appropriate habitats.

Night migrants aloft at dawn over coastal Delaware or the adjacent Atlantic Ocean within sight of land will direct themselves to the nearest landfall, particularly if winds and weather conditions are unfavorable. For example, at dawn in Nova Scotia, Richardson (1978) found that landbirds over the ocean in unfavorable winds reoriented themselves toward the coast to make landfall. At a bird banding station at Island Beach, New Jersey, Murray (1976) found that, on heavy flight nights, fall migrants made landfall in peak numbers up until 9:00 a.m., after which time arrivals dropped off sharply. Murray's observation indicates that offshore birds that can see land at dawn reorient themselves to fly toward land. This phenomenon has also been recorded by birdwatchers at Cape May, New Jersey (Sutton and Sutton 2006, Wiedner et al. 1992).

With regard to the Project site, it is likely that some night-migrating songbirds will use the shrubby thickets near the wind turbine to rest and feed. That habitat will be used most after peak migration nights, which normally occur after the passage of cold fronts in fall.

The traffic rate, altitude, and direction of nocturnal migration have been studied at several dozen wind-energy sites in the Eastern and Midwestern U.S. Reviewed by Kerlinger (in preparation), these studies report similar results, as would be expected from broad-front migration. Seasonal migration rates ranged from 135 to 661 targets/km/hr in fall and from 42 to 473 targets/km/hr in spring, with significant variation from night to night. Nonetheless, these rates are a fraction of those at heavy migration areas, such as the Gulf Coast, where seasonal rates on the order of 10,000 targets/km/hr have been recorded (Gauthreaux 1971, 1972, 1980).

Mean migration altitude ranged from 365 m to 583 m (1,197-1,912 feet) agl (above ground level) in the fall, and from 401 m to 528 m (1,315-1,732 feet) agl in the spring. Only between 4% and about 13% of night migrants in both seasons were found to fly below 125 m (~410 feet) agl, the height of a wind turbine. In other words, most migration occurs well above the rotor-swept area of wind turbines. Flight direction also did not vary greatly among sites. In the fall, it averaged 190° (south-southwesterly), in spring 38° (northeasterly).

Young and Erickson (2006) have also reviewed radar studies at proposed and existing wind-energy projects in the Eastern U.S. (see National Research Council 2007). Based on 21 studies, they found similar mean passage rates in spring and fall (258 versus 247 targets/km/hr, respectively). Mean height of flight was 409 m (1,342 feet) agl in spring and 470 m (1,542 feet) agl in fall, with 14% of targets below 125 m (410 feet) in spring and 6.5% below that height in fall. Mean flight directions were SSW (193 degrees) in fall and NNE (31 degrees) in spring. These averages are in line with Kerlinger's analysis.

4.2.2 Hawk Migration

In their global directory of raptor migration sites, Zalles and Bildstein (2000) do not list a globally significant migration site in Delaware, but the Hawk Migration Association of North America (HMANA; see http://www.hmana.org) does report data from the Cape Henlopen Hawk Watch, which is located 4 miles (6.4 km) east of the Project site. This hawk watch is active in both spring and fall migration. Table 4.2.2-1 reports average raptor counts during these two seasons over the last five years (2005-2009; data from hawkcount.org). During this time span, an average of 111.6 hours of observation were conducted in spring from March 15 to May 10; in fall, an average of 343.1 hours of observation were conducted from September 1 to November 30.

In terms of number of raptors counted, fall migration at Cape Henlopen is an order of magnitude greater than spring passage (9,302 versus 801 raptors). When the number of observation hours is considered, fall passage averages 27.1 raptors/hour, while spring passage averages 7.2 raptors/hour. The fall passage rate is relatively large compared with other hawk watches reported by HMANA (at hawkcount.org).

Table 4.2.2-1 2005-2009 average raptor count at Cape Henlopen Hawk Watch[1]

Species[2]	# of individuals Spring	Fall
Black Vulture (SGCN-2)	7.2	117.2
Turkey Vulture	15.4	421.4
Swallow-tailed Kite (*Yellow WatchList*)	0.4	-
Osprey (SGCN-1)	68.8	2,898.8
Bald Eagle (DE-E)	9.8	200.0
Northern Harrier (DE-E)	36.6	273.2
Sharp-shinned Hawk (SGCN-1)	216.2	2,928.4
Cooper's Hawk (DE-E)	38.0	611.6
Northern Goshawk	0.2	1.8
Red-shouldered Hawk (SGCN-2)	0.8	25.6
Broad-winged Hawk (SGCN-1)	1.6	79.0
Swainson's Hawk (*Yellow WatchList*)	-	0.4
Red-tailed Hawk	14.2	198.0
Rough-legged Hawk	-	-
Golden Eagle	0.2	3.8
American Kestrel	172.2	650.6
Merlin	170.0	402.0
Peregrine Falcon (SGCN-2)	4.6	312.6
Unidentified Raptor	44.6	178.0
Average count	**800.8**	**9,302.4**

[1] Data from HawkCount.org.

[2] Delaware-endangered species are indicated in boldface; see Table 4.1-1. Species of Greatest Conservation Concern (SGCN) and *WatchList* species are noted; see discussion in Section 4.1.

Sharp-shinned Hawk and Osprey are by a wide margin the most numerous fall migrants at Cape Henlopen. It is interesting to note, however, that the average number of Sharp-shinned Hawks at Cape Henlopen is an order of magnitude less than that recorded at the Cape May Hawk Watch in New Jersey, while Osprey numbers are about the same (hawkcount.org). This pattern relates to the tendency to attempt water crossings. Kerlinger (1985) studied water crossing by hawks at Cape May Point and at Whitefish Point, Michigan. He found that all species made water crossings on some occasions, but the tendency varied greatly. Turkey Vultures, Broad-winged Hawks, and Red-tailed Hawks crossed infrequently, whereas Sharp-shinned Hawks, Rough-legged Hawks, American Kestrels, and Merlins crossed more often. Ospreys, Northern Harriers, and Peregrine Falcons usually made crossings. His results suggest that the tendency for hawks to undertake water crossings is related to wing shape, with longer-winged species, often with pointed wings, having high aspect ratios that decrease induced drag and therefore the energetic cost of powered flight.

Among spring migrants, Sharp-shinned Hawk again was most numerous, but its average was less than a tenth of that in fall. Spring numbers of American Kestrels and Merlins were one-quarter and two-fifths that of fall numbers, but their passage rates in both seasons were fairly similar when observation hours are factored in; this was not the case, however, for Peregrine Falcon, the spring numbers of which were proportionally much lower than fall numbers.

Located 4 miles (6.4 km) west of Cape Henlopen and 0.5 miles (0.8 km) south of the barrier beach along Delaware Bay, the Project site is not on the main migration path of raptors. Nonetheless, migrating Osprey, Sharp-shinned Hawks, and falcons may be expected to hunt occasionally in the vicinity of the proposed turbine.

4.2.3 Waterbird Migration

Shorebird migration in Delaware Bay is significant. The Western Hemisphere Shorebird Reserve Network (WHSRN; see http://www.mnomet.org/WHSRN/) ranks Delaware Bay as a *Site of Hemispheric Importance*, WHSRN's highest priority category. Sites of Hemispheric Importance have at least 500,000 shorebirds annually, or at least 30% of the biogeographic population for a species. The Project site is located at the mouth of this bay.

Found at http://www.manomet.org/WHSRN/viewsite-new.php?id=6, WHSRN's habitat description for Delaware Bay reads as follows:

> Land included in reserve is coastal, from hightide line down. Mostly narrow, sandy beaches, some mud flats; area made up of shorefront and lowtide flats, including dunes, sandy beaches and sandy/muddy mouths of rivers, adjacent tidal salt marshes, and salt water impoundments. There are extensive freshwater and saltwater wetlands throughout the Delaware River and Bay estuary.
>
> The extensive wetlands in the Delaware River Estuary provide excellent resting habitat and nesting sites for many species of migratory waterfowl, bald eagles, ospreys, northern harrier, waders (including yellow and black crowned night herons) and migrating raptors. The area functions as a major staging area for 80 percent of the Atlantic flyway population of Snow Geese (up to 200,000). Several federal and state endangered and threatened species are supported including: Bald Eagle, Peregrine Falcon, Piping Plover, Pied-billed Grebe, Short-eared Owl, Delmarva Fox Squirrel, and Shortnose Sturgeon. Delaware Bay is also the site of the largest spawning concentration of horseshoe crabs along the Atlantic coast.
>
> The northbound migration of shorebirds coincides with horseshoe crab spawning in the bay. Shorebirds have been found to feed mostly on horseshoe crab eggs on the bay beaches, but some species, such as the Semipalmated Sandpiper, Dunlin, and Short-billed Dowitcher, rely more heavily on marsh habitats. All shorebirds move between the beaches and marshes for feeding, resting and roosting. NJ Division of Fish, Game and Wildlife, in conjunction with the Delaware Department of Fish and Wildlife - Nongame and Endangered Species Program, conducts annual surveys of shorebird abundance on beaches. Total birds counted on beaches in aerial surveys over the 6-week migration period range from 250,000 to over 600,000 (May through mid-June). Birds observed in tidal marsh habitats are estimated at 700,000, approximately two times that on bay beaches, but species that associate more with marshes than beaches are underestimated by aerial surveys.

Four species accounted for 99% of birds observed on Delaware Bay beaches:

- Semipalmated Sandpipers 30-70%
- Ruddy Turnstones 20-35 %
- Red Knots 15-20 %
- Sanderling 4-6 %

Dunlin and Short-billed Dowitchers account for another 2-8 % (numbers fluctuate yearly).

Red Knot, Sanderling, and Semipalmated Sandpiper are all *Yellow WatchList* species, while Ruddy Turnstone, Red Knot, and Sanderling are on the SGCN-1 list in Delaware. Red Knot is also a candidate for federal listing as an endangered species. According to Sutton and Sutton (2006), researchers in the 1980s estimated that at least 80% of the East Coast race (subspecies *rufa*) of the Red Knot staged on Delaware Bay to refuel in spring on their 10,000-mile migration from southern South America to the Arctic. The Red Knot population on Delaware Bay has apparently declined from a high of 100,000 birds in the 1980s to about 15,000 in 2005. This decline has been attributed to over-harvesting of the horseshoe crab, whose eggs are the principal food source for the knot and other shorebirds.

Located about 35 miles (56 km) northeast of the Project site, the Avalon Seawatch has documented that large numbers of seabirds migrate along the Atlantic coast in fall (visit http://www.njaudubon.org/Research/SeaWatch.html). Operating from September 22 to December 22, this count averages over 750,000 seabirds annually. Nearly 80 species are regularly recorded. The most abundant migrants are Double-crested Cormorant (average of 188,245), Surf Scoter (144,921), Black Scoter (126,294), dark-winged scoters (either Surf or Black, 80,088), Red-throated Loon (57,508), Northern Gannet (47,696), Laughing Gull (16,906), and Ring-billed Gull (12,902).

Where seabirds migrate along the coast depends on the wind (Sutton and Sutton 2006). In northwest winds, seabirds are often far at sea, but in northeast winds, the migration may come ashore, including over the marshes behind the barrier island of Avalon. Many of the seabirds, however, migrate along the nearshore zone, where they can easily access the shallow water where they feed.

Given that the Project site is located 4 miles (6.4 km) from the Atlantic coast, it is unlikely that seabird migration will extend over the site, even in strong onshore winds.

In his treatise on North American waterfowl, Bellrose (1980) shows significant waterfowl migration terminating along the Atlantic coast near Delaware. His map for duck migration shows a broad migration corridor used by between 3.0 and 5.3 million ducks that links what the Prairie Breeding Grounds of south-central Canada, the Dakotas, and Minnesota with wintering areas along the Mid-Atlantic coast. His map for goose migration shows a corridor between Hudson Bay and the Mid-Atlantic coast used by between 150,000 and 500,000 geese.

Most migration of waterfowl and other waterbird species takes place at night, but some extends to daylight hours, depending on the distance traveled. Radar studies show altitudes of 500 to

1,000 feet (152 to 304 m) or more at many locations for ducks, geese, loons, and other birds (Kerlinger 1982, reviewed by Kerlinger and Moore 1989). According to Bellrose (1980), aviation reports indicate that most Canada Geese in the Midwest fly at about 2,000 feet above the ground in fall, with 52% of flocks between 1,000 and 3,000 feet and some flocks as low as 500 feet and others as high as 11,000 feet; spring aviation records show the average altitude even higher, at 2,500 feet.

4.2.4 Migratory Birds, Conclusions

Nocturnal songbird migration is expected to occur on a broad front above the Project site, with most birds flying well above the sweep of wind-turbine rotors. In fall migration, however, fallout events may occasionally concentrate night-migrating songbirds in coastal woodland habitats, including the shrubland near the proposed turbine. Given that coastal woodlands and shrublands are well distributed along the Delaware coast, the limited shrubland at the Project site is not expected to attract particularly large numbers of songbird migrants.

Concentrated raptor migration has been documented in fall at Cape Henlopen, with Sharp-shinned Hawk and Osprey (both SGCN-1) most abundant. The Project site is sufficiently inland from Cape Henlopen and barrier beaches to be off the main raptor migration path, but migrating Osprey, Sharp-shinned Hawks, falcons, and other species may occasionally hunt in the vicinity of the proposed turbine.

Delaware Bay is of hemispheric importance as a staging site for Ruddy Turnstone (SGCN-1), Red Knot (SGCN-1 and *Yellow WatchList*), Sanderling (SGCN-1 and *Yellow WatchList*), and Semipalmated Sandpiper (*Yellow WatchList*) in spring migration. They mostly forage for horseshoe crab eggs in Delaware Bay, but they also forage and roost in saltmarshes. Nonetheless, give the location of the proposed turbine above the saltmarsh zone and away from Delaware Bay and the Atlantic Ocean, it is likely that few of these shorebirds, or other coastally migrating waterbirds, will fly in the vicinity of the turbine.

4.3 Wintering Birds

Audubon's Christmas Bird Count (CBC) provides an excellent overview of the birds that inhabit an area or region during early winter. Counts take place on a single day during a three-week period around Christmas, when dozens of birdwatchers comb a 15-mile (24 km) diameter circle (area of 177 square miles [453 km^2]) in order to tally the bird species and individuals they encounter. While most of these birdwatchers are unpaid amateurs, they are usually proficient or highly skilled observers.

Available at http://audubon2.org/birds/cbc/hr/count_table.html, CBC data are used by scientists, wildlife agencies, and environmental groups to monitor bird populations. To evaluate winter bird abundance at the Project site, we have examined the last ten years of data for the Cape Henlopen-Prime Hook CBC (coded DECH), the coverage of which includes the Project site. It was active in each of the last ten years (2000-2009), recruited between 19 and 38 observers per year, and recorded between 123 and 161 species.

To profile the winter bird community in the region including the Project site, Appendix E has been prepared. Sorted in taxonomic and abundance orders, this table displays the average abundance of birds, measured in birds/hour. In each year, abundances were determined by dividing the number of individuals tallied by the total number of party hours (i.e., the cumulative hours that parties of observers were in the field). These values were then averaged using the last ten years of data (2000 to 2009).

A total of 190 species were recorded at least once on the Cape Henlopen-Prime Hook CBC over the last ten years. Of them, 46 were recorded above 1.00 bird/hr and may be considered common to abundant. Listed in Table 4.3-1, individuals of these species made up over 98% of all individuals recorded on the count. The other 144 species were uncommon to rare (see Appendix E).

Recorded at 1,143.31 birds/hour, the abundance of Snow Goose on this CBC is highly noteworthy. 73% of all individual birds recorded on this CBC were Snow Geese. No other bird remotely approached Snow Goose in abundance. Hess et al. (2000) describe its habitat as saltwater cordgrass marshes, impoundments, bays, and upland fields. Thus, Snow Geese are expected to forage in saltmarshes adjacent to the turbine location. Other abundant to common waterfowl likely to feed in saltmarshes adjacent to the Project site are Canada Goose (SGCN-1 for the migratory population; 63.81 birds/hour) and American Black Duck (SGCN-1; 9.13).

Raptor diversity on the CBC was high, with 14 diurnal species recorded. Most abundant were Turkey Vulture (2.41 birds/hour), Northern Harrier (DE endangered as a breeder; 0.52), Black Vulture (0.49), Red-tailed Hawk (0.28), Bald Eagle (DE endangered, 0.19), Sharp-shinned Hawk (SGCN-1; 0.11), and American Kestrel (0.10). All other raptors were relatively scarce.

Table 4.3-2 highlights the special-status species recorded in the last ten years on this CBC. In addition to average abundance, it shows the percent of years in which a species was recorded and the range in individuals recorded.

Among endangered species, Forster’s Tern was most abundant, recorded every year, occasionally exceeding 100 individuals. Hess et al. (2000) describe its habitat as saltmarsh and adjacent coastal waters. Thus, it may occur in the vicinity of the proposed turbine in winter. Northern Harrier was also relatively abundant, but most of the birds recorded were likely not endangered Delaware breeders. It is likely to hunt regularly over saltmarshes adjacent to the site. Bald Eagle was also relatively abundant, recorded every year, sometimes in the dozens of birds. According to Buehler (2000), Bald Eagle is an opportunistic feeder that prefers fish, but it will take waterfowl and gulls. Thus, it may be expected to hunt Snow Geese and other large waterbirds in the saltmarshes adjacent to the Project. All other endangered species were relatively scarce.

