Appendix 5.7-H

Evaluation of the Roseate Tern and Piping Plover

APPENDIX 5.7-H
EVALUATION OF THE
ROSEATE TERN AND PIPING PLOVER
FOR THE CAPE WIND PROJECT
NANTUCKET SOUND

Internal Review Only

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1.0 INTRODUCTION

1.1 Endangered Species Act Regulations

This Evaluation of the Roseate Tern and Piping Plover ("Evaluation") has been prepared in accordance with the USACE Scope for the Cape Wind DEIS. This evaluation will be the basis for a subsequent biological assessment to be prepared in accordance with Section 7 of the Endangered Species Act (ESA) of 1973 (ESA, P.L. 93-205) which requires that all Federal agencies ensure that any action they authorize, fund, or execute will not jeopardize the continued existence of any endangered or threatened species (i.e., listed species) or result in the destruction or adverse modification of any critical habitat of such species (50 CFR Part 402). The "action" under consideration is the construction, operation, and maintenance of an offshore wind energy project, proposed by Cape Wind Associates, LLC (the "Applicant" or "Cape Wind"), on Horseshoe Shoal in Nantucket Sound along with a submarine electric transmission cable system that connects the power to the mainland electric grid.

Because the action will occur in federal waters, the ESA mandates that the federal agency responsible for the "action" (i.e., U.S. Army Corps of Engineers (USACE)) consult with the Department of the Interior, U.S. Fish and Wildlife Service (USFWS) which has jurisdiction over all bird species listed under the ESA. This consultation requires preparation of a Biological Assessment (BA), which will be provided to the USFWS at a later date, to determine if the proposed action is likely to result in adverse effects to threatened or endangered avian species.

1.2 Species Considered

In accordance with the USACE scope of work for the Cape Wind Environmental Impact Statement (EIS) which was developed in consultation with USFWS, MassWildlife, and Massachusetts Audubon Society (Mass Audubon), the threatened Piping Plover (*Charadrius melodus*) and the endangered Roseate Tern (*Sterna dougallii*) are discussed in this Evaluation.

1.3 Format of the Evaluation

A summary of the proposed action and affected physical and biological environment is included in Section 2 of the Evaluation. Section 3 presents life history information for each species considered, including population status and trends, seasonal distribution, preferred food and feeding habits, flight behavior, known disturbances and mortality factors, and use of Nantucket Sound and the Project Area. Potential impacts of the proposed action on the listed species are discussed in Section 4, and the management practices to minimize those impacts are discussed in Section 5. The conclusions are presented in Section 6. Literature cited in this document is presented in Section 7.

2.0 PROPOSED ACTION

2.1 Description of Proposed Action

The offshore wind energy project proposed by Cape Wind consists of the installation and operation of 130 3.6 megawatt (MW) Wind Turbine Generators (WTGs) with an associated Electric Service Platform (ESP) on Horseshoe Shoal in Nantucket Sound. Two additional sites within Nantucket Sound have been evaluated as alternatives for construction of the WTG array. All three sites, depicted in Figure 1, are located outside of the Massachusetts' three-mile state jurisdictional limit, exclusively within federal waters of Nantucket Sound.

The WTGs will produce an average of 170 megawatts (MW) (up to a maximum output of 454 MW) of energy using the natural wind resources off the coast of Massachusetts. Wind-generated energy produced by the WTGs will be transmitted via a 33 kV submarine transmission cable system to the ESP centrally located within the WTG array. The ESP will then transform and transmit this electric power via buried cables to the mainland electric transmission system via two 115 kV alternating current (AC) submarine cable circuits to the selected landfall site at New Hampshire Avenue in Yarmouth, Massachusetts. The buried cables (at their closest point) will pass within approximately 820 feet (250 m) of Kalmus Beach/Dunbar Point and approximately 1,210 feet (369 m) of Great Island. Support vessels associated with the cable installation will pass within approximately 670 feet (204 m) of Kalmus Beach / Dunbar Point and 1060 feet (323 m) of Great Island. The upland cable system will be installed underground within existing rights of way (ROWs) and roadways in the Town of Yarmouth and NSTAR Electric ROW, where it will interconnect with the existing NSTAR Electric Barnstable Switching Station.

The transition of the interconnecting 115 kV submarine transmission lines from water to land will be accomplished through the use of Horizontal Directional Drill (HDD) methodology in order to minimize disturbance within the intertidal zone and near shore area. HDD would be staged at the upland landfall area and involve the drilling of four boreholes from land toward the offshore exit point, approximately 100 feet offshore. Conduits would then be installed the length of the boreholes and the transmission lines would be pulled through the conduits from the seaward end toward the land. A below grade landfall transition vault will be installed in New Hampshire Avenue using conventional excavation equipment (backhoe) at the upland transition point where the submarine and land transmission lines would be connected. The energy produced by the Wind Park will be transmitted by this cable system to the electric transmission system serving Cape Cod, the Islands of Nantucket and Martha's Vineyard ("the Islands"), and the New England region.

The turbines will be approximately 4.7 miles (7.6 km) or more from the Cape Cod shoreline. Each WTG will be mounted on a monopole tower at about 246 feet (75 m) above mean lower low water (MLLW). Near the base of the tower, a pre-fabricated access platform and service vessel landing (approximately 32 feet (9.8 m) from MLLW) will be provided. Each of the three rotor blades will be 170 feet (52 m) in length and the rotor-swept area height will extend from 75 - 417 feet (23 to 127 m) above MLLW, with each WTG having a rotor-swept area 90,800 square feet (8,500 $m^{2)}$ (170 $feet^2 \times \pi$). Turbines will be installed on a grid of about 0.54 x 0.34 nautical mile (1.0 x 0.63 km), with connecting inner-array cables buried beneath the seafloor to an approximate depth of 6 feet (1.8 m). The turbines will rotate at 8.5 to 15.3 revolutions per minute (rpm) and will shut down at wind speeds above approximately 55 mph (25 m/sec).

The ESP will be approximately 200 feet long by 100 feet wide, with an overall height of approximately 100 feet above MLLW (61 m x 30m x 30m) and located near the center of the WTG array. It will house transformers and cables, as well as a boat landing and heliport. The lighting of the WTGs and ESP is discussed below (Section 5.0). For more information about design and construction of the WTGs and ESP, see Section 4.0 of the DEIS-DEIR document.

2.2 Affected Environment

This section describes the physical and biological characteristics of Nantucket Sound and of HSS in particular when possible. Additional information on these topics is available in Section 5.0 of the DEIS/DEIR/DRI prepared by the USACE pursuant to the National Environmental Policy Act (NEPA).

2.2.1 Physical Environment

This section is based on published information and studies by the Applicant and provides a basis for understanding the oceanographic and shoreline processes that affect listed birds in Nantucket Sound.

Hydrography: In general, the bathymetry in Nantucket Sound is irregular, with a large number of shoals present in various locations throughout the glacially formed basin. Charted water depths in the Sound range between 0 and 70 feet (0 and 21 m) at MLLW. The shoals have complex shapes. The Proposed Alternative Site (Site 1) is located on Horseshoe Shoal, a prominent geological feature in the center of the Sound with water depths as shallow as 0.5 feet (0.15 m) at MLLW.