Of the SGCN species, few saltmarsh and shrubland/edge species were common enough (>0.10 birds/hour) to be expected to frequent areas near the proposed turbine.

Table 4.3-1. Most abundant birds on 2000-2009 Cape Henlopen-Prime Hook CBC (DECH)[1]

Abundance Sort[1]	Avg. birds/hr
Snow Goose	1,143.31
Common Grackle	67.73
Canada Goose (SGCN-1 in part)	63.81
Red-winged Blackbird	57.53
European Starling	24.14
Ring-billed Gull	23.64
Herring Gull	18.70
American Robin	14.71
Northern Pintail	12.56
Dunlin (SGCN-2)	9.59
American Black Duck (SGCN-1)	9.13
Mallard (SGCN-2)	7.17
Surf Scoter (SGCN-2)	6.13
American Green-winged Teal	5.88
Yellow-rumped Warbler	5.30
White-throated Sparrow	5.04
Dark-eyed Junco	4.31
Great Black-backed Gull (SGCN-2)	3.92
Mourning Dove	3.89
House Finch	3.36
Bonaparte's Gull	3.31
Song Sparrow	3.29
Sanderling (SGCN-1, *Yellow WatchList*)	3.10
Rock Pigeon	3.09
Ring-necked Duck	2.89
Brown-headed Cowbird	2.81
Northern Shoveler (SGCN-2)	2.51
Turkey Vulture	2.41
Bufflehead (SGCN-2)	2.02
American Goldfinch	1.97
Brant (SGCN-2)	1.96
Black Scoter (SGCN-2)	1.77
Cedar Waxwing	1.77
American Pipit	1.68
Gadwall	1.57
Carolina Chickadee	1.56
Northern Cardinal	1.52
American Crow	1.42
Carolina Wren	1.41

Abundance Sort[1]	**Avg. birds/hr**
Tundra Swan (SGCN-2)	1.40
Savannah Sparrow	1.39
Swamp Sparrow (SGCN-1 in oart)	1.36
Lesser Scaup (SGCN-2)	1.23
House Sparrow	1.21
Red-breasted Merganser	1.07
Greater Scaup (SGCN-2)	1.04

[1] Recorded at 1.00 birds/hour or greater.

[2] Delaware-endagered species are indicated in boldface; see Table 4.1-1. Species of Greatest Conservation Need (SGCN) and *WatchList* species are noted; see discussion in Section 4.1.

In conclusion, Christmas Bird Count (CBC) data indicate that Snow Geese will be abundant winter visitors in the Cape Henlopen-Prime Hook region. As they feed in saltmarshes, they will frequent the vicinity of the proposed wind turbine and probably attract the endangered Bald Eagle to prey on them. Northern Harrier (Delaware endangered as a breeder) will also frequent adjacent marshes, and the endangered Forster's Tern may occasionally forage there too.

Table 4.3-2. Special-status species recorded on 2000-2009 Cape Henlopen-Prime Hook CBC (DECH)[1]

Conservation Priority and Taxonomic Sort[1]	Avg. birds/hr	% years recorded	Range # individuals
Pied-billed Grebe (DE-E)	**0.07**	100%	1-19
Black-crowned Night-Heron (DE-E)	**0.03**	70%	1-10
Bald Eagle (DE-E)	**0.19**	100%	5-32
Northern Harrier (DE-E)	**0.52**	100%	12-63
Cooper's Hawk (DE-E)	**0.06**	100%	2-8
Forster's Tern (DE-E)	**0.76**	100%	9-132
Black Skimmer (DE-E, *Yellow Watchlist*)	**0.00**	10%	1
Short-eared Owl (DE-E, *Yellow WatchList*)	**0.01**	70%	1-3
Red-headed Woodpecker (DE-E, *Yellow WatchList*)	**0.00**	20%	1
Loggerhead Shrike (DE-E)	**0.00**	20%	1
Brown Creeper (DE-E)	**0.10**	90%	3-18
Sedge Wren (DE-E)	**0.01**	70%	1-4
Canada Goose (SGCN-1 in oart)	63.81	100%	2444-8067
American Black Duck (SGCN-1)	9.13	100%	440-1100
Common Eider (SGCN-1)	0.08	60%	2-32
Sharp-shinned Hawk (SGCN-1)	0.11	100%	6-12
Ruddy Turnstone (SGCN-1)	0.44	100%	10-54
Sanderling (SGCN-1, *Yellow WatchList*)	3.10	100%	110-389
American Woodcock (SGCN-1)	0.13	100%	2-41
Long-eared Owl (SGCN-1)	0.02	70%	1-4
Prairie Warbler (SGCN-1, *Yellow WatchList*)	0.00	10%	1
Saltmarsh Sparrow (SGCN-1, *Red WatchList*)	0.02	70%	1-11
Seaside Sparrow (SGCN-1, *Red WatchList*)	0.02	60%	1-3
Swamp Sparrow (SGCN-1 in oart)	1.36	100%	30-214
Brant (SGCN-2)	1.96	100%	53-585
Tundra Swan (SGCN-2)	1.40	100%	15-255
Mallard (SGCN-2)	7.17	100%	175-910
Northern Shoveler (SGCN-2)	2.51	100%	56-529
Canvasback (SGCN-2)	0.02	30%	1-11
Redhead (SGCN-2)	0.01	20%	3-4
Greater Scaup (SGCN-2)	1.04	90%	15-184
Lesser Scaup (SGCN-2)	1.23	80%	72-358
scaup sp. (SGCN-2)	0.65	10%	639
Surf Scoter (SGCN-2)	6.13	100%	8-2208
White-winged Scoter (SGCN-2)	0.09	100%	2-19
Black Scoter (SGCN-2)	1.77	100%	1-979
scoter sp. (SGCN-2)	0.81	10%	800
Long-tailed Duck (SGCN-2)	0.20	100%	3-35
Bufflehead (SGCN-2)	2.02	100%	39-243
Hooded Merganser (SGCN-2)	0.38	100%	3-60
Northern Bobwhite (SGCN-2)	0.16	90%	9-28
Brown Pelican (SGCN-2)	0.00	10%	1
Double-crested Cormorant (SGCN-2)	0.51	100%	21-78
Great Cormorant (SGCN-2)	0.58	100%	1-135

Conservation Priority and Taxonomic Sort[1]	**Avg. birds/hr**	**% years recorded**	**Range # individuals**
American Bittern (SGCN-2)	0.02	70%	1-5
Great Blue Heron (SGCN-2)	0.99	100%	17-122
Great Egret (SGCN-2)	0.02	40%	1-5
Snowy Egret (SGCN-2)	0.00	10%	1
Tricolored Heron (SGCN-2)	0.00	10%	1
Black Vulture (SGCN-2)	0.49	100%	14-89
Red-shouldered Hawk (SGCN-2)	0.02	80%	1-4
Peregrine Falcon (SGCN-2)	0.02	70%	1-4
King Rail (SGCN-2, *Yellow WatchList*)	0.02	60%	1-7
Sora (SGCN-2)	0.00	10%	2
American Coot (SGCN-2)	0.11	50%	1-61
Black-bellied Plover (SGCN-2)	0.04	60%	1-14
Greater Yellowlegs (SGCN-2)	0.26	100%	2-45
Purple Sandpiper (SGCN-2)	0.72	100%	3-153
Dunlin (SGCN-2)	9.59	100%	235-1356
Little Gull (SGCN-2)	0.00	20%	1
Great Black-backed Gull (SGCN-2)	3.92	100%	172-361
Barn Owl (SGCN-2)	0.02	70%	1-5
Barred Owl (SGCN-2)	0.04	100%	1-6
Northern Flicker (SGCN-2)	0.60	100%	15-83
Brown-headed Nuthatch (SGCN-2)	0.43	100%	7-66
Marsh Wren (SGCN-2)	0.02	60%	1-3
Brown Thrasher (SGCN-2)	0.12	100%	2-32
Yellow-breasted Chat (SGCN-2)	0.00	20%	1
Eastern Towhee (SGCN-2)	0.31	100%	4-64
Field Sparrow (SGCN-2)	0.65	100%	4-116
Vesper Sparrow (SGCN-2)	0.00	10%	1
Baltimore Oriole (SGCN-2)	0.00	10%	1
Clapper Rail (*Yellow WatchList*)	0.07	90%	1-22
Iceland Gull (*Yellow WatchList*)	0.00	30%	1
Razorbill (*Yellow WatchList*)	0.01	20%	1-4
Le Conte's Sparrow (*Yellow WatchList*)	0.00	20%	1
Nelson's Sparrow (*Yellow WatchList*)	0.01	50%	1-3
Painted Bunting (*Yellow WatchList*)	0.00	10%	1
Rusty Blackbird (*Yellow WatchList*)	0.19	90%	1-116

[1] Delaware-endangered species are indicated in boldface; see Table 4.1-1. Species of Greatest Conservation Concern (SGCN) and *WatchList* species are noted; see discussion in Section 4.1.

5.0 Analysis of Sensitive Avian Habitats

The presence of Important Bird Areas (IBAs), reserves, and designated sensitive habitats at or near the Project site may indicate increased avian risk. We check for their presence here.

5.1 Important Bird Areas (IBAs)

The Important Bird Area (IBA) Program is sponsored by BirdLife International and Audubon. Described at http://www.audubon.org/bird/iba/, it seeks to identify and protect essential habitats for one or more species of breeding or non-breeding birds. The sites vary in size, but usually they are discrete and distinguishable in character, habitat, or ornithological importance from surrounding areas. In general, an IBA should exist as an actual or potential protected area, with or without buffer zones, or should have the potential to be managed in some way for birds and general nature conservation. An IBA, whenever possible, should be large enough to supply all or most of the requirements of the target birds during the season for which it is important.

According to information at http://www.delawareaudubon.org/birding/globaliba.html, Delaware Audubon has designated five IBAs, one of which is the Delaware Coastal Zone, which includes the Project site. It is described as follows:

> Delaware's Coastal Zone, including the C&D Canal, and the Inland Bays, contains approximately 270,000 acres. Excluding open water within this area, approximately 232,000 acres are wetlands and uplands. Breeding distribution maps indicate that the Delaware Coastal Zone contains breeding grounds for several WatchListed and endangered/threatened birds. These include the following species: Piping Plover; American Black Duck; Black Rail; Least Tern; Chuck-will's-widow; Wood Thrush; Prairie, Prothonotary, Worm-eating and Kentucky Warblers; Salt-marsh, Sharp-tailed and Seaside Sparrows; and Brown-headed Nuthatch. The importance of the Delaware Coastal Zone for birds cannot be overstated. More horseshoe crabs spawn here than anywhere else on earth. During their spring migration from South America to the Arctic, tens of thousands of the WatchListed Red Knot, Semipalmated Sandpipers, Ruddy Turnstones, Sanderlings, Dunlin, and Short-billed Dowitchers stop in Delaware to consume huge quantities of eggs laid by horseshoe crabs. This has made Delaware one of the most crucial sites for migrating shorebirds on the entire Atlantic Coast of North America. The high percentage of public and

> conservation lands in the Zone, plus its restrictions on heavy industry, make it a truly outstanding area for the protection of birds.

The American Bird Conservancy (ABC) has compiled a list of the 500 most important bird areas in the United States (ABC 2003). This list includes 35 IBAs in the New England/Mid-Atlantic Coast Bird Conservation Region (BCR 30; see Section 4.0), of which nine are on Delaware Bay. Two of these nine IBAs are located within 4 miles (6.4 km) of the Project site: Cape Henlopen State Park and Prime Hook Wildlife Area and National Wildlife Refuge. ABC highlights Delaware Bay for the over one million shorebirds that stage there in spring migration to feed on horseshoe crab eggs. The importance of the Delaware Bay estuary to shorebirds was discussed in Section 4.2.3.

5.2 Federal, State, and Private Protected Areas

As noted above, the Prime Hook National Wildlife Refuge is located as close as 2 miles (3.2 km) west of the Project site. Cape Henlopen State Park is located about 4 miles (6.4 km) east. American Bird Conservancy (ABC) classifies both as Important Bird Areas (IBAs). Cape Henlopen is the site of a spring and fall hawk watch (see Section 4.2.2).

Regarding private protected areas, The Nature Conservancy (TNC) manages the 17,000 Great Marsh and 149-acre Burton Farm outside of Lewes[3]. The website account does not specify the locations of these preserves, but appear to be within 2 miles (3.2 km) of the Project site. The Great Marsh preserve may abut the Project site.

In conclusion, the Project site is located in the Delaware Coastal Zone, which Delaware Audubon has classified as an Important Bird Area (IBA). The Project site is also located between Prime Hook National Wildlife Refuge and Cape Henlopen State Park, which the American Bird Conservancy (ABC) has classified as IBAs. The IBA descriptions emphasize the importance of Delaware Bay to a suite of special-status shorebirds that stage there in spring migration, and to a number of special-status breeders. Nonetheless, the Project site is not located on Delaware Bay where the shorebirds concentrate, and it appears to lack habitats that would attract special-status breeding birds.

[3] Visit http://www.nature.org/wherewework/northamerica/states/delaware/preserves/art10707.html.

6.0 Literature Review of Documented Avian Risk at Wind Farms

An increasing number of post-construction studies at U.S. wind farms has greatly improved understanding of avian impacts. We summarize this research below. Then, in the next section, we compare the Project site's avian profile (see Sections 3.0 through 5.0) with the principal research findings. In this way, we arrive at probabilistic assessments of avian risk.

Two general types of avian impacts have been documented: 1) displacement as a result of the construction and operation of wind turbines and related infrastructure, and 2) fatalities resulting from collisions with turbines and other infrastructure. They are detailed below.

This review focuses on U.S. research, as the bird species involved are the same as, or similar to, those found at the Project site. When applicable, we report on the extensive research that is being conducted in Europe.

6.1 Displacement Impacts

The footprint of turbine pads, roads, and other infrastructure required for a wind farm is generally a small percentage of a site, often estimated at two to four percent. Therefore, in general, overall land use is changed minimally by wind-power development, and actual habitat lost is generally small. This is particularly true in agricultural landscapes. But, in forested landscapes, the construction of a wind farm and its connection to the electricity grid may fragment habitat in a significant way, affecting wildlife populations (National Research Council 2007).

Despite the relatively small footprint of a wind farm, the amount of wildlife habitat altered by a wind-power project sometimes extends beyond the limits of disturbed ground. This results from the presence and operation of the wind turbines, which are large new structures in the landscape, and increased human activity to construct and maintain them. Various studies have examined wind-turbine presence to determine whether birds avoid or are displaced from an area as a result of these new features.

We discuss these studies in the following order, given the habitat composition of the Project site: 1) Grassland and Open Habitats, 2) Forest, Woodland, and Shrubland, and 3) Raptor Use.

6.1.1 Displacement in Grassland and Open Habitats

In the U.S., studies documenting disturbance, avoidance, and displacement have focused mainly on birds living in grassland and other open-country habitats, including farm fields. The most cited study took place at the **Buffalo Ridge Wind Resource Area** in southwestern Minnesota (Leddy et al. 1999). There, Conservation Reserve Program (CRP) grasslands without turbines and CRP areas located at least 180 m (590 feet) from turbines were found to support greater densities of grassland birds than CRP areas within 80 m (260 feet) of turbines. At the turbine bases, mean bird density was measured at 58.2 males/100 ha; at 40 m, 66.0 males/100 ha; and at 80 m, 128.0 males/100 ha. At 180 m, mean bird density rose to 261.0 males/100 ha. In CRP control plots, mean bird density was calculated at 312.5 males/100 ha. Bobolinks, Red-winged

Blackbirds, and Savannah Sparrows were the commonest species in CRP grasslands with turbines, whereas Bobolinks, Sedge Wrens, and Savannah Sparrows were commonest in CRP grasslands without turbines. Other birds recorded were Common Yellowthroat, Clay-colored Sparrow, Grasshopper Sparrow, Le Conte's Sparrow, Dickcissel, Western Meadowlark, and Brown-headed Cowbird.

The Buffalo Ridge study appears to demonstrate that displacement was greatest close to turbines and decreased with distance from turbines. In other words, after turbine construction, some birds either did not nest or forage near the turbines or did so at lower densities. It should be noted, however, that the Buffalo Ridge turbines were shorter (hub height of 37 m, rotor diameter of 33 m) than the turbine proposed for the Project. The Buffalo Ridge turbines were also spaced closely (separated by 91-183 m). Furthermore, the Buffalo Ridge study appears to have been conducted in the first year after construction, when vegetation at turbine construction sites may not have fully recovered and birds may not have had time to habituate to the project.

At the **Foote Creek Rim Wind Plant** in Wyoming (Johnson et al. 2000), the number of Mountain Plovers (*Red WatchList*) nesting in shortgrass prairie declined after turbine construction. Plover productivity also declined, but successful nesting was noted within 200 m (660 feet) of operating turbines.

The Buffalo Ridge and Foote Creek Rim studies show impacts extending beyond project footprints, but other studies demonstrate no differences in breeding densities.

At the **Oklahoma Wind Energy Center** (O'Connell and Piorkowski 2006, reviewed in Mabey and Paul 2007) breeding bird densities were measured at three distances: adjacent to turbines, intermediate (1 to 5 km away), and distant (5 to 10 km away). Northern Bobwhite, Scissor-tailed Flycatcher, Horned Lark, Bewick's Wren, Cassin's Sparrow, Grasshopper Sparrow, Painted Bunting, Dickcissel, and Eastern Meadowlark showed no differences in breeding density in relation to proximity to wind turbines. The same was true of an analysis of all breeding birds combined. Curiously, Killdeer was found to be most abundant at intermediate distances from turbines, and Greater Roadrunner and Western Meadowlark were found to be most abundant at distant sites. The authors concluded that most breeding grassland birds experienced no negative effects from wind turbines that would translate into a reduction of breeding density.

At the **Maple Ridge Wind Power Project** in Lewis County, New York, an impact gradient study (Kerlinger and Dowdell 2008) was conducted to determine whether birds nesting in hay fields were displaced by wind turbines erected the previous year. Mean bird densities were found to be 15.2/ha in turbine plots and 18.5/ha in reference plots, with Savannah Sparrows and Bobolinks accounting for nearly all individuals. Bobolink density was significantly lower within 75 m of turbines, but this may have been because vegetation had not yet been fully restored. Savannah Sparrow density did not reveal a displacement gradient, possibly because dirt piles near the turbines served as singing perches, attracting males. Killdeer density was greater within 75 m of turbines, undoubtedly because they nested on the bare earth and gravel pads beneath the turbines.

If displacement was occurring at Maple Ridge, it was only evident within about 75-100 m of the turbines. But, as indicated above, the displacement effect noted may have been related to impacts on vegetation rather than resulting from wind-turbine presence. It should be noted that turbine and reference plots were mowed for hay after the study, eliminating all nests. This led the authors to the conclusion that impacts from hay mowing were orders of magnitude greater than displacement by turbines, which they judged to be minimal.

At the **Erie Shores Wind Farm** in Port Burwell, Ontario, along the shore of Lake Erie (James 2008), Killdeer nested at distances of 3 to 40 m (10 nests) from the bases of turbines, Horned Larks at 15, 21, 37 and 40 m, Vesper Sparrow at 30 m, and Savannah Sparrow at 16 and 20 m. The author concluded that these species were more affected by the farming practices, including hay mowing and tilling, than by turbines.

At two wind farms in **East Anglia, England** (Devereux et al. 2008), wintering farmland birds were found not to avoid areas close to wind turbines. This study looked at the distributions of four bird groups (seed-eaters, corvids, gamebirds and skylarks) at distances ranging from 0–150 m to 600–750 m from wind turbines. Only in Ring-necked Pheasant did abundance increase with distance from wind turbines, but turbine proximity had no effect on Red-legged Partridge.

In **Europe**, a review (Hötker et al. 2006) looked at population effects, avoidance distances, and habituation at wind farms mainly in farmland and open habitats. It found that no negative population effects could be verified for any breeding birds, including Mallard, Common Buzzard, two gamebirds, four shorebirds (including Black-tailed Godwit, Redshank, Oystercatcher, and Lapwing), and various songbirds (20 species). However, breeding shorebirds and gamebirds displayed reduced numbers in connection with wind farms. Outside the breeding season, reduced densities were apparent in various geese, European Wigeon, Lapwing, and Golden Plover. For European Starling, impacts were generally positive. For most species, however, effects could not be statistically verified.

For avoidance distances, the review found a wide range of values, with some studies recording a species within 50 m of turbines, while others found the same species not approaching within hundreds of meters. Avoidance distances during the breeding season were smaller than outside the breeding season. Birds of open habitats, such as geese, ducks, and shorebirds, generally avoided turbines by several hundred meters, but there were some notable exceptions, namely, Grey Heron, raptors, Oystercatcher, gulls, European Starling, and crows.

For habituation (i.e., avoidance reactions decreasing over time), the review analyzed 122 data sets that included waterfowl, raptors, shorebirds, gulls, and songbirds. For breeding birds, 38 of 84 data sets (45%) indicated habituation. For non-breeding birds, 25 of 38 data sets (66%) indicated habituation. In other words, about half of the species analyzed demonstrated habituation. The observed degree of habituation in most cases was small, leading to the conclusion that habituation could not be ruled out, but it appeared not to be a widespread or strong phenomenon. Long-term studies should answer this question.

In North America, two studies have looked at displacement of waterbirds in agricultural habitats. Two years of post-construction studies at the **Top of Iowa Wind Plant** (Jain 2005, Koford et al. 2005) revealed that Canada Geese were not significantly displaced by the construction of 89 turbines. At the **Erie Shores Wind Farm** (James 2008), Canada Geese appeared not to be inhibited from flying through the wind farm or from using fields and ponds within 200 m of operating turbines. Goose tracks were found within 25 m (80 feet) of turbines on five occasions, with some of the tracks within 10 m (33 feet) of a tower. Tundra Swans appeared to differentiate between operating and non-operating turbines. Of 280 swans seen flying less than 300 m (990 feet) from operating turbines at rotor height, only three flew within 100 m (330 feet). But, of 240 swans seen flying past non-operating turbines, just over 20% flew less than 50 m (165 feet) from those turbines.

6.1.2 Displacement in Forest, Woodland, and Shrubland Habitats

In a recent literature review on the ecological effects of wind-energy development (National Research Council 2007), the following was concluded regarding effects on forest ecosystems:

1. Forest clearing resulting from road construction, transmission lines leading to the grid, and turbine placements represents perhaps the most significant potential change through habitat loss and fragmentation for forest-dependent species.
2. Changes in forest structure and the creation of openings may alter microclimate and increase the amount of forest edge.
3. Plants and animals throughout the ecosystem respond differently to these changes, and particular attention should be paid to species of concern that are known to have narrow habitat requirements and whose niches are disproportionately altered.

Research indicates that shrubland and forest-interior birds are likely to respond to wind farm development in different ways. The removal of forest canopy and subsequent release of the understory can benefit shrub-nesting species, such as Eastern Towhee, as has been demonstrated in timber-managed tracts (Duguay 1997, Duguay et al. 2000, 2001, cited in National Research Council 2007). On the other hand, habitat for Ovenbirds and Blackburnian Warblers is negatively correlated with understory density and positively correlated with the size and density of hardwood trees (Hagan and Meeham 2002, cited in National Research Council 2007). Territory densities of Ovenbirds were 40% less within edge areas (0 to 150 m from unpaved roads through forest) than within interior areas (150 to 300 m from roads) (Ortega and Capen 1999).

In other words, populations of shrubland species may be expected to respond positively to wind farm construction in forested areas, at least until the forest canopy fills in. Populations of forest-interior species, however, may be expected to respond negatively in the vicinity of cleared areas, with a reduction in density of territories. In heavily logged or significantly fragmented forests, effects would be less than in undisturbed forests.

Pre and post-construction studies in high-elevation forest at **Searsburg, Vermont** (Kerlinger 2000a, 2002) demonstrated a reduction in some forest-interior species, and increases in edge species, following construction of a wind farm. But, a number of common forest breeders – in order of abundance, Yellow-rumped Warbler, Dark-eyed Junco, White-throated Sparrow, Blackpoll Warbler, and Magnolia Warbler – appeared to habituate to the turbines within a year of construction. Swainson's Thrush was heard deep in the forest following construction, but during a site visit six years after construction (P. Kerlinger, personal communication), it was found singing (and likely nesting) within the forest adjacent to turbines. The management recommendation to allow forest to grow up to turbines and roadways appeared to have reduced fragmentation impacts at that site, but it was also possible that habituation had occurred.

At **Erie Shores Wind Farm** (James 2008; John Guarnaccia, personal observation), some turbines are situated at the edge of woodlots, but resident woodland and woodland-edge birds appeared to habituate readily to their presence, including forest-interior species, such as Wood Thrush (*Yellow WatchList*). Forest-edge birds lived as close as habitat allowed, including below the rotating turbine blades.

6.1.3 Displacement of Nesting and Migrating Raptors

Resident raptors appear to habituate readily to wind turbines. When Red-tailed Hawks trained for falconry were exposed at 100 feet (30 m) to the turbines at the **Altamont Pass Wind Resource Area** (APWRA) of California, at first they would not fly. Within weeks, however, they had habituated to turbines in a manner comparable to resident Red-tailed Hawks (R. Curry, personal communication). Anecdotal evidence suggests that raptor use at the APWRA may have increased since installation of the wind turbines (Orloff and Flannery 1992).

At **Erie Shores** (James 2008), construction activity displaced a pair of Bald Eagles nesting 400 m (1,310 feet) of a proposed turbine location, but the pair established a new nest about 900 m (2,950 feet) away and successfully raised two young. This pair returned to the new nest the following year, but the nest failed for unknown reasons. These adults and juveniles were seen perched within 200 m (660 feet) of active turbines, and on a few occasions they were observed flying closer than 100 m (330 feet) of rotating blades. Over the course of two years, Bald Eagles were noted flying past active turbines within 300 m (985 feet) of the towers on about 170 occasions. Most of these were along the Lake Erie shore, where they routinely soared past at less than 200 m (660 feet) away (137 times noted), but only 5 or 6 occasions were they seen less than 50 m (165 feet) of turning blades.

Also at Erie Shores (James 2008), a pair of Red-tailed Hawks nested within 135 m (215 feet) of a turbine under construction. The turbine was in operation about a month before the young had fledged, during which time the adults made hundreds of trips to the nest. They were observed on numerous occasions negotiating the airspace around the operating rotors. In 2007, possibly the same pair returned to nest, but they moved to 265 m (870 feet) from the same turbine. This location was within a quadrangle of turbines instead of on the edge of the wind farm. Cooper's Hawk nests were found at 112 m (367 feet) and 175 m (574 feet) away from the closest turbines.

At **Montezuma Hills** in California, similar numbers of raptor nests were found before and after construction of the project's first phase (Howell and Noone 1992). At **Stateline** on the border of Oregon and Washington, two years of raptor nest monitoring showed no measurable change in density (Erickson et al. 2004). A survey of breeding Golden Eagle territories at the APWRA found that, within a sample of 58 territories, all territories occupied by eagle pairs in 2000 were also occupied in 2005 (Hunt and Hunt 2006).

Regarding migrating raptors and other birds, a study at **Tarifa** in Spain (Janss 2000, de Lucas et al. 2004) appeared to indicate that birds were aware of, and possibly avoided, wind turbines. On one ridge with turbines and two ridges without turbines, over 72,000 migrating birds (principally Black Kites, White Storks, House Martins, and Swallows) were recorded during nearly 1,000 hours of observation from fixed observation points. Changes in flight direction were recorded more often over the wind farm than over the other two areas, with migrants tending to fly higher over the wind farm. Abundance also did not appear affected by the presence of wind turbines. In contrast, resident Griffon Vultures were not observed to fly higher over the wind farm.

At **Searsburg** in Vermont (Kerlinger 2000a, 2002), a pre-construction study observed about 50% of migrating hawks over the mountaintop where wind turbines would be constructed. The other half migrated over the mountain flanks. After construction, only 10% were observed over the turbine sector. This appears to indicate avoidance by migrating hawks.

The **Erie Shores Wind Farm** is located within two miles of Lake Erie in a well-documented, fall raptor migration corridor. Twenty miles (32 km) west of Erie Shores is Hawk Cliff Hawk Watch, which averages 37,000 raptors per fall season (Zalles and Bildstein 2000). James (2008) logged more than 2,300 observations of Sharp-shinned Hawks passing through the wind farm area, with 1,534 passing within 300 m (990 feet) of the turbines. Few birds, if any, hesitated to fly near an operating wind turbine, and there were only seven instances in which single birds got close enough to spinning rotors to be judged at risk. Indeed, just over 21% of birds made course changes that brought them closer to turbines. Most of these involved birds moving along a woodland edge or a "fencerow" of trees. Had birds not changed their headings, they would have passed turbine towers at distances greater than 100 m (330 feet), but shifting course to continue to follow tree lines brought them within 50 m (160 feet) of a turbine tower. Overall, there was nothing to indicate that the turbines were an impediment to the migration of Sharp-shinned Hawks. A concurrent mortality study found one Sharp-shinned Hawk carcass in two years of study.

Other autumn migrant raptors observed at Erie Shores flying within 300 m of wind turbines were Turkey Vulture (about 1,000 observations), Osprey (12), Bald Eagle (170), Northern Harrier (115), Cooper's Hawk (60), Northern Goshawk (6), Red-shouldered Hawk (4), Broad-winged Hawk (3), Red-tailed Hawk (300), Golden Eagle (4), American Kestrel (463), Merlin (21), and Peregrine Falcon (8). In all cases, the wind farm appeared to pose no impediment to migration, and birds appeared to negotiate the wind farm without hesitation or difficulty.

6.1.4 Displacement of Seabirds

Waterbird interactions with coastal wind farms have been well studied in Europe, where coastal and offshore wind farms have been in operation since the early 1990s. A German review of the impacts to seabirds from offshore wind farms (Dierschke and Garthe 2006) has summarized studies at five coastal wind farms.

At **Bythe Harbor** in northeastern England, nine, fairly short turbines (rotor diameter 25 m, total height 38 m) were constructed on a pier at 200 m intervals. Dierschke and Garthe (2006) report that, during a seven-year study (Still et al. 1996, Painter et al. 1999), large numbers of Great

Cormorants, Common Eiders, Black-headed Gulls, Herring Gulls, and Great Black-backed Gulls were present for several months of the year. Great Cormorants were found to cross the turbine string regularly, with 10% flying at rotor height and the rest below. In the first years, eiders flew between the turbines to enter the harbor, but later, they entered the harbor only by swimming. Large gulls made 80% of the flights between turbines, but many more flew along the turbine row (20-300 flights per ten minutes) than between them (0.7-1.5 flights per ten minutes). Great Black-backed Gulls and Herring Gulls crossed the turbines at rotor height 16% and 13% of the time respectively, with most crossing below rotor height and very few above. There were also anecdotal reports of Northern Fulmars, Black-headed Gulls, Black-legged Kittiwakes, and Sandwich Terns passing through the wind farm.

At **Maasvlakte** wind farm in the Netherlands two rows of nine and 13 turbines were built on a seawall near a breeding colony of gulls and Common Terns. The turbines are at 130-m intervals with heights of 56.5 m and rotor diameters of 35 m. According to Dierschke and Garthe (2006), van den Bergh at al. (2002) observed flight behavior of breeding birds in July of 2001. They found that 92% of seabirds at one turbine row and 62% at the other crossed below rotor height. Of those birds, 3.1% of gull flocks and 5.3% of Common Tern flocks exhibited a behavioral reaction, but only one gull turned back. Among gulls, this was about the same reaction rate as gulls flying above the turbines (3.0%). The authors concluded that the turbine rows posed no apparent barrier to foraging flights. They saw their results as showing a rapid habituation (or reduced sensitivity) to the presence of the turbines.

At **Zeebrugge** in Belgium, Everaert et al. (2002) studied flight behavior at 23 turbines of different dimensions (but all small in comparison with modern turbines) constructed on a pier. Thirteen turbines were located on the shoreline at close distance to a tern colony. The terns as well as gulls breeding elsewhere in the harbor regularly crossed the wind farm to forage at sea. According to Dierschke and Garthe's summary of the study, the majority of birds (54-82%) crossed the turbines below rotor height; only a small fraction (1-14%) crossed above. Depending on species and flight altitude, the percentage of avoidance reactions varied. We highlight the results for Common Tern, an endangered species in Delaware. At 50-m tall turbines, 498 Common Terns were recorded passing. Of the 408 birds (81.9% of total) passing at 0-15 m, 15 (3.7%) showed an avoidance reaction. Of the 35 birds (7.0%) passing at 16-50 m (rotor height), 11 (31.4%) exhibited avoidance behavior. Of the 55 birds (11.0%) passing at 51-65 m, 6 (10.9%) exhibited avoidance behavior. Interestingly, very few Least Terns exhibited avoidance behavior at any height class (5 of 1860 birds [0.2%], including 4 of 828 birds [0.5%] at rotor height; none of the 1,010 flying below rotor height demonstrated avoidance).

At **Den Oever** in the Netherlands, a single turbine was situated in the morning and evening flight paths of Black Terns and Common Terns. Dierschke and Garthe (2006) report a study during the 1997 breeding season (Dirksen et al. 1998a) in which visual and radar observation were employed to record the flight behaviors of up to 15,000 Black Terns and up to 6,500 Common Terns. These birds deviated their flight courses on both sides of the turbine, keeping a distance of 50-100 m from the turbine. Therefore, the direct vicinity of the turbine was used less than adjacent areas.