Water depths between Horseshoe Shoal and the Cape Cod shoreline are variable, with an average depth of approximately 15 to 20 feet (4.6 to 6.0 m) at MLLW. Along the submarine cable system route, depths vary from about 16 to 40 feet (4.9 to 12.2 m) at MLLW, with an average depth of approximately 30 feet (9.1 m) at MLLW. Water depths in Lewis Bay and Hyannis Harbor are variable ranging from eight to 14 feet (2.4 to 4.3 m) at MLLW in the center of the bay to less than five feet (1.5 m) at MLLW along the perimeter and between Dunbar Point and Great Island. Water depths along this route in Lewis Bay range from five to 15 feet (1.5 to 4.6 m), with an average of ten feet (3 m). The shallowest portions of Lewis Bay/Hyannis Harbor along this route exist between Great Island and Dunbar Point, with depths of one to four feet (0.3 to 1.2 m) at MLLW.

Currents: The water currents in Nantucket Sound are driven by strong, reversing, semidiurnal tidal flows. Wind-driven currents are only moderate because of the sheltering effect of Nantucket and Martha's Vineyard. The tidal range and diurnal timing are variable because of the semi-enclosed nature of the Sound and the regional variations in bathymetry. Typical tidal heights are in the range of one to four feet (0.3 to 1.2 m). Times of high and low tides differ throughout the Sound by up to two hours.

Tidal flow and circulation within the Sound generate complex currents, generally flowing to the east during the flood tide (incoming) and to the west during the ebb tide (outgoing). Peak tidal currents often exceed two knots and the intensity of tidal flow, in general, decreases from west to east. There is a slow net drift of the water mass toward the east in the Sound. The net drift is about $200m^2$ per tidal cycle; roughly 5% of the total easterly and westerly tidal flows (Bumpus et al. 1971).

Mean tidal current velocities were calculated to be approximately 2 feet/second at Horseshoe Shoal; less than 2 feet/second at Tuckernuck Shoal, and more than 2.5 feet/second at Monomoy-Handkerchief Shoal. Wind-driven current velocities modeled at Horseshoe Shoal were found to be much lower than tidal velocities and concentrated over the crest of the shoal (Appendix 5.2-A of the DEIS-DEIR).

Sediment Distribution: Nantucket Sound generally contains sand- and silt-sized surficial marine sediments, with localized patches of clay, gravel and/or cobbles. Small areas of glacially deposited rocks and boulders near the northern shore of the Sound are continuously subaerially exposed, or exposed at low tide and shifting sandbars, covered only by storm-tides, are characteristic of the area near Muskeget Island, but no such exposures occur in the alternate sites for the turbines. Subtidal boulders are widespread near the northern shore off the entrance to Hyannis Harbor but are rare in the three alternative areas for the turbines. Some areas of subtidal cobbles are uncovered seasonally by movements of sand. The sediments were derived from material originally transported from upland areas during glacial and post-glacial periods, and are now continually sorted and reworked by tidal, current, wave, and storm actions. Shallow marine sediments were collected in vibracores and benthic grabs during 2001 and 2002 across the Proposed and alternative sites. Visual analysis of sediments within the 0- to 2-foot (0 to 0.6 m) depth range beneath the seabed indicates the presence of fine- to coarse-grained sands in areas of relatively shallow bathymetry, with fine to silty sands and silts predominating in deeper surrounding waters across the three sites. This distribution is consistent with the higher-energy marine environments typically found in shallower waters, where finer sediments are winnowed away by current and wave action. The fines then settle out and deposit in the surrounding lower-energy deeper water areas.

Medium-grained sands predominate atop the U-shaped Horseshoe Shoal, with fine-grained sands found in the east-opening embayment. Localized fractions of silt, gravel, and/or cobbles, consistent with glacial drift may also be present in the area. Fine to silty sands were encountered in the deeper water portions surrounding the shoal area. Fine sands predominate in the western and central portions of Monomoy-Handkerchief Shoal, with silty sands to the east in deeper waters. Across Tuckernuck Shoal, fine sands predominate, with an area of medium to coarse sands traversing the center of the shoal and oriented parallel to the tidal currents sweeping between Martha's Vineyard and Nantucket. Silty sands were encountered to the east of Tuckernuck Shoal, again in the deeper water areas surrounding the shoal.

A geophysical survey across Horseshoe Shoal conducted in 2001 identified areas of sand waves, especially in the south central portion of the shoal. The sand wave crests were oriented generally in a north-south direction, with long period wavelengths ranging between 100 to 600 feet (30 to 183 m). Short period sand waves are located between the larger crests. The average sand wave height was 4 to 5 feet (1.2 to 1.5 m), but waves as high as 15 feet (4.8 m) were found. The size of the sand waves attest to the dynamic shallow water environment on Horseshoe Shoal. The symmetry of the sand waves indicates migration to the east or west, depending on where they formed on the shoal. In other areas of the shoal, the majority of the seafloor contained few significant features and smooth sandy bottoms (Ocean Surveys, Inc., July 2002).

Along the submarine cable system route, seabed sediments contain fine to coarse size sands, with patches of clay, silt, gravel, and/or cobbles. Intermittent glacially transported boulders may also be present along the route, especially off the entrance to Hyannis Harbor.

Sediment Quality: Bulk chemical analyses were performed on selected core samples obtained from the WTG array area and along the proposed submarine cable route into Lewis Bay to determine whether the sediments could contain harmful contaminants and thus pose an environmental concern. To assess the relative environmental quality of these sediments, the laboratory results for the chemical analyses were compared to sediment guidelines typically used by agencies to evaluate risk from contaminants in marine and estuarine sediments (NOAA Effects Range-Low (ER-L) and Effects Range-Median (ER-M) guidelines). None of the targeted chemical constituents were detected in the samples above ER-L or ER-M guidelines (Long et al., 1995) for marine sediments. The ER-L and ER-M guidelines use numerous modeling, laboratory, and field studies to establish values for evaluating marine and estuarine sediments. Concentrations below the ER-L represent a concentration range in which adverse effects are rarely observed. Section 5.1 of the DEIS-DEIR has more detailed information on sediment quality in the Project Area.

Sediment Transport: Analytical Modeling conducted for the Project (see Appendix 5.2-A) found that active sediment transport occurs at Horseshoe Shoal, even under typical wave and tidal current conditions. The highest transport rates are focused locally on the shallowest portions of the shoal, and there is relatively little transport in the deeper regions for typical conditions. Seasonal variations in sediment movements on the shallowest shoal result in changes in the surficial layers. Additional information is summarized in Section 5.2 of the DEIS-DEIR.

Shore: Where the sea meets the land is an everchanging zone affected by processes of erosion and deposition. Piping Plovers prefer undisturbed dynamic sandy beaches that are periodically washed out by storms, which may cut through the dunes creating 'blowouts', ephemeral pools, and overwash fans (USFWS 1996) Important features of these beaches include areas above summer high tides, formed by winter storms, that are used for nesting, and extensive adjacent feeding areas in the intertidal zone. Disturbance from development (hardening of the shore) and human use (compacting etc) have adverse effects on physical features of these habitats. Within 2 miles (3 km) of the project area, nearest to the submarine transmission cable, there are beaches suitable for nesting and feeding at Dunbar Point, Hyannis and on the westward and seaward sides of Great Island. More distant from the project area numerous suitable beaches exist around Nantucket Sound some of which are indicated on Figure 1 by the presence of nesting plovers (see Melvin and Mostello 2003).