At **Lely** wind farm in the Netherlands, four turbines have been constructed 800 m (0.5 miles) offshore. These turbines had a total height of 60 m, rotor diameters of 41 m, and spacing of 200 m. Dierschke and Garthe (2006) report that Dirksen et al. (1998b) used radar to study the flight paths of two diving ducks (Pochard and Tufted Duck) whose flight paths between diurnal roosts and nocturnal feeding grounds intersected the wind farm. On moonlit nights, the ducks could apparently perceive the wind farm, because a higher proportion of ducks flew close to the wind farm and included a low rate of flights between turbines. No birds turned back, but detour reactions were common. On moonless nights, these ducks avoided approaching the wind farm; instead, they flew parallel to it. The authors also found that resident birds, in contrast to migrants stopping over, habituated to the presence of turbines, even if they constituted a barrier to their regular movements. A second study (Dirksen et al. 2000, van der Winden et al. 2000) demonstrated the same results for Greater Scaup.

6.1.4 Displacement Impacts, Conclusions

In summary, avian displacement has not been consistently demonstrated at wind farms, but they have been documented in some grassland and prairie birds and in some waterfowl and shorebirds. Forest birds, on the other hand, do not generally appear to be disturbed or displaced in a significant way by wind turbine operation; but, forest fragmentation, as a result of cutting trees and brush for wind farm construction, may impact forest-interior birds that are sensitive to edge effects and removal of forest canopy. Resident raptors may be displaced by construction activities during nesting season, but they appear to habituate to the turbines after the construction phase. Migrating raptors, however, have been shown to detect the presence of turbines and divert their course around them, but their abundance appeared not to be affected. Gulls, terns, and other waterbirds have been found to habituate to the presence of wind turbines in coastal environments and adjust their flight paths to avoid them.

6.2 Collision Mortality

6.2.1 Collision Mortality in Context

Collision mortality is well documented at wind-power sites in the United States. It is studied by systematically searching below turbines to record bird and bat carcasses found. This number is then adjusted to take into account searcher efficiency (because searchers do not find all the carcasses) and carcass removal (because scavengers may remove some carcasses before searchers look for them). According to best practices (Anderson et al. 1999, National Research Council 2007), searcher efficiency and carcass removal tests should be regularly conducted to account for different habitats, seasonal changes in ground cover, and fluctuations in scavenger populations.

A recent review of the environmental impacts of wind-energy development (National Research Council 2007) analyzed fourteen studies that measured collision mortality for an annual period and incorporated searcher-efficiency and scavenging biases into estimates. Although the protocols used in these studies varied, they generally followed the guidance in Anderson et al. (1999).

Table 6.2.1-1. Mortality Reported at U.S. Wind-Energy Projects (from National Research Council 2007)

Wind Project	# Turbines	Turbine MW	Project MW	All Bird Mortality: Turbine per year	All Bird Mortality: MW per year	Reference
Pacific Northwest						
Stateline, OR/WA[1]	454	0.66	300	1.93	2.92	Erickson et al. 2004
Vansycle, OR[1]	38	0.66	25	0.63	0.95	Erickson et al. 2004
Combine Hills, OR[1]	41	1.00	41	2.56	2.56	Young et al. 2005
Klondike, OR[1]	16	1.50	24	1.42	0.95	Johnson et al. 2003
Nine Canyon, WA[1]	37	1.30	62	3.59	2.76	Erickson et al. 2003
Rocky Mountain						
Foote Creek Rim, WY, Phase I[2]	72	0.60	43	1.50	2.50	Young et al. 2001
Foote Creek Rim, WY, Phase II[2]	33	0.75	25	1.49	1.99	Young et al. 2003
Upper Midwest						
Wisconsin[3]	31	0.66	20	1.30	1.97	Howe et al. 2002
Buffalo Ridge, MN, Phase I[3]	73	0.30	33	0.98	3.27	Johnson et al. 2002
Buffalo Ridge, MN, Phase I[3]	143	0.75	107	2.27	3.03	Johnson et al. 2002
Buffalo Ridge, MN, Phase II[3]	139	0.75	104	4.45	5.93	Johnson et al. 2002
Top of Iowa[3]	89	0.90	80	1.29	1.44	Koford et al. 2004
East						
Buffalo Mountain, TN[4]	3	0.66	2	7.70	11.67	Nicholson 2003
Mountaineer, WV[4]	44	1.50	66	4.04	2.69	Kerns and Kerlinger 2004

[1] Agricultural/grassland/Conservation Reserve Program (CRP) lands
[2] Shortgrass prairie
[3] Agricultural
[4] Forest

As can be seen in Table 6.2.1-1, mortality estimates were similar among these fourteen studies, despite differences in methodology, geography, and habitat. This suggests that these results are quantitatively robust. When the studies are averaged, they yield fatality rates of 2.51 birds/turbine/year and 3.19 birds/MW/year. The values at the Tennessee site were greater than other sites, but they do not suggest a biologically significant impact. It should be noted that a recent study at the Tennessee site (Fiedler et al. 2007) found mortality levels more in line with the other studies (see below).

Erickson et al. (2005) attempted to put this mortality in context. Based on various studies, they estimated that annual bird mortality from human-caused sources easily approaches one billion birds in the U.S. alone. The principal mortality sources they listed were:

- Collisions with windows (550 million birds, 58.2%; Klem 1990)
- Collisions and electrocutions with electric transmission lines (130 million, 13.7%; Koops 1987)
- Predation by cats (100+ million, 10.6%; Coleman and Temple 1996)
- Collisions with cars and trucks (80 million, 8.5%; Hodson and Snow 1965, Banks 1979)
- Poisoning by pesticides (67 million, 7.1%; Pimental et al. 1991)
- Collisions with communications towers (4.5 million, 0.5%; Manville 2005)

Erickson et al. (2005) did not include hunting among their mortality sources. Richkus et al. (2008) estimate that hunters harvest 100 million waterfowl and other game birds each year.

While the uncertainties in these mortality estimates are large, the numbers are so large that they cannot be obscured even by the uncertainties (National Research Council 2007). Erickson et al. did not include the impacts of hunting, oil spills, by-catch in the fishing industry, hay mowing, and several other sources of avian mortality, which together would add another 100+ million birds to their total.

In contrast, Erickson et al. found that, collisions from wind turbines amounted to <0.01% of human-caused mortality for the sources he included. Using a likely range in mortality rates averaging 2.11 birds/turbine/year and 3.04 birds/MW/year, they estimated that 20,000 to 37,000 birds were killed at about 17,500 wind turbines of 6,374 MW of total U.S. capacity in 2003. Today, with more than 30,000 wind turbines operating in the U.S., it is likely that the total numbers of fatalities at wind plants has grown to more than 75,000 per year (assuming <3 birds per turbine per year).

Based on best available estimates, Erickson et al. (2005) figured that human-caused mortality takes approximately 5% to 10% of the U.S. landbird population each year. The biological significance of this take may be uncertain, but best wildlife management practices routinely allow harvests at or above these levels for waterfowl and gamebird populations, including some species of conservation concern. Using a common species as an example, in 2007, about 1.1 million hunters harvested 20.5 million Mourning Doves (Richkus et al. 2008). This is slightly more than 15% of the total population of about 130 million individuals (Rich et al. 2004) and additive to the other human-caused Mourning Dove mortality discussed above.

For context in Delaware, we have prepared a list (Table 6.2.1-2) of SGCN species that are hunted in the state, along with their Tier status (http://www.dnrec.state.de.us/nhp/information/dewaptoc.shtml), daily bag limits, possession limits, and approximate annual harvest during the 2007 and 2008 hunting seasons (Richkus et al. 2008). Note that a total of 19 or more SGCN species are also hunted in Delaware. What is significant about this list is that it shows that even rarer species may be harvested without significant impacts to the species' populations. A comparison with wind turbine harvests is most interesting because the impacts to these species at most wind turbine sites may be counted on one hand, if not with one or two fingers. Also of note is the fact that the margin of error (confidence intervals) provided by the agencies that keep track of hunting harvests are on the order of thousands of individuals for species like waterfowl and for rails there appears to be orders of magnitude differences between high and low estimates of hunting harvest for a particular year.

Table 6.2.1-2. Summary of selected SGCN species that are hunted in Delaware and may be present at the Project site (King Rail, American Black Duck, Northern Bobwhite, and American Woodcock have all been shown to be declining in the U.S. Margin of error for Canada Geese and ducks ranges from 20-35%+ and for woodcock it was 100%.)

Species	Tier Status	Daily Bag Limit/Possession Limit Per Hunter	Average Harvest 2007 and 2008
Canada Goose	Tier 1 - Migratory	2/4	~25,000
	No Tier - Resident	15/30	
Mallard	Tier 2	4/8	~19,000
American Black Duck	Tier 1	1/2	~6,000
King (or Clapper Rail)*	Tier 2	10	<50 ± 170%
Northern Bobwhite	Tier 2	6/12	Not Available
American Woodcock	Tier 2	3/6	±1,000

*Virtually indistinguishable between species, especially when hunting.

In other words, collisions with wind turbines are a small fraction of incidental bird mortality. When added to other mortality sources, wind-turbine collisions appear unlikely to affect bird populations in a biologically significant way. This is particularly true because studies (discussed in Section 6.2.4) show that fatalities are spread among dozens of species. Nonetheless, there are taxonomic differences in collision susceptibility (see discussion of night-migrating songbirds and raptors below) and population sensitivity.

We estimate that more than 50,000 carcass searches at individual wind turbines at more than 30 sites have been conducted to date in the United States. Many more have been conducted in studies in Europe, Canada, and Australia. This research far exceeds post-construction wildlife-impact studies for all other types of electricity generation (coal, natural gas, nuclear, hydro, etc.), which account for the other 99% of electricity generation in the U.S. Permitting agencies are not requesting or requiring post-construction studies for traditional forms of electricity generation, so it is not possible to make comparisons with wind power. Granted, the wildlife effects of traditional electricity generation are generally indirect and difficult to quantify (e.g., effects of acid rain, mercury bioaccumulation, habitat fragmentation, strip mining, oil spills, and climate change), sometimes extending hundreds or thousands of miles from the point sources. But, indications are that these effects are probably immense.

For example, the Wood Thrush (*Yellow WatchList*) is a forest-interior species that breeds in the eastern North America, downwind of Midwest power-plant emissions. A Cornell University study (Hames et al. 2002) has demonstrated a strong correlation between acid rain occurrence and decreases in Wood Thrush numbers (estimated at 1.7% per year). The suspected reason is the leaching of calcium in the environment by acid rain, which results in eggshell thinning or scarcity of calcium in the diets of developing birds. While it is difficult to make a per megawatt comparison of Wood Thrush mortality between electricity sources, it is not hard to see that a decrease in fecundity over a species' range has a population effect, whereas the removal of a small number of individuals through turbine collisions does not.

This conclusion is supported by a recent review (Environmental Bioindicators Foundation and Pandion Systems 2009) that found that, overall, non-renewable electricity generation sources, such as coal and oil, pose higher risks to wildlife than renewable electricity generation sources, such as hydro and wind. Based on the comparable amounts of SO_2, NO_X, CO_2, and mercury emissions generated from coal, oil, natural gas, and hydro and the associated effects of acidic deposition, climate change, and mercury bioaccumulation, the authors found that coal as an electricity generation source is by far the largest contributor to risks to wildlife in the New York/New England region. They also detailed impacts caused by the extraction (mining and drilling) of fossil fuels, which do not occur as part of the wind-energy generation lifecycle.

6.2.2 Collision Risk Factors: Night-Migrating Songbirds

At the fourteen projects summarized in Table 6.2.2.1-1, the percentage of night-migrating songbirds among all bird fatalities was found to increase from west to east – from 24% at Stateline in the West and 48% at Foote Creek Rim in the Rocky Mountains, to 70% at Buffalo Ridge in Minnesota and 71% at Mountaineer in West Virginia (National Research Council 2007). At Buffalo Mountain in Tennessee, all birds killed were night migrants (Nicholson 2002, as well as the more recent Fiedler et al. 2007). A recent study at Maple Ridge in northern New York State (Jain et al. 2007) found that 80% of casualties were night migrants. This pattern is likely the result of the more dense nocturnal migration over eastern North American than over the western part of the continent (see Gauthreaux et al. 2003, Lowrey and Newman 1966).

These percentages translate to about one night-migrating songbird killed per turbine per year in the west, while rates in the east are, about three-five/six birds or more. What is notable, however, is that most night-migrant fatalities at wind turbines are of single birds. This is very different from the large-scale, episodic mortality events that have been documented over the past sixty years at communication towers, where some fatality events have been recorded in the hundreds or thousands of birds (Kerlinger 2000b).

Not all communication towers are responsible for large-scale, episodic mortality events. Those that do are almost all taller than 500-600 feet (152-183 m) (Kerlinger 2000b). This is likely due to the increasing volume of nocturnal migration with altitude, which was discussed above in

Section 3.2.1. Presently, the rotor-swept area of most wind turbines extends upward to about 400 feet (122 m). However, engineering advances have increased the height of wind turbines to harvest stronger winds aloft. Already, 500-foot (152-m) turbines are being proposed at some sites.

Where large mortality events have been recorded at communication towers less than 500 feet, those towers were almost without exception adjacent to sources of bright lights, such as steady-burning sodium-vapor lights (Kerlinger 2004). Very attractive to birds, sodium-vapor and other very bright lights are different from the lights the Federal Aviation Administration (FAA) stipulates for wind turbines. Sodium-vapor lights were implicated in the collisions of 30 night-migrating songbirds on a foggy night in May 2003 at the Mountaineer Wind Energy Facility in West Virginia (Kerns and Kerlinger 2004). Sodium-vapor lamps at the ridgeline substation attracted the birds, which collided with the three closest turbines (mostly the closest turbine) and the substation infrastructure. Almost no birds were found at the 41 other turbines at that project, despite 11 of them being lit with L-864 flashing red lights.

Gehring et al. (2009) have demonstrated that lighting affects the frequency of avian collisions at communication towers. In Michigan, they found a mean of 3.7 songbird fatalities per migration season under 116-146 m above ground level (agl) towers equipped with only red or white flashing obstruction lights, whereas towers with non-flashing/steady burning lights in addition to flashing lights were responsible for 13.0 fatalities per season. They also found no significant differences in fatality rates among towers lit with only red strobes, white strobes, and red, incandescent flashing lights. Their results suggest that avian fatalities can be reduced, perhaps by as much as 50-71% (about 2 million birds), at guyed communication towers simply by removing non-flashing/steady burning red lights.

Wind turbines almost never have steady-burning red L-810 obstruction lights. Rather, they are equipped with L-864 flashing red lights (preferred by FAA) and sometimes L-865 flashing white lights. Moreover, the FAA does not require that all wind turbines be lit. Instead, gaps between lights may not exceed one-half mile (0.8 km) (see FAA Advisory Circular, available at http://www.windaction.org/documents/7912). In this regard, a recent review (Kerlinger et al., unpublished manuscript) of studies at 31 wind farms showed no detectable difference in fatality rates between wind turbines deployed with L-864 flashing red lights and turbines without lights. The Kerlinger et al. study summarized the results of 25,000+ individual turbine fatality searches and revealed fatality rates at turbines across North America at between about one and five/six birds per turbine per year.

Where L-810 steady-burning red lights have been used on wind turbines, higher bird fatalities have sometimes been recorded. At Buffalo Ridge in Minnesota, a small fatality event involving 14 migrants at two adjacent turbines (seven under each turbine) was probably the result of the steady-burning red light on one of the turbines combined with weather conditions. At Erie Shores in Ontario, Canada, turbines with lighting (in all cases steady-red) averaged more night-migrant fatalities than unlit turbines. For this reason, Environment Canada requested that the lighting be changed to flashing red. This suggests that L-810 steady-burning red lights can attract birds.

It should be noted that, in its guidance document (USFWS 2003), the USFWS recommends only white strobes to avoid attracting night migrants. But as noted above, the color of the lighting appears not to matter, so long as it is not steady burning.

Finally, guy wires on tall communication towers (at many heights arrayed in three directions) probably account for almost all of the collisions, as birds attracted by lights circle the towers in a disoriented way (Gauthreaux and Besler 2006). It is noteworthy that the literature reveals few fatalities (between zero and two birds/tower/year) at freestanding (i.e., unguyed) communication towers, some of which are as tall as 475 feet (145 m) (Gehring and Kerlinger 2007a and 2007b).

In summary, wind turbines essentially lack the major risk factors implicated in large-scale mortality events involving nocturnal migrants at communication towers. These risk factors are: 1) height above 500-600 feet (152-183 m), 2) attractive lighting, and 3) guy wires. In contrast, wind turbines: 1) are relatively short in height when compared with tall communication towers, 2) have flashing lights that appear not to attract nocturnal migrants, and 3) lack guy wires.