2.2.2 Biological Environment

This section provides a basis for understanding the biological and ecological conditions within the proposed Project Area that contribute to the habitats for the endangered and threatened species.

Submerged Aquatic Vegetation: Submerged aquatic vegetation (SAV), including eelgrass, provides habitat for many species of benthic invertebrates and fish and so may be important foraging areas for terns. The MADEP Wetlands Conservancy Program has mapped SAV beds one quarter acre or larger in size along the coastline using aerial photography, GPS, and a digital base map. Mapping was completed in 1995 and 2000; the 1995 data are available from MassGIS for areas within the 3-mile state territorial limit. One SAV bed has been mapped within Lewis Bay, located to the west of Egg Island in the Town of Barnstable. A December 2002 telephone conversation with Mr. Charles Costello of the MADEP Wetlands Conservancy Program indicates that the mapped SAV bed has not changed much in size between 1995 and 2000. In addition to the mapped SAV in Lewis Bay, MADEP has mapped areas of SAV in Hyannis Harbor in the Town of Barnstable and to the west of Great Island in the Town of Yarmouth. Two potential areas of submerged aquatic vegetation were also identified within the Project area, beyond the Massachusetts 3-nautical mile (5.6-km) limit, during project related geophysical surveys. Field investigations have been conducted to determine the extent of mapped SAV beds in the vicinity of the proposed project. The submarine cable system will be no closer than 70 feet from the edge of the eelgrass bed located near Egg Island.

Plankton Communities: Plankton refers to those plants (phytoplankton) and animals (zooplankton) that cannot maintain their distribution against the movement of water masses. Individual plankters are generally very small or microscopic; however, organisms such as jellyfish are often considered with the plankton community. Review of the scientific literature suggests that little information exists describing the plankton communities of Nantucket Sound. However, because all coastal and offshore waters contain both phytoplankton and zooplankton communities, it is expected that the waters within Nantucket Sound also support a diverse and abundant plankton community. Plankton abundance and distribution is of particular interest since, in the case of phytoplankton, they form the base of the marine food web. Larger zooplankters, including crustaceans and larval stages of many fish are taken by terns. Phytoplankton dynamics in all waterbodies, including those of Nantucket Sound are controlled by a suite of variables including light, temperature, nutrients, grazing by higher trophic level organisms and species interactions. These planktonic communities are generally variable in time and space resulting in relatively patchy distributions. The turbulence resulting from tidal currents over the shoals results in extensive mixing of the surface layers of the Sound, facilitating harvest of planktonic organisms by other trophic levels, including terns.

Benthic Communities: The benthic fauna is of crucial importance to bottom-feeding bird species, notably the wintering seaducks, but its composition is not directly important to the surface feeding terns.

Shorelines: The shorelines where plovers feed and nest provide a diverse array of food items that include planktonic animals washed in by the waves and wind, as well as the interstitial fauna of intertidal sand flats and mud flats. Regions of the beach only reached by storm tides are also important feeding areas, especially the wracklines where insects and sometimes amphipods are the likely prey. The feeding requirements of plovers are described in greater detail in section 3.1.3.

Finfish: The waters of Nantucket Sound support a diverse fish community. Many of the fish found within the region are local inhabitants that remain year-round, while other species are migratory and move into and out of the Sound in response to temperature changes. Small fish serve as the primary prey for Roseate Terns. Piping Plovers do not feed on fish, but forage mainly on terrestrial and marine invertebrates.

The migration patterns and seasonal presence of the fish that are prey of terns influence the areas where terns forage. The seasonal presence of bluefish, striped bass, and other large predatory fish is also very important for surface-feeding terns because these predators drive small baitfish to the surface where the terns can catch them. In New England, terns, especially Roseates, feed primarily on sand eels or sand lance (*Ammodytes*), also on other fish such as herrings (*Clupea harengus, Alosa aestivalis*), anchovies (*Anchoa* spp), mackerel (*Scomber scombrus*), or silversides (*Menidia menidia*) , depending on their availability. All of these species have been observed in Nantucket Sound during some time of the year.

Sand lance or sand eels (*Ammodytes*) occur in estuarine, open coastal, and offshore habitats, generally over sandy substrates. They are habitat dependant and are typically found in areas with high bottom current velocities. Juveniles and adults are generally found in schools during the day with larger schools found in deep waters, and smaller schools found over shoal habitat (Auster and Stewart, 1986). No specific data on the abundance and distribution of sand lance in Nantucket Sound were found (see Appendix 5.4-A), but the habitat characteristics of Nantucket Sound indicate that sand lance are likely present in the Project Area.

Herring (*Clupea harengus*) form large schools in coastal waters throughout the Gulf of Maine and off southern New England (Reid et al. 1999). In the summer and fall, juveniles move from nearshore waters to overwinter in deep bays or near bottom in offshore areas. Some juveniles spend at least the spring and early summer off southern New England, especially off southern Massachusetts (through at least mid-June) before moving into the Gulf of Maine or offshore, presumably east of Cape Cod. According to the Massachusetts inshore trawl surveys (1978-1996), as reported by Reid et al. (1999), juveniles in spring were most abundant northwest of Cape Ann, throughout Cape Cod Bay, along the northern shore of Nantucket Island and southern shore of Martha's Vineyard, and Buzzard's Bay. Juveniles were also found to a lesser degree in the northeast corner of Nantucket Sound near Monomoy Island and off the south shore of Dennis, MA. In the fall, the largest catches of juveniles occurred around Cape Ann, in central and western Cape Cod Bay, off Buzzard's Bay, and off the southern shore of Martha's Vineyard. Therefore, herring are found in Nantucket Sound, but data indicate that they seem to be more prevalent on the outer reaches of the Sound, outside of the Project Area.

Mackerel (*Scomber scombrus*) have the same geographic distribution as herring, but the migration patterns differ. Juveniles are common in Nantucket Sound from August to November and adults in March, April, and October to December as indicated by the Estuarine Living Marine Resources (ELMR) Program database provided by NOAA. Occurrences of juvenile Atlantic mackerel were highest in the fall and occurrence of adults were highest in the spring (Studholme et al. 1999). Yet, based on a Massachusetts coastal zone survey in Studholme et al. (1999), juvenile and adult mackerel in Nantucket Sound occur only randomly.

Silversides (*Menidia menidia*) are highly abundant in the shore-zone of salt marshes, estuaries and tidal creeks. Juveniles and adults prefer habitats of vegetated substrates compared to habitats of sand and gravel (Fay et al., 1983). Silversides spawn in the intertidal zone of estuaries and tributaries (Fay et al., 1983) and therefore are more likely to occur in the nearshore areas of Nantucket Sound and not within the WTG array. Juvenile and adult silversides inhabit intertidal creeks, marshes, and shore zones of bays and estuaries in spring, summer, and fall. During spring, summer, and fall, Atlantic silversides have often been reported as the most abundant species in marsh and estuarine habitats, yet they may be entirely absent from the same areas during winter. In populations from Chesapeake Bay northward, Atlantic silversides are rare or absent from shore zones or shallow waters in midwinter (Fay et al., 1983). Terns have been observed to feed on spawning schools of silversides but rarely at other stages. This foraging behavior in Nantucket Sound is therefore likely to occur in nearshore areas, outside of the WTG array.

Section 5.4 of the DEIS has more detailed information on finfish in Nantucket Sound from trawl surveys by MDMF. The USACE directed that this Evaluation should use fisheries data available from appropriate agencies, and Applicant need not gather new data.

3.0 FEDERALLY-LISTED THREATENED/ENDANGERED BIRD SPECIES

This section examines the natural history of the two federally-listed species to be considered in this Evaluation, the threatened Piping Plover and the endangered Roseate Tern. Both of these species are also state-listed threatened and endangered, respectively. (A third state-listed species, the Common Tern (Special Concern), is addressed specifically for the MEPA submission in Appendix 5.7-I). The Piping Plover is a summer-resident which nests on the shores of Nantucket Sound and individuals may cross the Project Area in the course of their annual movements. Both Roseate and Common Terns forage in the waters of Nantucket Sound, nest on nearby land, and travel throughout the general Project Area during the summer (late April – late September). All three species (2 terns, 1 plover) are migrants and many pass Nantucket Sound in spring and fall in addition to those nesting nearby. Many individuals that nest further north along the Atlantic Coast may pause in Nantucket Sound during the course of their annual travels but the extent of such “staging” is not well known: it is conspicuous in fall but less marked in spring. For each species the current information about status refers to the 2002 breeding season (and earlier). Complete data from the 2003 breeding season were not available.

3.1 Piping Plover

The Piping Plover (*Charadrius melodus*) is a small shorebird that occurs only in North America. It is approximately 7 inches (17 cm) long, has a wingspan of approximately 19 inches (38 cm), with pale sandy-colored upperparts and white underparts. Breeding birds have a single black breastband (often incomplete and thinner on the female) and a black bar across the forehead. The legs are orange and the short stout bill is orange with a black tip. Piping Plovers nest sparsely along coastal beaches, a habitat that is experiencing considerable pressure from development and human disturbance. A principal source for this natural history information is the account in the “Birds of North America” (Haig, 1992).

3.1.1 Population Status and Trends

Piping Plovers breed in only three geographic regions: the Atlantic Coast, the Northern Great Plains, and the Great Lakes region. In January 1986, the Atlantic Coast and Northern Great Plains populations were listed as threatened and the Great Lakes population was listed as endangered. Some mingling of individuals from these three populations occurs in their wintering grounds but no interchange of breeders has been reported. Atlantic Coast Piping Plovers are thought to form a distinct breeding population (USFWS, 1996). Critical habitat was designated in 2001 for the wintering population of Piping Plovers and for the Great Lakes breeding populations, but not for the Atlantic Coast breeding population. (see http://pipingplover.fws.gov/; http://plover.fws.gov/)). The USFWS designated the shorelines along the South Atlantic and Gulf Coasts as critical habitat for the wintering population which includes shoreline areas in North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas (http://www.epa.gov/fedrgstr/EPA-SPECIES/2000/August/Day-30/e22118.htm).

At the time of listing, in 1986, the Atlantic Coast population was estimated as 790 pairs. Increases to 957 pairs by 1989 were attributed partly to increased survey efforts. The estimated total for the Atlantic Coast population in 1996 was 1,348 breeding pairs and in 2002 was 1,690 pairs. The increase was unevenly distributed, and occurred in association with intensive protection efforts (USFWS, 1996; 2002, 2003). In the same period in Massachusetts, the plover population increased nearly 20% (about 3.3% per year), again a result of intensive management. Numbers in the Atlantic population are summarized in Table 1. The breeding range extends from the Magdalen Islands in the Gulf of St Lawrence to South Carolina.

Table 1
Atlantic Coast Population of Piping Plovers in 1990 and 2002 (breeding pairs)

	1990	**2002**
Atlantic Canada	229	275
Maine	17	65
New Hampshire	---	7
Massachusetts	139	538
Rhode Island	28	58
Connecticut	43	31
NY-NJ Region	323	507
Southern Region	201	209
Atlantic Coast Total	**980**	**1690**

In Massachusetts, breeding numbers increased rather steadily to about 450 pairs in 1996 and more slowly since that year. About 135 pairs nested around the shores of Nantucket Sound in 2002 (Melvin and Mostello, 2003).

3.1.2 Seasonal Distribution

Typically the first Piping Plovers arrive in Massachusetts in mid-March, and individuals continue to arrive at nesting beaches until early May and some move after failed nesting attempts. In April, males establish territories in nesting areas along coastal beaches or blowout areas in the dunes. Distribution of nesting birds is shown schematically in Figure 1. Behaviors employed in defending these territories and attracting females include local chases, as well as display flights to heights of about 33 feet (10 m). These are confined to the vicinity of the nesting beaches. The nest, consisting of a shallow scrape lined with pebbles and shell fragments, is made above the high tide line. The usual clutch is 4 eggs, which are incubated by both sexes for 27-30 days. Chicks are precocial, capable of moving on their own soon after hatching, and feed themselves; they are tended by one or both parents until they can fly at the age of 25-35 days. Piping Plovers generally raise only one brood in a season but may re-nest several times if previous nests are lost. Eggs may be present on the beach from mid-April to late July and young may be present until late August. Most young can fly by late July, and from this stage, adults and young leave nesting areas and congregate on preferred feeding grounds (staging areas) such as South Beach, Chatham before southward migration, principally in August and September (Haig, 1992). Occasional late records suggest that rare individuals may overwinter in Massachusetts (Veit and Petersen, 1993) but this has not been confirmed.

Migration patterns are not well documented. Plovers nesting in New England and further north may travel along the Atlantic coast or fly directly between their breeding grounds and wintering grounds, which are from North Carolina to Mexico, and across the ocean into the Bahamas and West Indies (Puerto Rico and Cuba). Areas of critical habitat for the wintering population were designated in 2001. Sightings at Bermuda are rare (USFWS, 1996) and many wintering plovers remained undetected in the second international census in 1996 (Plissner and Haig, 2000). About half of the Atlantic population (885/1,690 pairs in 2002, see Table 1) breeds in Massachusetts or further north (28% north of Nantucket Sound). There have been no systematic surveys of staging birds. Miscellaneous reports indicate late-summer peaks of 30 to 100 individuals in the vicinity of Chatham (Nauset Marsh to South Beach) and smaller numbers in spring. No other similar staging areas in the vicinity of Nantucket Sound have been identified and no flights have been observed so that it is impossible to characterize movements across the Project Area at this time (Veit and Petersen, 1993; Bird Observer database 1994-2001). Migrants traveling directly between staging areas near South Beach/Monomoy and winter quarters would not pass over Horseshoe Shoal.

Information about movements of individuals is limited and there are no current studies because color-banding was restricted by USFWS in 1989 because of damage caused by the bands. Earlier studies showed considerable philopatry (the tendency of an individual to return to, or stay in, its home area), both in summer and in winter (Haig, 1992). Some movements in the Cape Cod area were reported, both within and between years, by MacIvor (1991).

3.1.3 Food and Feeding Habits

Plover foods consist of a wide range of terrestrial and marine invertebrates, including worms, fly larvae, beetles, crustaceans, and mollusks. Food items are taken from the ground surface in a range of coastal habitats – often the intertidal parts of ocean beaches, but also wracklines, mudflats, and shorelines of coastal ponds. Foraging plovers walk or run within their feeding territories and detect their prey visually. In the breeding season, feeding areas are generally contiguous to nesting territories, but parents may lead young chicks up to several hundred meters away from the nest and may use other food-rich habitats such as salt marsh. After the breeding season, small parties of adults and flying young gather at favored locations and feed in similar habitats, but also in more remote marshes, before migrating. Reports suggest that plovers wintering on the Atlantic coast tend to gather near coastal inlets and other sites that are thought to provide good food supplies.