6.2.3 Collision Risk Factors: Raptors

Raptor mortality has been generally low at most U.S. wind farms. When averaged, the raptor mortality reported in fourteen U.S. studies analyzed by the National Research Council (2007; see Table 6.2.1-1) was 0.03 birds/turbine/year and 0.04 birds/MW/year. In its review, the National Research Council saw no evidence that fatalities caused by wind turbines had resulted in measurable demographic changes to U.S. bird populations, including raptors, but it did single out the Altamont Pass Wind Resource Area (APWRA) as a possible exception with respect to raptors. We examined the Altamont to shed light on factors that increase raptor collision risk.

Located east of San Francisco, the APWRA is one of three early wind farms constructed in California in the 1980s, the other two being Tehachapi and San Gorgonio (Palm Springs). Unlike present day wind farms, these early plants crowded thousands of small turbines into the landscape. Today, the APWRA still has between 5,000 and 5,400 turbines of various types and sizes (ranging from 40 kW to 300 kW, with 100 kW the most common) that total approximately 550 MW (102 kW/turbine) (National Research Council 2007). Sited in treeless grassland on rolling hills, the APWRA contains abundant perching sites for raptors on the lattice towers of the older turbines and on aboveground transmission lines (National Research Council 2007). Already in progress, repowering will substantially decrease the number of turbines, as older models are replaced with new ones, but the APWRA's total rotor-swept area will likely not decrease (Thelander and Smallwood 2007).

Raptors are remarkably abundant in the APWRA. In one study (Thelander et al. 2003), the five most commonly observed species among all birds were Red-tailed Hawk (30% of observations), Turkey Vulture (14%), Common Raven (13%), Golden Eagle (7%), and American Kestrel (7%). Mortality searches found that Golden Eagle, Red-tailed Hawk, and American Kestrel were killed more often than expected based on abundance, while Turkey Vulture and Common Raven were rarely killed (Orloff and Flannery 1992, 1996).

Golden Eagle mortality was particularly high, estimated at 1,500-2,300 individuals over the past two decades (Thelander and Smallwood 2007), but these estimates have been questioned. According to the National Research Council (2007), a four-year radio telemetry study conducted by Hunt (2002), concluded that the APWRA's Golden Eagle population was self-sustaining, but fatalities resulting from wind-energy development were concerning because the population apparently depended on immigration of eagles from other subpopulations to fill vacant territories. A follow-up survey in 2005 (Hunt and Hunt 2006) found that, within a sample of 58 territories, all territories occupied by eagle pairs in 2000 were also occupied in 2005.

Several factors are believed to contribute to raptor risk in the APWRA (Howell and DiDonato 1991, Orloff and Flannery 1992, 1996), namely:

- **High raptor abundance,** related to a high density of California ground squirrels and other prey
- **High turbine density creating many obstacles to flight,** with thousands of closely spaced turbines (less than 10 m [30 feet] between rotors)
- **Some turbines sited in high risk situations,** such as in canyons, where mortality was found to be greater
- **Rotor-swept area close to ground** (within 10 m [30 feet]) in airspace where raptors forage extensively
- **Lattice towers that encourage perching on turbines**, drawing birds to the turbines
- **Rotors that are difficult to see,** because they revolve at high rates (40-72 rpm)

Fortunately, new turbine designs avoid or minimize most of these risk factors. For example, raptors cannot perch on the tubular towers of late-model turbines, and they can better see the rotors, which spin slowly (at 12-18 rpm). Raptors have more room to maneuver among late-model turbines, because they are spaced more than 250 m (800 feet) apart, and their rotors do not sweep lower than 30 m (100 feet).

Of particular importance, however, is improved understanding, gained through mortality studies, of what siting and habitat conditions increase risk. Thelander and Smallwood (2007) found that fatality rates at the APWRA were weakly related to most landscape elements, such as slope conditions, but turbines in canyons killed more raptors, especially Golden Eagles. Red-tailed Hawk fatalities appear to be strongly linked to pocket gopher distribution, whereas turbine strings where Golden Eagles are killed appear to be associated with rock piles, which provide cover for cottontail rabbits.

These findings suggest a number of actions to minimize fatalities, such as not placing turbines in canyons, not piling rocks cleared from lay-down areas near turbines, and not grazing cattle intensively near turbines (because short grass attracts rodent colonies and the raptors that prey on them). High raptor abundance at the APWRA is expected to continue, but with repowering, avoiding turbine placements in canyons, and managing habitat to draw raptors away from turbines, raptor mortality should decrease significantly.

No other wind-power site in North America has a raptor abundance approaching that of the APWRA. But, with modern turbine designs, attention to avoiding risky turbine placements, and, when necessary, habitat management to draw raptors away from turbines, wind farms may minimize raptor mortality and avoid regional population effects.

6.2.4 Review of Avian Mortality Studies

Based on the reports to which we have access, more than 40 avian mortality studies have been conducted at wind farms in the United States and Canada. They are listed with a summary of mortality data in Appendix F. In this section, we review the results by region and discuss noteworthy findings.

In the **Eastern United States**, wind farms are mostly located in farmland and on forested ridges, but coastal projects are beginning to be built. The empirically estimated fatality rate at a mountaintop site in Tennessee (Nicholson 2003) was greater (7.7 birds/turbine/year) than at other U.S. sites (see Table 6.2.2.1-1), but a more recent study (Fiedler et al. 2007) has shown much reduced mortality (1.8 birds/turbine/year) at that site. In general, fatality rates in the East (above 4 birds/turbine/year) are greater than in the far west, likely because of greater densities of night-migrating songbirds (see Gauthreaux et al. 2003, Lowrey and Newman 1966). Raptor mortality has been low, consisting mainly of resident Turkey Vultures and Red-tailed Hawks (various studies). This is despite intensive wind-farm development on Appalachian ridges, where a heavy fall raptor migration occurs (Zalles and Bildstein 2000). On those ridges, a raptor species of special concern is Golden Eagle, because a large, but unknown, fraction of its relatively small eastern North American population migrates along central Appalachian ridges in both late fall and early spring (Brandes 2005). To date, Golden Eagle mortality has not been recorded. One Peregrine Falcon and two Osprey (both state-listed) were recorded among 29 carcasses found at a small coastal wind farm bordering saltmarsh in New Jersey (New Jersey Audubon 2008). Very few waterbirds have been recorded at inland sites, but mainly gulls made up 11 of 29 carcasses discovered at the coastal New Jersey site.

In the **Central United States**, wind farms are sited mainly in farmland. Measured fatality rates (correcting for searcher efficiency and scavenging) have been low, between 0.98 and 4.45 birds/turbine/year (see Table 6.2.1-1). As already noted, night-migrating songbirds made up about 70% of fatalities at one site. Raptor fatalities have generally been low, but recent studies from Texas (Tierney 2007) and Oklahoma (Schnell et al. 2007) show surprising mortality among Turkey Vultures. This species frequents many U.S. wind farms, but it is infrequently recorded in mortality studies (see APWRA discussion above). In the Texas study, most of the Turkey Vultures that could be aged were juveniles, suggesting that younger birds may be more collision prone. Regarding waterbirds, at the Top of Iowa wind farm, a study (Jain 2005, Koford et al. 2005) of 89 turbines located within one to two miles of three waterfowl management areas reporting >1.5 million duck and goose-use-days per year revealed no fatalities of Canada Geese or other waterfowl, despite intense use of the turbine fields. Waterfowl use of the wind-farm area did not diminish after construction. At Buffalo Ridge in Minnesota (Johnson et al. 2002), few waterbirds were recorded among victims, despite their regular presence and the wind farm's location on a major migration route (Bellrose 1980). Similarly, no waterfowl fatalities were found during a study at the Crescent Ridge wind plant in north-central Illinois (Kerlinger et al. 2007).

In the **Rocky Mountains**, wind turbines have mostly been constructed in rangeland and shortgrass prairie. Fatality rates have been recorded at less than 2 birds/turbine/year (see Table 6.2.1-1). At a site in Wyoming (Young et al. 2003), about half of the fatalities were migrating songbirds. Most of the recorded fatalities at a Colorado site (Kerlinger et al., unpublished manuscript) were resident Horned Larks, which were likely struck on their aerial courtship flights. At that site, raptor fatalities have been infrequent, involving mostly resident American Kestrels. Very few waterbird casualties have been recorded.

In **California and the Pacific Northwest**, wind farms are mostly situated in farmland and grassland. Outside the Altamont (APWRA, see Section 6.2.3), reported fatality numbers have been small. At facilities in Oregon and Washington, fatality rates have ranged from 0.63 to 3.59 birds/turbine/year (see Table 6.2.1-1), with night-migrant casualties calculated at 24% at Stateline on the Washington/Oregon border (Erickson et al. 2004). It is important to note that the large number of raptor fatalities recorded at the APWRA has not been recorded at other California wind farms (Tehachapi and San Gorgonio) that also have thousands of older turbine models (Anderson et al. 2000). This strongly suggests that raptor abundance at the APWRA was the principal risk factor, along with topography and dense spacing of turbines. Elsewhere, raptor mortality has been low, including studies with no raptors recorded among victims. Waterbird mortality has been very low.

In **Canada**, mortality at the Erie Shores Wind Farm in Ontario (James 2008) was estimated at between 2.0 and 2.5 birds/turbine/year, including a rate of 0.04 birds/turbine/year for raptors. Mortality was slightly greater at wind turbines within 200 m (660 feet) of the Lake Erie shore bluffs, at turbines with steady red aviation-warning lights, and within 50 m (165 feet) of woodlands. In future installation of wind farms in the Great Lakes area, James (2008) recommends that all turbines be kept at least 250 m (820 feet) away from shore bluffs or shores, aviation-warning lights should be flashing, and turbine bases should be kept at least 50 m (165 feet) from trees. Two other studies in Ontario revealed mortality levels similar to those at Erie Shores.

In **Europe**, bird collisions with wind farms have been less comprehensively investigated than in the U.S. (Hötker et al. 2006). Data compiled by Dürr (2001, 2004; reviewed by Hötker et al.) show notably high raptor mortality at mountain sites (especially Griffon Vulture) and among gulls and raptors (especially White-tailed Eagle) at wetland and coastal sites. High Red Kite mortality has occurred in Germany where wind turbines were placed in pastures and fallow fields, where birds hunt for rodents, but converting fields to cropland appears to be an effective method for drawing birds away from turbines and reducing mortality (Jan Blew, personal communication). Hötker et al. (2006) have found that species or species groups that show little avoidance reaction to wind farms (e.g., birds of prey, gulls, and starlings) are more likely to be collision victims than species that tend to avoid wind farms (e.g., geese and shorebirds). Crows are a notable exception in that they do not avoid wind farms, yet they are rarely killed.

Migrant fatalities have been relatively rare at European sites, notably so at migration bottlenecks, such as Tarifa, Spain, where several hundred thousand soaring birds, including more than 100,000 raptors, and millions of other birds, converge on the Straits of Gibraltar to cross between Europe and Africa (Marti Montes and Barrios Jaque 1995, Janss 2000, Barrios and Rodriguez

2004, and de Lucas et al. 2004). Moreover, as discussed above, migrants were found not to exhibit behaviors that put them at risk of collision, such as flying within 5 m (16 feet) of wind turbines (Barrios and Rodriguez 2004). Nonetheless, mortality at Tarifa was relatively high in resident Griffon Vultures and Kestrels, the former in winter wind conditions that limited their maneuverability, the latter during the breeding season at turbine locations in preferred hunting habitats (Barrios and Rodriguez 2004). Elsewhere in Spain, significant Griffon Vulture mortality has been recorded at wind farms in the Pyrenees Mountains of Navarre, where high mortality was found at closely spaced turbines on ridges habitually used for soaring by nearby colonies, with higher rates in wind conditions that limited maneuverability (Lekuona 2001). There is also a recent report from Valencia of 250 Griffon Vultures killed in one month at a wind farm (Bowyer et al. 2009).

6.2.5 Collision Mortality, Conclusions

Post-construction fatality studies have demonstrated that fatalities are relatively infrequent events at wind farms. In a recent literature review, calculated mortality rates at U.S. wind farms were similar, averaging 2.51 birds per turbine per year and 3.19 birds per MW per year. Rates were greater in the eastern U.S. (up to about 7 birds/turbine/year) than in the west, presumably because of the denser nocturnal migration of songbirds in eastern North America. To date, no federally listed endangered or threatened species have been killed, and only occasional waterfowl or shorebird fatalities have been documented. For raptors, only at the Altamont Pass Wind Resource Area (APWRA) and at some European sites have fatality levels been suggestive of biologically significant impacts. However, research indicates that raptor fatalities can be minimized by avoiding high-risk turbine placements and by managing habitat so that raptors hunt away from turbines.

7.0 Avian Risk Assessment for the University of Delaware Wind Turbine Project

7.1 Displacement Risk

The wind turbine at the University of Delaware site will be constructed on what appears to be barren fill bordering a 10-acre (4-ha) patch of disturbed shrubby woodland. An extensive saltmarsh of many hundreds of acres begins at about 200 feet (60 m) from the turbine base. Thus, a small number of individuals of an assortment of mainly common shrubland/edge species are expected to inhabit the shrubland, while larger numbers of a few saltmarsh-specialty species are expected to inhabit the adjacent marsh.

We define displacement risk as the probability that bird densities around wind turbines decrease to the point of having a population effect. Using this measure, it is likely that bird species inhabiting the Project site and vicinity will not be at significant risk of displacement, because they have large populations that have withstood environmental disturbance (e.g., agriculture, residential development, draining of saltmarshes, etc.). Possible exceptions would be endangered species, because they have small populations and generally require less disturbed habitats, but data sources indicate that endangered species are not likely to nest close enough to the proposed turbine to be displaced by it.

It is uncertain whether saltmarsh breeding birds, such as Saltmarsh Sparrow and Seaside Sparrow (both SGCN-1 and *Red WatchList*), will be reduced in the vicinity of the turbine. Nonetheless, a small reduction in density, if it occurs, is unlikely to have a population effect, given that the populations of these species are reasonably large and abundant habitat occurs in the Project vicinity. Furthermore, it will probably be impossible to test for reduced densities given that sample sizes will be too small around a single turbine.

7.2 Collision Risk

To begin this section, we summarize a fatality study conducted at a coastal wind farm in New Jersey. The results of that study are particularly applicable to the Project because of habitat and geographic similarities. New Jersey Audubon (2008) studied collision mortality at the Atlantic County Utility Authority (ACUA) Wind Energy Facility (see Figure 1), a 5-turbine wind farm located 57 miles (92 km) northeast of the Project site. It is situated on a tidal creek in saltmarsh 2 miles (3.2 km) from the Atlantic Ocean. New Jersey Audubon searched each turbine about 100 times from August 2007 to September 2008 (roughly three migration, one winter, and one nesting season) and found 23 avian carcasses:

- **9 gulls (39%),** 7 Laughing Gulls, one Herring Gull, and one Great Black-backed Gull
- **6 night-migrating songbirds (26%),** one each of Red-eyed Vireo, Ruby-crowned Kinglet, Blue-gray Gnatcatcher, Gray Catbird, Swamp Sparrow, and Baltimore Oriole.
- **3 raptors (13%),** two Osprey (NJ threatened and Delaware SGCN-1) and one Peregrine Falcon (NJ endangered and Delaware SGCN-2)
- **2 shorebirds (9%),** one Short-billed Dowitcher and one American Woodcock
- **2 unknown species (9%)**
- **1 Red-winged Blackbird (4%),** a diurnal migrant

Note that among the fatalities during three migration seasons, as well as one winter and one nesting season, there were no waterfowl and only two shorebirds reported, despite the site being located in one of the most dense concentration areas of shorebirds and waterfowl along the East Coast. Preconstruction studies (Kerlinger 2003) revealed that more than 3,600 waterfowl and 1,100+ shorebirds were present within the boundaries of the ACUA turbine areas during fall 2002. The ACUA site is also adjacent to a designated Western Hemisphere Shorebird Reserve Network site (Forsythe National Wildlife Refuge) and a New Jersey Wildlife Management Area. Thus, although these birds were present in large numbers, they were not highly susceptible to colliding with the five wind turbines. The relative scarcity of waterfowl and shorebird fatalities has also been demonstrated in more than 30 studies at wind farms across North America (see Section 7.2.3 discussion). Many of those wind farms are situated adjacent to waterfowl management areas or migration stopover areas where tens of thousands to millions of these birds occur during fall and spring migration.

Given that New Jersey Audubon has not reported searcher efficiency and carcass removal rates, mortality rates of some species at the ACUA facility cannot be directly compared with other wind farms. Nonetheless, waterbird mortality, excluding gulls, was minimal and not that much different from what has been recorded at inland wind farms in the U.S. Ducks and geese were absent, as were herons, egrets, ibis, rails, terns, and other waterbirds. Higher gull fatality rates are to be expected, given the ACUA wind farm's coastal situation, and given that gulls were attracted by the thousands to sewage treatment tanks and settling ponds adjacent to turbines. The number of discovered carcasses of night-migrating songbirds (even when the two unknown species are added) does not appear to indicate that much greater mortality than that documented at inland wind farms in the Eastern U.S., but we await New Jersey Audubon's final report.

Given that collision risk varies with bird type, we will discuss the various bird groups separately: night-migrating songbirds, raptors, waterbirds, and listed species.

7.2.1 Night-migrating Songbirds

As discussed in Section 6.2.2, wind turbines essentially lack the risk factors demonstrated for large-scale mortality events involving nocturnal migrants at tall communication towers. In contrast, wind turbines: 1) are shorter than tall communication towers, 2) have flashing lights that do not attract nocturnal migrants (Gehring et al. 2009, Kerlinger et al. in prep.), and 3) lack guy wires, which are responsible for a vast majority of collisions.

Regarding collision risk to night-migrating songbirds at the Project site, the studies discussed in Section 4.2.1 strongly suggest that nocturnal migration occurs across a broad front at altitudes mostly above the sweep of wind-turbine rotors. A small percentage of migrants is likely to fly below 125 m (410 feet, the height of the proposed wind turbine) and to be at risk of collision. If L-864 red-flashing lights (likely to be recommended by the FAA) are installed on the Project's turbine, evidence suggests that these birds will not be attracted to collide. Therefore, significant fatality events at the University of Delaware site are not an issue, and the number of fatalities on a per turbine per year basis will likely be similar to that found at Eastern U.S. wind farms, which generally have reported fewer than five night migrants per turbine per year. This is further supported by the small number of observed fatalities of night migrants (N = 6) at the coastal ACUA wind farm.

The Atlantic Ocean is a migration barrier that can precipitate fallout events in coastal woodlands after heavy flight nights. It is unlikely, however, that extraordinary numbers of songbirds will use the shrubland patch at the Project site, given the patch's small size and distance from the coast, and given that similar habitat is abundant in the Delaware coastal zone.

7.2.2 Raptors

In Section 6.2.3, the discussion of raptor risk factors focused on the Altamont Pass Wind Resource Area (APWRA), the only U.S. wind farm where potentially significant raptor mortality has been reported. Because modern turbines will be used at the Project site, raptor risk factors involving older turbines at the APWRA do not apply (e.g., high turbine density creating many obstacles to flight, rotor-swept area close to the ground, lattice towers that encourage perching on turbines, rotors that are difficult to see). Therefore, we examine the other risk factors that could conceivably apply: high raptor abundance and high-risk situations.

Data from the Breeding Bird Survey (BBS; see Section 4.1.2) and Christmas Bird Counts (CBC; see Section 4.3) indicate that raptor abundance is relatively low in the breeding and winter seasons. Data from Cape Henlopen (see Section 4.2.2) indicate a significant coastal raptor migration in fall, with Osprey and Sharp-shinned Hawk (both SGCN-1) particularly abundant. Raptor numbers are an order of magnitude less in spring migration, when no species is particularly abundant.

The Project site is sufficiently inland from Cape Henlopen and barrier beaches to be off the main raptor migration path, but migrating Osprey, Sharp-shinned Hawks, falcons, and other species may occasionally hunt in the vicinity of the proposed turbine. As explained in Section 6.1.3, studies from Tarifa, Spain, and Erie Shores, Canada, indicate that migrating raptors tend to avoid wind turbines and are not particularly collision prone. Nonetheless, two Osprey (SGCN-2) and one Peregrine Falcon (SGCN-2) were recorded among fatalities in 18 months of research at the ACUA wind farm (see above).

Topography at the site does not present a risk to soaring raptors. The site lacks canyons and steep hills (where raptor mortality was particularly high at the APWRA), as well as traditional soaring ridges (where Griffon Vulture mortality was high at sites in Spain).

7.2.3 Waterbirds

Waterbird mortality at U.S. wind farms has been demonstrated to be relatively low (but see the ACUA example above) and in many cases, nonexistent. In a review of bird collisions reported in 31 studies at wind-energy facilities, Erickson et al. (2001, cited in National Research Council 2007) reported that 5.3% of fatalities were waterfowl, 3.3% waterbirds (mainly rails and coot), and 0.7% shorebirds. It is interesting that waterfowl and shorebirds are mostly nocturnal migrants, but they do not appear to be attracted to lights (FAA or other types). Hüppop et al. (2006) demonstrated this in their carcass searches at the illuminated FINO 1 platform in the

North Sea, where they found no waterfowl and only one shorebird (a Dunlin) among 442 carcasses.

Given that the Project site is located on a saltmarsh, waterbird mortality may be similar to that reported at the ACUA wind farm (see above), which was mainly gulls and no waterfowl. Nonetheless, the Project would consist of only one turbine and the site lacks the sewage settling ponds that attracted gulls to the ACUA site. Thus, even gull mortality is likely to be low. Gull mortality, if it occurs, is unlikely to result in a population effect. Wildlife managers kill thousands of gulls each year at New York City-area airports to minimize risk of bird collisions with aircraft, but this program has not curbed regional gull populations in a significant way (Dolbeer et al 1993).

7.2.4 Listed Species

Any listed species that habituates to the Project's turbine and regularly flies at or near rotor height may be at greater risk of collision. In this regard, the Delaware-endangered Bald Eagle may qualify because wintering eagles are likely to hunt Snow Geese and other waterbirds in the saltmarsh adjacent to the turbine. It is important to point out, however, that Bald Eagle has not been reported in collision studies at any U.S. wind farms. Note, however, that closely related White-tailed Eagle in Europe has been killed at coastal wind farms in Germany (Dürr 2001, 2004) and Norway (reported by BirdLife International).

Other listed species are likely to fly over the saltmarsh adjacent to the turbine, but they would do so mostly at altitudes lower than the rotor-swept zone. Thus, collision risk would be low. Possibilities include Black-crowned Night-Heron, Yellow-crowned Night-Heron, Northern Harrier, American Oystercatcher (also *Yellow WatchList*), Common Tern, Forster's Tern, Least Tern (also federally endangered and *Red WatchList*), and Black Skimmer (also *Yellow WatchList*). All of these species were observed near the ACUA turbines, yet none were found dead by New Jersey Audubon despite intensive search effort.

7.2.5 Collision Risk, Conclusions

In most respects, fatality numbers and species impacted are likely to be similar, on a per turbine per year basis, to those found at Eastern U.S. wind farms. Those fatalities are not likely to be biologically significant because there will be only one turbine at the Project site and because the small number of fatalities likely to result will be distributed among several species. Collision risk to night-migrating songbirds is likely to be similar to other sites examined because migration occurs on broad fronts at altitudes mostly above the rotor-swept zone; in addition, habitat at the Project site is unlikely to attract large numbers of songbirds in coastal fallout events. Collision risk factors for raptors also will likely be minimal, given that raptor abundance is generally low, the Project is removed from coastal migration paths, and the proposed turbine placement does not appear to be problematic. The Project may register slightly greater waterbird mortality, particularly among gulls, than inland wind farms because of its coastal location. Among listed species, the Delaware-endangered Bald Eagle may be at slightly elevated collision risk because some eagles are likely to hunt Snow Geese and other waterbirds in the saltmarsh adjacent to the turbine.

8.0 Recommendations

Pre-construction Studies

- A seasonal flight-use study may be considered, although the project is so small as to make impacts minimal and, therefore, preconstruction studies cannot predict risk precisely or reliably. Such a study would measure flight use of the site (particularly at altitudes equivalent to the rotor-swept zone) by raptors, waterbirds, and landbirds, paying particular attention to the endangered Bald Eagle and other special-status species.

Construction Guidelines

- Electrical lines within the Project site should be underground. Any new above-ground lines from the site to a substation or transmission line should follow Avian Power Line Interaction Committee (APLIC) guidelines for insulation, spacing, and obstruction marking.
- Permanent meteorology towers, if any are proposed, should be freestanding (i.e., without guy wires) to prevent the potential for avian collisions.
- Size of roads and turbine pads should be minimized to disturb as little habitat as possible. After construction, the area around the turbine should be maintained as mowed lawn to facilitate a mortality study.
- Lighting of turbines and other infrastructure should be minimal to reduce potential for attracting night-migrating songbirds and other species. Federal Aviation Administration (FAA) night-obstruction lighting should only be flashing beacons (L-864 red or white strobe [or LED], or red-flashing L-810) with the longest permissible off cycle. Steady-burning (L-810) red FAA lights should not be used. Sodium vapor lamps and spotlights should not be used at any facility (e.g., lay-down area or substation) at night except when emergency maintenance is needed.

Post-construction Studies

- A mortality study following best practices should be conducted over a two-year period, with the second year contingent on what is found during the first year. In other words, if fatalities in the first year are construed as biologically significant, a second year of study would be conducted.
- Results of the mortality study should be compared with cradle-to-grave (life-cycle) cumulative impacts to birds from other types of power generation now supplying electricity in Delaware. This comparison would facilitate long-term planning with respect to electrical generation and wildlife impacts. The study should seek information from USFWS, DDFW, and environmental organizations regarding existing energy-generation impacts to wildlife in Delaware. If information is not available, these agencies and organizations should consider funding such studies.

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Appendix A. Photographs of representative habitats

Appendix A. **Photographs of representative habitats (continued)**

<u>Appendix B.</u> Birds observed during 4 December 2009 site visit

Species listed in the Delaware Wildlife Action Plan (Allen et al. 2006) are indicated. Delaware-endangered (DE-E) species are shown in boldface, and Species of Greatest Conservation Need (SGCN) are noted; see Section 4.1 discussion.

Snow Goose
Canada Goose (SGCN-2)
American Black Duck (SGCN-1)
Mallard (SGCN-2)
Bufflehead (SGCN-2)
Northern Gannet
Double-crested Cormorant (SGCN-2)
Great Blue Heron (SGCN-2)
Black Vulture (SGCN-2)
Turkey Vulture
Bald Eagle (DE-E)
Northern Harrier (DE-E when breeding)
Cooper's Hawk (DE-E when breeding)
Red-shouldered Hawk (SGCN-2)
Red-tailed Hawk
Merlin
Killdeer
Ring-billed Gull
Herring Gull
Great Black-backed Gull
Rock Pigeon
Mourning Dove
Belted Kingfisher
Red-bellied Woodpecker
Downy Woodpecker
Northern Flicker
Blue Jay
American Crow
Fish Crow
Horned Lark
Carolina Chickadee
Tufted Titmouse
Carolina Wren
Winter Wren
Golden-crowned Kinglet
Hermit Thrush
American Robin
Gray Catbird
Northern Mockingbird
Brown Thrasher (SGCN-2)
European Starling
American Pipit
Cedar Waxwing
Yellow-rumped Warbler
Eastern Towhee (SGCN-2)
Field Sparrow (SGCN-2)
Fox Sparrow
Song Sparrow
Swamp Sparrow (SGCN-1)
White-throated Sparrow
Dark-eyed Junco
Northern Cardinal
Red-winged Blackbird
Common Grackle
Brown-headed Cowbird
House Finch
American Goldfinch
House Sparrow

58 species

Appendix C. Correspondence from USFWS and DDFW.

Letters could not be scanned because of poor quality of pdf file. Letters to be inserted in final version of report.

Appendix D. Average breeding bird abundance on 2000-200 Harrington BBS route (21003)

Taxonomic Sort[1]	Avg. birds/hr	Abundance Sort[1]	Avg. birds/hr
Canada Goose (SGCN-2)	9.20	Common Grackle	109.08
Wood Duck	0.36	European Starling	58.08
Gadwall	0.04	Red-winged Blackbird	45.72
American Black Duck (SGCN-1)	0.40	American Robin	40.04
Mallard (SGCN-2)	2.04	Laughing Gull	34.96
Ring-necked Pheasant	0.04	House Sparrow	30.12
Wild Turkey	0.08	Purple Martin	29.04
Northern Bobwhite (SGCN-2)	2.60	Mourning Dove	28.52
Pied-billed Grebe (DE-E)	**0.04**	Barn Swallow	24.68
Double-crested Cormorant (SGCN-2)	3.60	Turkey Vulture	19.52
Least Bittern (SGCN-2)	0.04	Northern Cardinal	17.56
Great Blue Heron (SGCN-2)	3.00	Northern Mockingbird	16.40
Great Egret (SGCN-2)	0.08	Indigo Bunting	15.24
Snowy Egret (SGCN-2)	1.48	Ring-billed Gull	15.04
Tricolored Heron (SGCN-2)	0.04	American Crow	15.00
Cattle Egret (SGCN-2)	0.04	Carolina Wren	14.48
Green Heron	1.36	Song Sparrow	14.44
Black-crowned Night-Heron (DE-E)	**0.08**	Horned Lark	10.12
Glossy Ibis (SGCN-2)	0.40	Willet (SGCN-2)	9.92
Black Vulture (SGCN-2)	2.12	House Finch	9.88
Turkey Vulture	19.52	American Goldfinch	9.88
Osprey (SGCN-1)	0.92	Blue Grosbeak	9.60
Mississippi Kite	0.04	Canada Goose	9.20
Bald Eagle (DE-E)	**0.16**	Rock Pigeon	8.68
Northern Harrier (DE-E)	**0.08**	Common Yellowthroat	8.48
Cooper's Hawk (DE-E)	**0.12**	Red-eyed Vireo	8.04
Red-shouldered Hawk (SGCN-2)	0.04	Chimney Swift (SGCN-2)	7.76
Red-tailed Hawk	1.08	Tufted Titmouse	7.44
American Kestrel	0.12	Chipping Sparrow	7.28
Clapper Rail (*Yellow WatchList)*	1.16	Brown-headed Cowbird	7.17
Killdeer	2.36	Red-bellied Woodpecker	5.80
Black-necked Stilt (SGCN-2)	0.32	Seaside Sparrow (SGCN-1, *Red WatchList*)	5.64
Willet (SGCN-2)	9.92	Fish Crow	5.44
Laughing Gull	34.96	Cedar Waxwing	5.44
Ring-billed Gull	15.04	Great Crested Flycatcher (SGCN-2)	5.24
Herring Gull	3.40	Wood Thrush (SGCN-1, *Yellow WatchList*)	4.76
Great Black-backed Gull	0.36	Boat-tailed Grackle	3.96
Forster's Tern (DE-E)	**1.04**	Blue Jay	3.76
Least Tern (DE-E, *Red WatchList*)	**0.12**	Eastern Wood-Pewee	3.72
Black Skimmer (DE-E, *Yellow WatchList*)	**0.24**	Double-crested Cormorant (SGCN-2)	3.60
Rock Pigeon	8.68	Orchard Oriole	3.60

Mourning Dove	28.52
Yellow-billed Cuckoo	0.36
Great Horned Owl	0.12
Barred Owl (SGCN-2)	0.04
Common Nighthawk (SGCN-1)	0.08
Chuck-will's-widow	0.20
Whip-poor-will (SGCN-2)	0.04
Chimney Swift (SGCN-2)	7.76
Ruby-throated Hummingbird	0.44
Belted Kingfisher	0.12
Red-bellied Woodpecker	5.80
Downy Woodpecker	1.24
Hairy Woodpecker	0.68
Northern Flicker (SGCN-2)	1.12
Pileated Woodpecker	0.32
Eastern Wood-Pewee	3.72
Acadian Flycatcher	2.76
Willow Flycatcher (SGCN-2, *Yellow WatchList*)	0.56
Eastern Phoebe	0.44
Great Crested Flycatcher (SGCN-2)	5.24
Eastern Kingbird (SGCN-2)	1.88
White-eyed Vireo	1.60
Yellow-throated Vireo (SGCN-2)	0.08
Red-eyed Vireo	8.04
Blue Jay	3.76
American Crow	15.00
Fish Crow	5.44
unid. Crow	1.08
Horned Lark	10.12
Purple Martin	29.04
Tree Swallow	3.32
Northern Rough-winged Swallow	0.60
Bank Swallow (SGCN-2)	1.28
Barn Swallow	24.68
Carolina Chickadee	1.92
Tufted Titmouse	7.44
Carolina Wren	14.48
House Wren	1.04
Marsh Wren (SGCN-2)	1.88
Blue-gray Gnatcatcher	1.32
Eastern Bluebird	2.00
Wood Thrush (SGCN-1, *Yellow WatchList*)	4.76
American Robin	40.04
Gray Catbird	3.16
Northern Mockingbird	16.40
Brown Thrasher (SGCN-2)	1.12
European Starling	58.08