3.1.4 Flight Behavior

The characteristics of plover flight are not well known and no activity budgets focusing on altitudes have been established for this or most species. During the breeding season they are generally observed flying low over the water or adjacent land (as between feeding sites), usually <33 feet (10 m) above sea level (asl) but also higher. Such flights include departures towards land beyond the horizon that may include flights across the Sound (S. Hecker, pers. comm.). Display flights in the vicinity of the nesting territory are at similarly low altitudes.

There are no specific data on migration for Piping Plovers, however, some are known to cross open water to breed and/or winter on oceanic islands, as noted above. Many shorebirds migrate at high altitudes, typically higher than songbirds. Shorebird flocks leaving Nova Scotia, observed by radar, were at a mean height of approximately 6,600 feet (2,000 m) asl (Richardson, 1979). Common patterns shown by long-distance migrants are initially to climb steeply to high elevations and to select flight altitudes with favorable winds (Alerstam, 1990; Eastwood, 1967). A study in the North Sea reported on visual observations of migrating birds within about 300 m of the sea surface made from the island of Heligoland , in which the flight altitudes were summarized as above or below 50m asl (Dierschke and Daniels 2003, as cited by ICES 2003). For 8,476 shorebirds (of 28 species) 3,129 (36.9%) were flying above 50 m.

Very little is known about the altitude of local movements by shorebirds. Nocturnal movements of several species of shorebirds wintering in coastal areas of The Netherlands, studied by radar, recorded substantial numbers flying between widely separated upland roosts and tidal feeding areas at altitudes up to approximately 330 feet (100 m) and more, within the range of the turbine rotors at the site (Van der Winden et al., 1999). However, such flights are of uncertain relevance for interpreting movements across the open waters of Nantucket Sound, where no roosting flights have been identified and shorebirds may fly close to the water surface, or higher. Insufficient data are available to characterize the movements of plovers across the Sound.

3.1.5 Known Disturbance and Mortality Factors

Restrictions on banding noted above have not only limited studies of movements, they have also hampered estimates of survival. Early studies based on resighting of color-banded birds on Cape Cod, 1985-1989, indicated mean annual survival probabilities of 0.74 for adults, and 0.48 for fledglings. Viability analysis indicated that extinction probabilities are sensitive to small changes in survival rates (Melvin and Gibbs, 1996). Additional modeling to extend these analyses is summarized in Section 4.2.5 below.

Numerous factors have been identified that adversely affect nesting plovers or their chicks; however they will be examined only cursorily here because they are, for the most part, irrelevant to this Project. Major contributions to the species decline have been the loss of habitat due to beachfront development and shoreline stabilization.

Mortality in the breeding season affects principally eggs and chicks but predators take some adults (Melvin and Mostello, 2003). People, pets, and motorized vehicles are all important causes of disturbance (Burger, 1994) as well as of direct mortality. These are direct consequences of increased recreational use of beaches, which also has indirect effects by increasing the numbers of predators such as crows, gulls, foxes, raccoons, coyotes, and feral cats attracted by garbage. Disturbance may cause adults to avoid otherwise desirable areas, to desert nests, and to feed more slowly; it also interferes with chick feeding and growth.

3.1.6 Use of Nantucket Sound and Project Area

As indicated above, Piping Plovers are beach-dwellers and are found widely around the coastal areas of Nantucket Sound where about 120 pairs nested in 2002, with a particular concentration on South Monomoy (Melvin and Mostello 2003). They feed and nest on beaches and do not spend time in the offshore areas proposed for the wind turbines. Some plovers may fly across these areas, from one side of the Sound to another, but no data have been recorded, and sightings of plovers on beaches do not suggest any concentrated flightlines. None were seen during the boat surveys conducted during the two years of Project related studies (See Appendices 5.7-D, F, G, K, L, and M) but these studies were aimed at quantifying bird numbers in the project area in Nantucket Sound, and not designed for measuring such movements. The proposed landfall for the project is on the northeastern side of Lewis Bay in Yarmouth, at the end of New Hampshire Avenue. This site is 0.8 mi (1.3 km) from the nearest known nesting sites of Piping Plover on the opposite (seaward) side of Great Island and 1.5 mi (2.4 km) from those at Kalmus Beach/Dunbar Point, Hyannis and the north-western corner of Great Island (Fig. 1). The buried cables (at their closest point) will pass within approximately 820 feet (250 m) of Kalmus Beach/Dunbar Point and approximately 1,210 feet (369 m) of Great Island. About 28% of the Atlantic Coast population nests to the north of Nantucket Sound and some of these birds may cross Horseshoe Shoal in the course of their spring and fall migrations.

3.1.7 Summary

The available evidence indicates that small numbers of Piping Plovers nest where they might incur transient effects during construction. There were no records of birds crossing the proposed sites for the WTGs during the fieldwork although the methods used are not likely to detect such movements and the frequency of such movements is unknown. Some of those movements might occur at rotor height. During the course of their annual migrations some number of the Piping Plovers that nest from Nantucket Sound northwards will cross the Project area.

3.2 Roseate Tern

The Roseate Tern (*Sterna dougallii*) is a medium-sized marine tern weighing about 3.5 oz (100 g), with a wingspan of 27.6 inches (70 cm); it is pale in color, with a black-capped head, and an exceptionally long, deeply-forked, white tail. The underside of an adult Roseate Tern is white with a tinge of pink that gives the bird its name. The legs and feet are orange. In May, the bill of Massachusetts birds is entirely black but in June and July an orange base develops.

The Roseate Tern has a wide global distribution, breeding principally in the tropical Indian and Pacific Oceans, with smaller numbers in temperate waters. In the northwestern Atlantic, Roseate Terns nest only in mixed colonies with the more abundant Common Tern (*S. hirundo*) and also feed, roost, and may migrate in mixed flocks. The two species are similar in appearance so that characterization of Roseate numbers and activities is sometimes difficult and some conclusions have to be drawn from observations that do not differentiate the two species.

Principal sources for this account of natural history are the following: Gochfeld et al 1998, Nisbet 1980, Nisbet 1981, Nisbet 1989, Nisbet 2002, and USFWS 1998.

3.2.1 Population Status and Trends

In the North Atlantic, Roseate Terns are migratory and they presently nest in four distinct areas: (a) widely scattered on islands in the Caribbean Sea (including the Florida Keys and the U.S. Virgin Islands), (b) the northwest Atlantic, along the coast from Long Island, NY to Nova Scotia and the Gulf of St. Lawrence, (c) several islands in the Azores, and (d) Northwestern Europe (Great Britain, Ireland, France). Wintering areas of these terns are not well established: most American breeders probably travel to the coast of Brazil (as far as 18°S) where some individuals from other North Atlantic populations also occur (Hays et al., 1999). For 14 years there has been intensive trapping and observation of individually marked birds at the colonies. However, during this period, no interchange of breeders has been reported between the four areas, but movements within the northwest Atlantic population have been measured (Lebreton et al., 2003) and one 2-year old tern from Europe has been seen in Massachusetts (Nisbet and Cabot 1995).