Herring Gull	3.40
Tree Swallow	3.32
Gray Catbird	3.16
Great Blue Heron (SGCN-2)	3.00
Acadian Flycatcher	2.76
Northern Bobwhite (SGCN-2)	2.60
Killdeer	2.36
Black Vulture (SGCN-2)	2.12
Mallard (SGCN-2)	2.04
Eastern Bluebird	2.00
Swamp Sparrow (SGCN-1)	2.00
Carolina Chickadee	1.92
Eastern Kingbird (SGCN-2)	1.88
Marsh Wren (SGCN-2)	1.88
Ovenbird	1.80
Scarlet Tanager (SGCN-2)	1.76
Eastern Meadowlark	1.76
White-eyed Vireo	1.60
Snowy Egret (SGCN-2)	1.48
Yellow Warbler	1.40
Green Heron	1.36
Blue-gray Gnatcatcher	1.32
Prothonotary Warbler (SGCN-2, *Yellow WatchList*)	1.32
Bank Swallow (SGCN-2)	1.28
Downy Woodpecker	1.24
Field Sparrow (SGCN-2)	1.20
Clapper Rail (*Yellow WatchList)*	1.16
Northern Flicker (SGCN-2)	1.12
Brown Thrasher (SGCN-2)	1.12
Red-tailed Hawk	1.08
unid. Crow	1.08
Grasshopper Sparrow (SGCN-2)	1.08
Forster's Tern (DE-E)	**1.04**
House Wren	1.04
Osprey (SGCN-1)	0.92
Yellow-breasted Chat (SGCN-2)	0.72
Eastern Towhee (SGCN-2)	0.72
Hairy Woodpecker	0.68
Northern Rough-winged Swallow	0.60
Willow Flycatcher (SGCN-2, *Yellow WatchList*)	0.56
Pine Warbler	0.52
Ruby-throated Hummingbird	0.44
Eastern Phoebe	0.44
American Black Duck (SGCN-1)	0.40
Glossy Ibis (SGCN-2)	0.40
Yellow-throated Warbler (SGCN-2)	0.40
Kentucky Warbler (SGCN-2, *Yellow WatchList*)	0.40

Cedar Waxwing	5.44
Northern Parula (DE-E)	**0.04**
Yellow Warbler	1.40
Yellow-throated Warbler (SGCN-2)	0.40
Pine Warbler	0.52
American Redstart (SGCN-1)	0.20
Prothonotary Warbler (SGCN-2, *Yellow WatchList*)	1.32
Worm-eating Warbler (SGCN-2)	0.08
Ovenbird	1.80
Louisiana Waterthrush (SGCN-2)	0.12
Kentucky Warbler (SGCN-2, *Yellow WatchList*)	0.40
Common Yellowthroat	8.48
Hooded Warbler (DE-E)	**0.04**
Yellow-breasted Chat (SGCN-2)	0.72
Summer Tanager	0.12
Scarlet Tanager (SGCN-2)	1.76
Eastern Towhee (SGCN-2)	0.72
Chipping Sparrow	7.28
Field Sparrow (SGCN-2)	1.20
Grasshopper Sparrow (SGCN-2)	1.08
Saltmarsh Sparrow (SGCN-1, *Red WatchList*)	0.04
Seaside Sparrow (SGCN-1, *Red WatchList*)	5.64
Song Sparrow	14.44
Swamp Sparrow (SGCN-1)	2.00
Northern Cardinal	17.56
Blue Grosbeak	9.60
Indigo Bunting	15.24
Dickcissel	0.12
Red-winged Blackbird	45.72
Eastern Meadowlark	1.76
Boat-tailed Grackle	3.96
Common Grackle	109.08
Brown-headed Cowbird	7.17
Orchard Oriole	3.60
Baltimore Oriole (SGCN-2)	0.20
House Finch	9.88
American Goldfinch	9.88
House Sparrow	30.12
125 species	

Wood Duck	0.36
Great Black-backed Gull	0.36
Yellow-billed Cuckoo	0.36
Black-necked Stilt (SGCN-2)	0.32
Pileated Woodpecker	0.32
Black Skimmer (DE-E, *Yellow WatchList*)	**0.24**
Chuck-will's-widow	0.20
American Redstart (SGCN-1)	0.20
Baltimore Oriole (SGCN-2)	0.20
Bald Eagle (DE-E)	**0.16**
Cooper's Hawk (DE-E)	**0.12**
American Kestrel	0.12
Least Tern (DE-E, *Red WatchList*)	**0.12**
Great Horned Owl	0.12
Belted Kingfisher	0.12
Louisiana Waterthrush (SGCN-2)	0.12
Summer Tanager	0.12
Dickcissel	0.12
Wild Turkey	0.08
Great Egret (SGCN-2)	0.08
Black-crowned Night-Heron (DE-E)	**0.08**
Northern Harrier (DE-E)	**0.08**
Common Nighthawk (SGCN-1)	0.08
Yellow-throated Vireo (SGCN-2)	0.08
Worm-eating Warbler (SGCN-2)	0.08
Gadwall	0.04
Ring-necked Pheasant	0.04
Pied-billed Grebe (DE-E)	**0.04**
Least Bittern (SGCN-2)	0.04
Tricolored Heron (SGCN-2)	0.04
Cattle Egret (SGCN-2)	0.04
Mississippi Kite	0.04
Red-shouldered Hawk (SGCN-2)	0.04
Barred Owl (SGCN-2)	0.04
Whip-poor-will (SGCN-2)	0.04
Northern Parula (DE-E)	**0.04**
Hooded Warbler (DE-E)	**0.04**
Saltmarsh Sparrow (SGCN-1, *Red WatchList*)	0.04
Cumulative Abundance	**764.97**

[1] Delaware-endangered species are indicated in boldface; see Table 4.1-1. Species of Greatest Conservation Concern (SGCN) and *WatchList* species are noted; see discussion in Section 4.1.

Appendix E. Average abundance of wintering birds on 2000-2009 Cape Henlopen-Prime Hook CBC (DECH)

Taxonomic Sort[1]	Avg. birds/hr
Greater White-fronted Goose	0.00
Snow Goose	1,143.31
Ross's Goose	0.03
Brant (SGCN-2)	1.96
Cackling Goose	0.01
Canada Goose (SGCN-1 in oart)	63.81
Mute Swan	0.07
Tundra Swan (SGCN-2)	1.40
Wood Duck	0.08
Gadwall	1.57
Eurasian Wigeon	0.00
American Wigeon	0.59
American Black Duck (SGCN-1)	9.13
Mallard (SGCN-2)	7.17
Blue-winged Teal	0.00
Northern Shoveler (SGCN-2)	2.51
Northern Pintail	12.56
American Green-winged Teal	5.88
Canvasback (SGCN-2)	0.02
Redhead (SGCN-2)	0.01
Ring-necked Duck	2.89
Greater Scaup (SGCN-2)	1.04
Lesser Scaup (SGCN-2)	1.23
scaup sp. (SGCN-2)	0.65
Common Eider (SGCN-1)	0.08
Harlequin Duck	0.00
Surf Scoter (SGCN-2)	6.13
White-winged Scoter (SGCN-2)	0.09
Black Scoter (SGCN-2)	1.77
scoter sp. (SGCN-2)	0.81
Long-tailed Duck (SGCN-2)	0.20
Bufflehead (SGCN-2)	2.02
Common Goldeneye	0.05
Hooded Merganser (SGCN-2)	0.38
Common Merganser	0.08
Red-breasted Merganser	1.07
Ruddy Duck	0.79
Wild Turkey	0.01
Northern Bobwhite)SGCN-2)	0.16
Red-throated Loon	0.95
Common Loon	0.15
Pied-billed Grebe (DE-E)	**0.07**
Horned Grebe	0.07
Northern Gannet	0.37

Abundance Sort[1]	Avg. birds/hr
Snow Goose	1,143.31
Common Grackle	67.73
Canada Goose (SGCN-1 in oart)	63.81
Red-winged Blackbird	57.53
European Starling	24.14
Ring-billed Gull	23.64
Herring Gull	18.70
American Robin	14.71
Northern Pintail	12.56
Dunlin (SGCN-2)	9.59
American Black Duck (SGCN-1)	9.13
Mallard (SGCN-2)	7.17
Surf Scoter (SGCN-2)	6.13
American Green-winged Teal	5.88
Yellow-rumped Warbler	5.30
White-throated Sparrow	5.04
Dark-eyed Junco	4.31
Great Black-backed Gull (SGCN-2)	3.92
Mourning Dove	3.89
House Finch	3.36
Bonaparte's Gull	3.31
Song Sparrow	3.29
Sanderling (SGCN-1, *Yellow WatchList*)	3.10
Rock Pigeon	3.09
Ring-necked Duck	2.89
Brown-headed Cowbird	2.81
Northern Shoveler (SGCN-2)	2.51
Turkey Vulture	2.41
Bufflehead (SGCN-2)	2.02
American Goldfinch	1.97
Brant (SGCN-2)	1.96
Black Scoter (SGCN-2)	1.77
Cedar Waxwing	1.77
American Pipit	1.68
Gadwall	1.57
Carolina Chickadee	1.56
Northern Cardinal	1.52
American Crow	1.42
Carolina Wren	1.41
Tundra Swan (SGCN-2)	1.40
Savannah Sparrow	1.39
Swamp Sparrow (SGCN-1 in oart)	1.36
Lesser Scaup (SGCN-2)	1.23
House Sparrow	1.21

Brown Pelican (SGCN-2)	0.00
Double-crested Cormorant (SGCN-2)	0.51
Great Cormorant (SGCN-2)	0.58
American Bittern (SGCN-2)	0.02
Great Blue Heron (SGCN-2)	0.99
Great Egret (SGCN-2)	0.02
Snowy Egret (SGCN-2)	0.00
Tricolored Heron (SGCN-2)	0.00
Black-crowned Night-Heron (DE-E)	**0.03**
Black Vulture (SGCN-2)	0.49
Turkey Vulture	2.41
Bald Eagle (DE-E)	**0.19**
Northern Harrier (DE-E)	**0.52**
Sharp-shinned Hawk (SGCN-1)	0.11
Cooper's Hawk (DE-E)	**0.06**
Northern Goshawk	0.00
Red-shouldered Hawk (SGCN-2)	0.02
Red-tailed Hawk	0.28
Rough-legged Hawk	0.01
Golden Eagle	0.00
American Kestrel	0.10
Merlin	0.03
Peregrine Falcon (SGCN-2)	0.02
Clapper Rail (*Yellow WatchList*)	0.07
King Rail (SGCN-2, *Yellow WatchList*)	0.02
Virginia Rail	0.04
Sora (SGCN-2)	0.00
American Coot (SGCN-2)	0.11
Black-bellied Plover (SGCN-2)	0.04
Semipalmated Plover	0.01
Killdeer	0.37
Greater Yellowlegs (SGCN-2)	0.26
Lesser Yellowlegs	0.15
Ruddy Turnstone (SGCN-1)	0.44
Sanderling (SGCN-1, *Yellow WatchList*)	3.10
Western Sandpiper	0.05
Least Sandpiper	0.05
Pectoral Sandpiper	0.00
Purple Sandpiper (SGCN-2)	0.72
Dunlin (SGCN-2)	9.59
Long-billed Dowitcher	0.05
Common Snipe	0.08
American Woodcock (SGCN-1)	0.13
Laughing Gull	0.10
Little Gull (SGCN-2)	0.00
Black-headed Gull	0.01
Bonaparte's Gull	3.31

Red-breasted Merganser	1.07
Greater Scaup (SGCN-2)	1.04
Great Blue Heron (SGCN-2)	0.99
Snow Bunting	0.98
Red-throated Loon	0.95
Northern Mockingbird	0.90
Eastern Meadowlark	0.88
Eastern Bluebird	0.86
Blue Jay	0.84
scoter sp. (SGCN-2)	0.81
Ruddy Duck	0.79
Forster's Tern (DE-E)	**0.76**
Tufted Titmouse	0.76
Purple Sandpiper (SGCN-2)	0.72
Golden-crowned Kinglet	0.71
Boat-tailed Grackle	0.70
scaup sp. (SGCN-2)	0.65
Field Sparrow (SGCN-2)	0.65
Northern Flicker (SGCN-2)	0.60
American Wigeon	0.59
Great Cormorant (SGCN-2)	0.58
Northern Harrier (DE-E)	**0.52**
Double-crested Cormorant (SGCN-2)	0.51
Black Vulture (SGCN-2)	0.49
Horned Lark	0.49
Downy Woodpecker	0.48
Ruddy Turnstone (SGCN-1)	0.44
Brown-headed Nuthatch (SGCN-2)	0.43
Hooded Merganser (SGCN-2)	0.38
Red-bellied Woodpecker	0.38
Northern Gannet	0.37
Killdeer	0.37
Tree Swallow	0.31
Eastern Towhee (SGCN-2)	0.31
Red-breasted Nuthatch	0.29
Red-tailed Hawk	0.28
Great Horned Owl	0.28
Greater Yellowlegs (SGCN-2)	0.26
Hermit Thrush	0.23
Ruby-crowned Kinglet	0.22
Long-tailed Duck (SGCN-2)	0.20
Bald Eagle (DE-E)	**0.19**
Rusty Blackbird (*Yellow WatchList*)	0.19
White-crowned Sparrow	0.17
Northern Bobwhite)SGCN-2)	0.16
Winter Wren	0.16
Fox Sparrow	0.16

Ring-billed Gull	23.64
Herring Gull	18.70
Iceland Gull (*Yellow WatchList*)	0.00
Lesser Black-backed Gull	0.05
Glaucous Gull	0.00
Great Black-backed Gull (SGCN-2)	3.92
Caspian Tern	0.00
Forster's Tern (DE-E)	**0.76**
Black Skimmer (DE-E, *Yellow Watchlist*)	**0.00**
Razorbill (*Yellow WatchList*)	0.01
Rock Pigeon	3.09
Mourning Dove	3.89
Barn Owl (SGCN-2)	0.02
Eastern Screech-Owl	0.14
Great Horned Owl	0.28
Barred Owl (SGCN-2)	0.04
Long-eared Owl (SGCN-1)	0.02
Short-eared Owl (DE-E, *Yellow WatchList*)	**0.01**
Northern Saw-whet Owl	0.02
Rufous Hummingbird	0.00
Belted Kingfisher	0.13
Red-headed Woodpecker (DE-E, *Yellow WatchList*)	**0.00**
Red-bellied Woodpecker	0.38
Yellow-bellied Sapsucker	0.04
Downy Woodpecker	0.48
Hairy Woodpecker	0.14
Northern Flicker (SGCN-2)	0.60
Pileated Woodpecker	0.03
Eastern Phoebe	0.02
Loggerhead Shrike (DE-E)	**0.00**
Northern Shrike	0.00
Blue Jay	0.84
American Crow	1.42
Fish Crow	0.02
Horned Lark	0.49
Tree Swallow	0.31
Carolina Chickadee	1.56
Tufted Titmouse	0.76
Red-breasted Nuthatch	0.29
White-breasted Nuthatch	0.02
Brown-headed Nuthatch (SGCN-2)	0.43
Brown Creeper (DE-E)	**0.10**
Carolina Wren	1.41
House Wren	0.01
Winter Wren	0.16
Sedge Wren (DE-E)	**0.01**
Marsh Wren (SGCN-2)	0.02

Common Loon	0.15
Lesser Yellowlegs	0.15
Eastern Screech-Owl	0.14
Hairy Woodpecker	0.14
American Woodcock (SGCN-1)	0.13
Belted Kingfisher	0.13
Brown Thrasher (SGCN-2)	0.12
Sharp-shinned Hawk (SGCN-1)	0.11
American Coot (SGCN-2)	0.11
American Kestrel	0.10
Laughing Gull	0.10
Brown Creeper (DE-E)	**0.10**
White-winged Scoter (SGCN-2)	0.09
Gray Catbird	0.09
Wood Duck	0.08
Common Eider (SGCN-1)	0.08
Common Merganser	0.08
Common Snipe	0.08
Mute Swan	0.07
Pied-billed Grebe (DE-E)	**0.07**
Horned Grebe	0.07
Clapper Rail (*Yellow WatchList*)	0.07
Cooper's Hawk (DE-E)	**0.06**
Common Goldeneye	0.05
Western Sandpiper	0.05
Least Sandpiper	0.05
Long-billed Dowitcher	0.05
Lesser Black-backed Gull	0.05
Virginia Rail	0.04
Black-bellied Plover (SGCN-2)	0.04
Barred Owl (SGCN-2)	0.04
Yellow-bellied Sapsucker	0.04
American Tree Sparrow	0.04
Chipping Sparrow	0.04
Purple Finch	0.04
Ross's Goose	0.03
Black-crowned Night-Heron (DE-E)	**0.03**
Merlin	0.03
Pileated Woodpecker	0.03
Pine Siskin	0.03
Canvasback (SGCN-2)	0.02
American Bittern (SGCN-2)	0.02
Great Egret (SGCN-2)	0.02
Red-shouldered Hawk (SGCN-2)	0.02
Peregrine Falcon (SGCN-2)	0.02
King Rail (SGCN-2, *Yellow WatchList*)	0.02
Barn Owl (SGCN-2)	0.02