In 1987 the US Fish and Wildlife Service determined the northeastern population (that nesting in the northwestern Atlantic Ocean) to be endangered and the Caribbean population to be threatened. The Canadian population (contiguous with the northeastern population) was designated as threatened in 1986 (Kirkham and Nettleship, 1987). Principal reasons for listing were declines in numbers and concentration of breeders into very few colonies. No critical habitat was designated. Since 1975, management has focused on protecting existing colonies and restoring former colony sites. Productivity at most existing colonies has generally been satisfactory, except for predation at some inshore colonies. Twelve former tern colonies, from Maine to Long Island, NY, have been restored by removal of gulls that had usurped the sites. Common Terns have recolonized all these sites and Roseates appear to be established at three of them. One site in Buzzards Bay, Massachusetts has been restored successfully and is now used by both Roseate and Common Terns (Ram Island, Mattapoisett). A second restored site, Penikese Island, also in Buzzards Bay is now used by small numbers of Common Terns, and, since 2003, by Roseate Terns following the Bouchard 120 Oil Spill. Muskeget Island in Nantucket Sound, formerly the site of a huge tern colony taken over by gulls, has received extensive attention but is not yet the site of a stable tern colony and no Roseates have nested recently.

The regional population is summarized in Table 2. The two main colonies in Massachusetts are both in Buzzards Bay (Figure 1), about 25 miles (40 km) from the Project Area (as most terns fly, see 3.2.6, below). These colonies are located on Bird Island in Marion and Ram Island in Mattapoisett (about 6 miles (10 km) apart). Since 2000, these 2 colonies have held about 1,500 pairs, about 40% of the Atlantic breeding population. A large colony east of Long Island, NY, on Great Gull Island (130 km (81 miles) from Bird Island), also has about 1,500 pairs. Very small numbers of Roseates (3 pairs in 2002) nest on Monomoy, within a large colony of Common Terns, but none nest near the location of the project's proposed landfall (Blodget 2001).

Table 2
Nesting pairs of Roseate Terns in the Northwest Atlantic in 1990 and 2002
(estimated "Peak Period" numbers)

Region	1990	2002
Atlantic Canada (2 sites)	120	133
Maine and New Hampshire (4 sites)	102	293
Massachusetts		
Bird Island	1547	505
Ram Island	0	952
Other (5, 1 site(s))	38	3
New York and Connecticut		
Great Gull Island	1026	1505
Falkner Island	150	65
Other (4, 3 sites)	133	158
Total	**3116**	**3614**

Source: Data from USFWS 1998 and J. Spendelow, USGS (the data from Canada are approximate interpolations).
Other (n,n) = the number of minor sites in 1990 and 2002, respectively.

3.2.2 Seasonal Distribution

In spring most Roseate Terns arrive in Massachusetts in late April and early May. They are first seen in flocks near Nantucket and Muskeget Islands and also congregate near other preferred feeding locations, such as Woods Hole and the entrance to Waquoit Bay, before dispersing to the breeding colonies, principally in Buzzards Bay, where eggs are laid (from mid-May) and young raised (until early August). Courtship activities are conspicuous early in the season, both before and after arrival at the colonies and include both displays on the ground and spectacular courtship flights. During such flights, the terns spiral steeply upward, sometimes to heights of approximately 300 feet (100 m) or more. From these colonies, the terns travel on several flights each day, sometimes to distant feeding grounds (over 30 miles (48 km)) and carry fish back for their mates and young. Early in the season (May) unmated birds and pairs in the early stages of breeding may spend much of the day near distant feeding areas. Some foragers travel routinely to Nantucket Sound from Buzzards Bay, and Horseshoe Shoal is within the potential foraging range of Roseates nesting throughout the Bay and the Sound (see Section 3.2.6 below).

The Roseate Tern usually lays 1 or 2 eggs that are incubated by both sexes. In this area they generally select nest-sites under vegetation, rocks or other shelters such as boards or nest-boxes. The eggs hatch after approximately 23 days and the young fledge at 25 days of age. The young birds remain dependent on their parents for several weeks after they can fly and travel together to the post-nesting aggregations in Buzzards Bay and at South Beach and other sites near Nantucket Sound.

After the breeding season, both Roseate and Common Terns disperse from the colonies to feeding areas around Cape Cod and the Islands. By mid August many gather at large roosts on South Beach, Chatham, and at other locations near the Sound including Eel Point and Smith Point on Nantucket, and on Tuckernuck Island, see Figure 1. (Trull et al., 1999) and some may remain in Buzzards Bay. At these staging areas, Roseate and Common Terns are joined by birds from other parts of New England (Veit and Petersen, 1993). It is possible that all Roseate Terns from the northwestern Atlantic are present at these staging areas, at one time or another. Reading of bands by telescope has shown the presence of birds from as far away as Maine and Connecticut. During late summer, Roseate and Common Terns are more difficult to distinguish than earlier in the year. The Roseates molt their long outer tail feathers immediately after nesting and their bill-color changes from all black (in May) to orange with black tip: in both respects they are more like Commons. In addition, Roseates are much more vocal than Commons, so that species-characteristic calls are unreliable for establishing numbers in mixed flocks.

Migratory movements are not known in detail. Roseates migrate in flocks, possibly with Commons, and are thought to fly directly from staging areas, such as Monomoy or Nantucket Island, to the Caribbean or South America, departing in September (there are few records of migrants from intervening coasts.). Altitude of migration has not been measured but large flocks (sometimes thousands of terns) departing staging areas on Cape Cod in the fall, heading seawards, climbed rapidly to heights at which they would usually pass unseen, likely > 650 feet (200 m) (Veit and Petersen, 1993; S. Perkins, pers. comm., 2002). Common and Arctic Terns (*S. paradisaea*) migrating in fall, tracked by radar across southern Sweden, climbed rapidly to altitudes of approximately 3000-10,000 feet (1,000 – 3,000 m) while some migrants flew close to the surface along the coast when facing contrary winds (Alerstam, 1985). Flight altitudes of coastal migrant terns (all < 80 feet (25 meters)) have been reported by Kruger and Garthe (2001), see below. Spring arrivals in Massachusetts may also follow long flights over the ocean; they have not been described in sufficient detail to include altitudes of incoming birds.

3.2.3 Food and Feeding Habits

Roseate Terns feed almost entirely on small fish (only rarely squid and small crustaceans) that they capture by day principally by plunge-diving from heights up to 40 feet (12 m) (usually 6-20 feet (2 – 6 m); less frequently they forage by surface-dipping (Gochfeld et al., 1998). In New England, sandlance (*Ammodytes*) predominate in the diet, and various other fish are taken, usually schooling species such as herrings (*Clupea harengus, Alosa aestivalis*), anchovies (*Anchoa* spp), mackerel (*Scomber scombrus*), or silversides (*Menidia menidia*), depending on their availability. Roseates most frequently forage at shallow sandbars or over schools of predatory fish that drive prey to the surface. Movement of water across steeply-shelving subsurface topography is also thought to be one major factor that brings small fish within reach of surface-feeding terns.

Roseate Terns have been documented foraging commonly as far as 22 mi (35 km) from the colony (Heinemann, 1992). The foragers depend upon the availability of prey and thus on bottom topography and the occurrence of predatory fish. Foraging tends to be concentrated at a few sites that may change unpredictably from year to year. When not tending eggs or chicks at the colony, Roseates often rest near feeding areas on rocks or exposed sandbars.