Golden-crowned Kinglet	0.71
Ruby-crowned Kinglet	0.22
Eastern Bluebird	0.86
Hermit Thrush	0.23
American Robin	14.71
Gray Catbird	0.09
Northern Mockingbird	0.90
Brown Thrasher (SGCN-2)	0.12
European Starling	24.14
American Pipit	1.68
Cedar Waxwing	1.77
Orange-crowned Warbler	0.01
Yellow-rumped Warbler	5.30
Pine Warbler	0.02
Prairie Warbler (SGCN-1, *Yellow WatchList*)	0.00
Palm Warbler	0.02
Northern Waterthrush	0.00
Common Yellowthroat	0.02
Yellow-breasted Chat (SGCN-2)	0.00
Eastern Towhee (SGCN-2)	0.31
American Tree Sparrow	0.04
Chipping Sparrow	0.04
Clay-colored Sparrow	0.00
Field Sparrow (SGCN-2)	0.65
Vesper Sparrow (SGCN-2)	0.00
Savannah Sparrow	1.39
Le Conte's Sparrow (*Yellow WatchList*)	0.00
Nelson's Sparrow (*Yellow WatchList*)	0.01
Saltmarsh Sparrow (SGCN-1, *Red WatchList*)	0.02
Seaside Sparrow (SGCN-1, *Red WatchList*)	0.02
Fox Sparrow	0.16
Song Sparrow	3.29
Lincoln's Sparrow	0.00
Swamp Sparrow (SGCN-1 in oart)	1.36
White-throated Sparrow	5.04
White-crowned Sparrow	0.17
Dark-eyed Junco	4.31
Snow Bunting	0.98
Northern Cardinal	1.52
Painted Bunting (*Yellow WatchList*)	0.00
Red-winged Blackbird	57.53
Eastern Meadowlark	0.88
Rusty Blackbird (*Yellow WatchList*)	0.19

Long-eared Owl (SGCN-1)	0.02
Northern Saw-whet Owl	0.02
Eastern Phoebe	0.02
Fish Crow	0.02
White-breasted Nuthatch	0.02
Marsh Wren (SGCN-2)	0.02
Pine Warbler	0.02
Palm Warbler	0.02
Common Yellowthroat	0.02
Saltmarsh Sparrow (SGCN-1, *Red WatchList*)	0.02
Seaside Sparrow (SGCN-1, *Red WatchList*)	0.02
Cackling Goose	0.01
Redhead (SGCN-2)	0.01
Wild Turkey	0.01
Rough-legged Hawk	0.01
Semipalmated Plover	0.01
Black-headed Gull	0.01
Razorbill (*Yellow WatchList*)	0.01
Short-eared Owl (DE-E, *Yellow WatchList*)	**0.01**
House Wren	0.01
Sedge Wren (DE-E)	**0.01**
Orange-crowned Warbler	0.01
Nelson's Sparrow (*Yellow WatchList*)	0.01
Red Crossbill	0.01
Greater White-fronted Goose	0.00
Eurasian Wigeon	0.00
Blue-winged Teal	0.00
Harlequin Duck	0.00
Brown Pelican (SGCN-2)	0.00
Snowy Egret (SGCN-2)	0.00
Tricolored Heron (SGCN-2)	0.00
Northern Goshawk	0.00
Golden Eagle	0.00
Sora (SGCN-2)	0.00
Pectoral Sandpiper	0.00
Little Gull (SGCN-2)	0.00
Iceland Gull (*Yellow WatchList*)	0.00
Glaucous Gull	0.00
Caspian Tern	0.00
Black Skimmer (DE-E, *Yellow Watchlist*)	**0.00**
Rufous Hummingbird	0.00
Red-headed Woodpecker (DE-E, *Yellow WatchList*)	**0.00**
Loggerhead Shrike (DE-E)	**0.00**

Common Grackle	67.73	Northern Shrike	0.00
Boat-tailed Grackle	0.70	Prairie Warbler (SGCN-1, *Yellow WatchList*)	0.00
Brown-headed Cowbird	2.81	Northern Waterthrush	0.00
Baltimore Oriole (SGCN-2)	0.00	Yellow-breasted Chat (SGCN-2)	0.00
Purple Finch	0.04	Clay-colored Sparrow	0.00
House Finch	3.36	Vesper Sparrow (SGCN-2)	0.00
Red Crossbill	0.01	Le Conte's Sparrow (*Yellow WatchList*)	0.00
Common Redpoll	0.00	Lincoln's Sparrow	0.00
Pine Siskin	0.03	Painted Bunting (*Yellow WatchList*)	0.00
American Goldfinch	1.97	Baltimore Oriole (SGCN-2)	0.00
House Sparrow	1.21	Common Redpoll	0.00
190 species		**Cumulative Abundance**	**1,567.12**

[1] Delaware-endangered species are indicated in boldface; see Table 4.1-1. Species of Greatest Conservation Concern (SGCN) and *WatchList* species are noted; see discussion in Section 4.1.

Appendix F. Annotated review of avian fatality studies at North American wind farms

Recorded fatalities are the number of carcasses found. Fatality estimates (/turbine/yr, except where indicated) factor in searcher efficiency and carcass removal (see Section 6.2.1). Modern turbines have a height range of about 58.5 m (192 feet) to above 122.0 m (400 feet), older turbines below 50 m (164 feet). No turbine had guy wires. Citations may be found at end of appendix.

Eastern U.S. – Farmland, Forest, and Saltmarsh

Mars Hill, ME: 28 modern turbines on forested ridge, two years of study using daily (first year only) and weekly searches, plus seasonal dog-assisted searches: 36 recorded fatalities, mostly night-migrating songbirds except for one Ruffed Grouse and one Barred Owl; fatality estimated at 0.44-2.65/turbine/year (Stantec 2008, 2009)

Hull, MA: 1 modern turbine adjacent to high school on island in Boston Harbor, dozens of informal searches by high school students for at least one year: 0 recorded fatalities (Malcolm Brown, personal communication in 2002)

Atlantic County Utility Authority, NJ: 5 modern turbines in filled saltmarsh along waterway, searches from August 2007 to September 2008: 23 observed fatalities, including 3 raptors (2 Osprey and 1 Peregrine Falcon), 9 gulls, 2 shorebirds, and 6 night-migrating songbirds (New Jersey Audubon Society 2008)

Clinton, NY: 67 modern turbines in farmland with woodlots, with 23 turbines searched at daily, 3-day, or weekly intervals over six months spanning migration seasons: 14 recorded fatalities, including 9 night migrants, 1 raptor (Broad-winged Hawk), 2 Killdeers, and 1 Rock Pigeon; fatality estimated at 1.4-3.3/turbine/year (Jain et al. 2009a)

Eagle, NY: 67 modern turbines in farmland with woodlots, with 23 turbines searched at daily, 3-day, or weekly intervals from April 21 to November 14: 20 recorded fatalities, including 14 night migrants, 4 raptors (Sharp-shinned and Red-tailed hawks), and 2 gamebirds (Ruffed Grouse and American Woodcock); fatality estimated at 0.7-4.3/turbine/year (Jain et al. 2009b)

Ellenburg, NY: 54 modern turbines in farmland with woodlots, with 18 turbines searched at daily, 3-day, or weekly intervals from April 28 to October 13: 12 recorded fatalities, including 8 night migrants, 1 raptor (Broad-winged Hawk), 1 woodpecker (Northern Flicker), 1 Tree Swallow, and 1 European Starling; fatality estimated at 1.2-2.1/turbine/year (Jain et al. 2009c)

Madison, NY: 7 modern turbines in farmland, one year of study: 4 recorded fatalities, including 2 night-migrating songbirds, 1 owl, and 1 woodpecker, no diurnal raptors or waterbirds (Kerlinger 2002a)

Maple Ridge, NY: 195 modern turbines in farmland adjacent to fragmented forest on Tug Hill Plateau, with 50-64 turbines searched mostly at weekly intervals (daily and 3-day intervals in first year), three years of study: ~90 recorded fatalities per year in searches, most of which were night migrants, few raptors (range of 1 to 3); fatality estimated at 3.1-4.6/turbine/year based on weekly search interval (Jain et al. 2007, 2009d, 2009e)

Tug Hill Plateau, NY: 2 older turbines in farmland, 2 migration seasons: 0 recorded fatalities (Cooper et al. 1995)

Garrett, PA: 8 modern turbines in farm fields in Somerset County, one year of study: 0 recorded fatalities (Kerlinger 2001)

Meyersdale, PA: 20 modern turbines on forested ridge in Somerset County, all turbines searched more than 20 times from July 30 to September 13, 2004: 13 recorded fatalities, mostly night-migrating songbirds, no raptors or waterbirds (Arnett et al. 2005)

Buffalo Mountain, TN: Two studies on forested, strip-mined mountain: 1) 3 modern turbines searched for three years: fatalities estimated at ~7/turbine/year (Nicholson 2003); 2) searched again after 15 taller turbines added: fatality estimated at 1.8/turbine/year (Fiedler et al. 2007)

Searsburg, VT: 11 modern turbines on forested mountain near Green Mountain National Forest, studied during nesting and fall migration seasons: 0 recorded fatalities (Kerlinger 2002b)

Mountaineer, WV: Two studies of 44 modern turbines on forested ridge: 1) 22 searches throughout year of all turbines in 2003: 69 recorded fatalities, ~75% night-migrating songbirds, 2 Turkey Vultures, 1 Red-tailed Hawk; fatalities estimated at 4.04/turbine/year (Kerns and Kerlinger 2004); 2) 20+ searches from July 31 to September 11, 2004: 15 recorded fatalities (Arnett et al. 2005)

Mount Storm, WV: 82 modern turbines on wooded ridge, of which 27 turbines searched (two-thirds weekly and one-third daily; 978 total searches) in July-October 2008: 29 recorded fatalities, over 80% night-migrating songbirds, 1 Turkey Vulture; fatality estimates for study period were 3.81/turbine for daily search interval and 2.41/turbine for weekly search interval (Young et al. 2009)

<u>Central U.S. – Farmland</u>

Algona, IA: 3 modern turbines in farmland, 3 migration seasons: 0 recorded fatalities (Demastes and Trainer 2000)

Top of Iowa, IA: 89 modern turbines, of which 26 studied over two years, in tilled farmland: 7 recorded fatalities, mostly songbirds, 2 Red-tailed Hawks, no waterfowl despite high use of nearby wildlife management areas; fatality estimated at 0.38-0.90/turbine/year (Jain 2005, Koford et al. 2005)

Crescent Ridge, IL: 33 modern turbines in farmland, 1,363 turbine searches in fall and spring migration: 10 recorded fatalities, mostly night migrants, 1 Red-tailed Hawk; fatality estimated at ~1/turbine/year (Kerlinger et al. 2007)

Jeffrey Energy Center, KS: 2 modern turbines in grassland/prairie adjacent to a coal-fired power plant, 66 turbine searches in two migration seasons: 0 recorded fatalities (Young et al. 2000)

Buffalo Ridge, MN: Over 400 mostly modern turbines in farmland and grassland, four years of study (1996-1999): 55 recorded fatalities among 31 species, of which 42 (76.4%) were songbirds, one raptor (Red-tailed Hawk); depending on the section of the wind farm studied, estimated fatality ranged from 2.27 to 4.45/turbine/year (Johnson et al. 2002)

Ainsworth, NE: 36 wind turbines in sandhills/grazing land studied during one year: 27 recorded fatalities, including 9 Horned Larks, 2 American Kestrels, 1 Sharp-tailed Grouse, 1 Upland Sandpiper, 1 Short-eared Owl, and songbirds; fatality rate of 2.7/turbine per year with 2.5/turbine/year for small birds (Derby et al. 2007)

Blue Canyon II, OK: 84 turbines, of which 50 studied over one year: 15 recorded fatalities, including 11 Turkey Vultures, 2 Red-tailed Hawks, and 2 songbirds; fatality estimated at 0.25/turbine/year for raptors and 0.27/turbine/year for songbirds (Schnell et al. 2007)

Buffalo Gap I, TX: 67 turbines, of which 21 studied over one year: 21 recorded fatalities, including 15 Turkey Vultures, 1 Red-tailed Hawk, and 3 passerines; fatality estimated at 2.37/turbine/year, including 0.43/turbine/year for raptors (Tierney 2007)

Kewaunee, WI: 31 modern turbines in farmland, two years of study (four migration seasons): 25 recorded fatalities, including three waterfowl, 14 songbirds (some night migrants), no raptors; fatality estimated at 1.3/turbine/year (Howe et al. 2002)

Shirley, WI: 2 modern turbines in farmland, 54 surveys over spring and fall migration in one year: 1 recorded fatality, a night-migrating songbird (Howe and Atwater 1999)

Western U.S. – Prairie and Farmland

Altamont Pass, CA: 5,400 older turbines mostly on lattice towers in grazing and tilled land, over 20 years of study: recorded fatalities number in the thousands, of which over 40% are raptors, with Red-tailed Hawk, Burrowing Owl, American Kestrel, and Golden Eagle most often found; fatality estimated recently (Smallwood and Thelander 2008) at 4.67/MW/year for all birds, 1.94/MW/year for raptors (Howell and DiDonato1991, Howell 1997, Orloff and Flannery 1992, 1996, Kerlinger and Curry 1997, Thelander and Rugge 2000, Smallwood and Thelander 2005, Smallwood and Thelander 2008, Altamont Pass Avian Monitoring Team 2008)

High Winds, CA: 90 modern turbines in tilled farmland, 4,220 turbine searches over two years: 163 recorded fatalities, including 71 raptors of 7 species (45 American Kestrels, 18 Red-tailed Hawks), 60 songbirds of 17 species, and 5 waterbirds; fatality estimated at 2.0-2.9/turbine/year (Kerlinger et al. 2006)

Montezuma Hills, CA: 237 older turbines, 11 modern turbines in tilled farmland, with 59 turbines searched twice weekly for 18 months: 13 recorded fatalities, including 5 Red-tailed

Hawks, 4 American Kestrels, 1 Mallard, 1 Rock Dove, and 2 Red-winged Blackbirds (Howell 1997)

San Gorgonio, CA: About 3,000 older turbines in desert, 423 turbines sampled every 90 days in two one-year periods: 61 recorded fatalities among 19 species, including two Red-tailed Hawks; raptor fatality unadjusted for searcher efficiency and scavenging estimated at 0.006/turbine/yr or 0.03/MW/year (Anderson et al. 2005)

Tehachapi Pass, CA: About 3,300 turbines in grazing land and scrub in mountains of Mojave Desert, 637 turbines sampled over 17 months: 127 recorded fatalities among 27 species, including 54 raptors (of most numerous, 14 Red-tailed Hawks, 13 Great Horned Owls, and 9 American Kestrels); raptor fatality estimated at 0.04/turbine/year, or 0.20/MW/year (Anderson et al. 2004)

Ponnequin, CO: 29 modern turbines in rangeland, increased to 41 in 2001, five years of study (1999-2003): ~24 recorded fatalities each year; Horned Lark most abundant, 1 teal, 1 American Kestrel, other songbirds (Kerlinger and Curry 2000, Kerlinger, unpublished data)

Judith Gap, MT: 90 turbines in cropland and grassland, of which 20 searched monthly: 26 recorded fatalities, including 10 songbirds, 1 Merlin, 1 Short-eared Owl, 1 Sharp-tailed Grouse, and 13 waterbirds (7 grebes, 2 ducks, 4 coots); fatality estimate for study period was 4.52/turbine (TRC Environmental Corporation 2008)

Klondike, OR: 16 modern turbines in rangeland and shrub-steppe, one year of study: 8 recorded fatalities, mostly songbirds, of which half night migrants, 2 Canada Geese, no raptors; fatality estimated at 1.3/turbine/year (Johnson et al. 2003)

Vansycle, OR: 38 modern turbines in farm and rangeland, one year of study: 12 recorded fatalities among 6 species, including 6 songbirds, of which at least 4 were night migrants, 4 game birds, 1 woodpecker, and 1 swift, no raptors or waterbirds; fatality estimated at 0.63/turbine/year (Erickson et al. 2000)

Stateline, OR/WA: 454 modern turbines in farmland, of which 399 searched over two years: 232 recorded fatalities among 35 species, of which nearly 40% were resident Horned Larks and nearly 25% night-migrating songbirds, most of 13 raptor fatalities were Red-tailed Hawks and American Kestrels; fatality estimated at 1.65/turbine/year for all birds, 0.06/turbine/year for raptors (Erickson et al. 2004)

Nine Canyon, WA: 37 modern turbines in prairie and farmland searched over one year: 36 recorded fatalities, with 47% Horned Larks, 14% Ring-necked Pheasant, and 6% Western Meadowlarks, two raptors (a kestrel and Short-eared Owl); fatality estimated at 3.59/turbine/year (Erickson 2003)

Foote Creek Rim, WY: 69 modern turbines in prairie/rangeland, two years of study: 122 recorded fatalities, of which 83 at turbines and 36 at guyed meteorology towers, with 92% songbirds (Horned Lark most common victim; nearly half of songbirds were night migrants), 3

American Kestrels, 1 Northern Harrier, 1 Short-eared Owl, 1 grebe; fatality estimated at 1.45-2.04/turbine/year (Young et al. 2003)

Canada

Erie Shores, ON: 66 modern turbines in farmland with woodlots, two migration seasons: fatalities estimated at 2.0-2.5/turbine/year, including 0.04/turbine/year for raptors (James 2008)

Exhibition Place, ON: 1 modern turbine on Toronto lakefront, 2 migration seasons: 2 recorded fatalities, European Starling and American Robin; fatalities estimated at 3/turbine/year (James and Coady 2003)

Pickering, ON: 1 modern turbine near a marsh, 2 migration seasons: 2 recorded fatalities, both night-migrating songbirds; fatalities estimated at ~4-5/turbine/year (James 2004)

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