3.2.4 Flight Behavior

Few quantitative studies of the altitude of flying terns have been conducted. However, the general pattern is familiar (pers. obs., J. Hatch; Gochfeld et al. 1998). Recent observations of flight behavior in Nantucket Sound are summarized in Section 3.2.6 below. Four categories of flight can be recognized in the context of potential risks from wind turbines. These categories apply to many terns although species may differ quantitatively. When foraging, Roseate Terns fly below about 40 feet (12 m) asl, often < 16 feet (5 m), and they have not been reported taking flying insects (In contrast, Common Terns have been recorded feeding on flying insects at much higher altitudes). Foraging terns are generally intent on the water below.

When traveling to a distant feeding site, roost, or colony, and when migrating near the shore, height of flight is strongly affected by the wind direction. Terns have been observed to fly near wavetops when flying into the wind, and higher if downwind. A study of coastal migrants in the North Sea (Kruger and Garthe 2001) showed strong effects of wind direction on altitude of flight. Flying birds were placed into four height zones. However, even in following winds, none of the terns were seen in the highest zone, >80 feet (25meters). This study reported on 271 Common/Arctic Terns (the 2 species are indistinguishable) and 959 Sandwich Terns, no Roseates were present. Another study in the North Sea reported on visual observations of migrating birds within about 300 m of the sea surface made from the island of Heligoland, in which the flight altitudes were summarized as above or below 50m (Dierschke and Daniels 2003, as cited by ICES 2003). For 18,464 terns (of 5 species) only 241 (1.3%) were flying above 50 m.

When flying over land, Roseates (and other terns) fly much higher. Roseate and Common Terns commuting over land between Bird Island and feeding sites in Nantucket Sound travel at 300 feet (100 m) or more. During migration over land Common/Arctic terns travel at heights greater than 1000 m (see Section 3.2.2) but there are no data for migrating Roseates.

During courtship, and other social activities, which generally occur near the nesting areas, but occasionally before the terns reach the nesting areas in the spring, Roseates may fly to 330 feet or more (100 m, see above).

3.2.5 Known Disturbance and Mortality Factors

Most mortality of adults appears to occur on migration or in the wintering areas and very little is known about it. Occasional instances are known of predation at colonies. Annual survival probability of adults (1988-1998) was estimated by modern mark-recapture methods as about 0.85 at 3 sites, but lower in 1991-1992, the year of Hurricane Bob. Estimated survival rates for the first two years of life ranged from 0.3 to 0.5 (Lebreton et al., 2003). Additional demographic information is summarized for population modeling in 4.2.5 below and Attachment 1.

Most breeding sites of this population are on protected islands and not subject to important disturbance. Low-level flights of planes or helicopters cause all terns to flee the colony or roost, but they rapidly return. Other terns (Least, Arctic) are known to nest close to airports and readily habituate to regular activity. Common Terns have nested successfully in an empty barge immediately adjacent to shipping lanes in the New York/New Jersey Harbor off Jersey City, New Jersey (pers. obs. P. Kerlinger). When foraging, Roseate Terns fish (dive) within 60 feet (20 m) of boats (pers. obs., J. Hatch) and do not appear to be disturbed. However, no published studies examining this have been found. Sport fishermen commonly approach feeding flocks of terns, seeking the predatory fish below; such flocks may then disperse, but apparently because the large fish leave and not because the terns respond directly to the boats. Photographers wishing to photograph Common and other terns often feed them small fish, which attracts these birds to within 5-10 m of a boats or dock (T. Vezo, personal communication). These observations suggest that terns habituate readily to the presence of human activities.

3.2.6 Use of Nantucket Sound

Both Common and Roseate Terns have long been known to occur extensively in Nantucket Sound. Roseates typically forage at shoals or over schools of predatory fish and are rarely seen close to shorelines or amongst moored boats, although Common Terns often occur in such spots. Thus, Roseates are less likely than Commons to occur in Lewis Bay but both species may occur over Horseshoe Shoal and nearby areas. Boat surveys in 1990 and 1991 showed that foraging Roseates from Bird Island in Buzzards Bay were particularly abundant over the Mashnee Flats near the southern entrance to the Cape Cod Canal, and over shoals in Vineyard Sound and the western end of Nantucket Sound (Heinemann, 1992). These shoal areas are as far as 22 mi (35 km) from Bird Island via Woods Hole and 15 mi (25 km) direct (overland). This was the first recognition that breeding Roseates might regularly travel so far in search of food. An unknown fraction of foragers take this triangular route, out over the water and return over land, and some travel both ways overland. These surveys did not extend as far as Horseshoe Shoal, but this shoal is within the potential foraging range of Roseates nesting throughout Buzzards Bay and Nantucket Sound. In 2002 3 pairs of Roseates nested in the large tern colony on North Monomoy, 16 miles (26 km) from Horseshoe Shoal.

Recent work has documented the locations, numbers, and behavior of terns more completely, focusing principally on occurrences in and near the project area. Four studies of terns (two studies include two years of observations) are summarized here, including data from five years, these data refer principally to terns traveling or foraging in the area: 1) A boat-based survey in 1990-1991, noted above, reported to USFWS (Heinemann, 1992); 2) a preliminary study in 2001, comprising six aerial surveys sponsored by Cape Wind; 3) systematic aerial surveys (46) from 2002-2004, plus 15 boat surveys, also funded by Cape Wind, and 4) similar flights (14) and boat surveys(13) in late summer 2002 and summer 2003 by Massachusetts Audubon Society (MAS), funded through Massachusetts Technology Collaborative. (The MAS studies are continuing in 2004). Because the abundance of birds at sea is very variable, a large study area was selected in Nantucket Sound for the systematic Cape Wind studies within which the distribution and density of birds were established during transect surveys, using GPS, throughout the annual cycle (Komdeur et al. 1992, Noer et al. 2000). The project area occupied 42.5 mi^2 (110 km^2) on Horseshoe Shoal, within a study area of 322 mi^2 (834 km^2) that comprised 58% of Nantucket Sound. The MAS aerial surveys followed similar protocols. These sampling methods were similar to those used by the U.S. Fish and Wildlife Service for sampling winter waterfowl and those employed in conjunction with offshore windfarms in Europe (Noer et al. 2000). They provide quantitative information regarding how many birds were in different parts of the Sound during different times of the year. No standardized protocols have yet been recommended for offshore sites by USFWS or by NWCC. Their principal limitation is that they are confined, for obvious practical reasons, to conditions of relatively moderate winds and good visibility. This summary also incorporates data from other sources

The aerial and boat surveys provided different information regarding avian use of Nantucket Sound. From the plane, the height chosen (250 ft (75 m)) enabled estimates of distribution and density by means of counts of birds within the narrow transects over a large area. Birds do not flush from planes at this height before they are counted. From the boat, observers could more readily identify individual birds to species, count bird flocks and record altitude and behavior since the vessel speed was slower than the airplane.

3.2.6.1 Distribution of Terns in Nantucket Sound

The spatial and temporal patterns established by the studies indicated above, and summarized below, showed that Nantucket Sound is an important feeding area for terns but that fewer were present at Horseshoe Shoal than in other parts of the Sound. Terns were more numerous there early in the season, apparently before breeding; the numbers after the breeding season were lower but not consistent between years.

In June and July of 1990-1991 at Bird Island, then the principal nesting site for Roseate Terns in this area (located in Buzzards Bay, see Figure 1), many Roseates returned with fish from south and southeast of the island. Boat surveys revealed that many foraged over several shoals in Vineyard Sound and the western end of Nantucket Sound (Heinemann, 1992), but these surveys did not extend as far as Horseshoe Shoal. In 2001, six exploratory aerial surveys showed Roseates foraging over some of the same western shoals during early July, the chick-feeding period when food demand is highest, with few over Horseshoe Shoal, more distant from the colony. Some birds returned from foraging sites in Nantucket Sound to Bird Island directly, flying overland. After the breeding season, in September when many terns staged in the Monomoy area, the only Roseates encountered were east of Horseshoe Shoal; such birds would not travel across the proposed site of the wind farm (Hatch, 2001; Appendix 5.7-C).

In the summer of 2002, Cape Wind funded systematic surveys of birds using the open waters of Nantucket Sound that are reported in Appendix 5.7-F. Terns were recorded on all six aerial surveys along transects of a large study area in the center of the Sound from May 22 to August 30, 2002. These transects were 1300 ft (400 m) in width and covered 19% of the area. Terns were also seen during the seven boat surveys, May - August 2002. Common and Roseate Terns were seen widely in the Sound during the surveys, but were more abundant near shore and outside of the study area. Densities over Horseshoe Shoal in 2002 were relatively low: 4.8 individuals/sq.km. The numbers of terns seen over Horseshoe Shoal varied from 0 to 52 birds per survey, being high in May and again in mid-August (one survey). Terns were observed singly and in flocks numbering up to 201 (mean = 5). Daytime loafing areas, sometimes used by hundreds of terns before and after the breeding season, included the jetties at the mouth of Waquoit Bay (north of the proposed wind farm) and the exposed sandbar northwest of Muskeget Island (“Fernando’s Fetch”) that is south of the proposed windfarm.

Within the Cape Wind study area, 1,801 terns (120 Roseate, 1,043 Common, 68 Least, and 570 Common-Roseate type) were recorded during the 2002 aerial surveys and 3,024 (205 Roseate, 1,205 Common, 112 Least, and 1,502 Common-Roseate type) were seen during the boat/groundtruthing 2002 surveys (Appendices 5.7-D, 5.7-F, and 5.7-G).

Also in 2002, Mass Audubon conducted 11 aerial surveys of Nantucket Sound from August 19 to September 19 to ascertain abundance and distribution of Roseate and Common Terns during the pre-migratory period (Perkins et al., 2003). Although the MAS methodology differed, their findings were very similar to those of the Applicant’s surveys: in both studies terns were much less abundant over Horseshoe Shoal and other central (“offshore”) parts of the Sound than near the northern and especially the eastern edges of the Sound. During the 11 flights, the observers recorded 5,721 terns in transects of width approximately 7,000 feet (2,133 m) (to limits of visibility), which included 634 Roseate, 1,767 Common, 3,311 Common-Roseate type and 9 Least Terns. The methods used by Mass Audubon were suited to counting but not measuring bird densities, although the findings seem to be similar to those of the Cape Winds research team.

In 2003, 24 aerial surveys for Cape Wind were conducted from January to December, principally examining the same study area as in 2002: these are reported in Appendices 5.7 –G, K, L, and M. Terns were seen on every survey from April 18 to November 19 (Roseates from May 12 to September 15). Larger numbers were present on Horseshoe Shoal in May, fewer thereafter. The year 2003 was unusual in that exceptionally large numbers of terns were present in Buzzards Bay after the breeding season (J.J.Hatch, personal obs.). Within the Cape Wind study area, 1,086 terns (120 Roseate, 564 Common, 15 Least, 1 Forsters and 386 Common-Roseate type) were recorded during the 2003 aerial surveys and 2,843 (2 Roseate, 2,500 Common, 3 Least, 1 Forsters 40 Black and 297 Common-Roseate type) were seen during the boat 2003 surveys (Appendices 5.7-G, 5.7-K, 5.7-L and 5.7-M). Densities over Horseshoe Shoal in 2003 were relatively low: 8.6 individuals/sq.km.

The combined results of the standardized surveys in 2002 and 2003 are presented in Figure 5.7-13 in Section 5.7 of the DEIS – DEIR to show the seasonal pattern of numbers in the study Area and over Horseshoe Shoal. The distribution and abundance of the roseate and mixed terns on the aerial and boat surveys are presented in Figure 2 and 3, respectively. More terns were seen near the edges of the study area than on Horseshoes Shoal. On the shoal, sightings of terns were widely scattered. Sightings of larger numbers of terns outside the study area, not shown on this map, are summarized in Attachment 2 of Appendices 5.7-F, 5.7-K and 5.7-L. The boat-based observations, which do not provide a uniform coverage of the area, are summarized in Figure 3: the large concentrations at several near-shore locations partly reflect places where terns loaf by day and/or roost at night.

Also in 2003, May 15– July 31, Mass Audubon examined tern activity during 13 boat surveys on Horseshoe Shoal and in three aerial surveys of a large study area in the Sound using narrow transects (unlike their 2002 surveys). These surveys showed similar temporal and spatial information to those reported by the Applicant. During the boat surveys, a total of 250 terns were observed on Horseshoe Shoal, and terns were recorded on all but four boat surveys. Terns were recorded on all three aerial surveys conducted by MAS: with 680 terns observed comprised of 472 Common Terns, nine Roseate Terns, and 199 Common-Roseate-type terns.

In summary, these surveys (including those by MAS), which were all conducted during conditions of good visibility, reported low numbers of Roseates, not only over Horseshoe Shoal, but also in areas from which commuting birds would cross that shoal on their way to and from a breeding colony (in Buzzards Bay) or a late-summer roost (on South Beach). These observations suggest that the numbers of Roseate Terns that regularly use Horseshoe Shoal are low in absolute numbers, as well as being relatively low with respect to other areas of Nantucket Sound and waters closer to the nesting colonies and to South Beach.

3.2.6.2 Tern Behavior and Altitude of Flight in Nantucket Sound

The following paragraphs include not only observations from the studies mentioned above, but also various additional records that shed some light on the tendency of terns to fly at altitudes where they might be at risk of collision with turbine rotors (75 – 417 feet (23 – 127 m)). It is difficult, of course, to record heights above the sea surface precisely; however, this does not seem to be a major problem because so few terns were observed to be close to the height of the rotors (see below), that increases in precision would have negligible effects. Although the Roseate and Common Terns tend to dive from different heights (Roseate higher with a maximum of 40 feet (12 m)), neither tern approaches rotor height while seeking aquatic prey. Because the two species are not known to commute at different heights and in many cases, the terns were not identified to species, the following discussion will group the observations for these two species.

All records of tern altitudes were made when observational conditions were excellent to fair. It is important to recognize that most commuters probably reach their overnight destinations before nightfall and leave after dawn and are therefore unlikely to travel past turbines at night. Terns are generally sociable at night, spending the period of darkness on shore, at colony- or roost- site; nocturnal flying is probably limited to within a mile (2 km) but most are thought to rest for most of the night. Terns taking off on migration across the ocean directly towards their wintering grounds would not cross Horseshoe Shoal.

Altitude estimates were made for 5,112 flying terns; of these, 5,009 were within approximately 60 feet (18 meters) of the water surface, and thus below the height of the rotors. Those flying below 40 feet (12 m) included both foraging and traveling individuals. One hundred and three (103) terns were observed above 60 feet (18 meters) asl. Of the 103 observed above 60 feet, 100 were observed flying at heights 75 feet and above (within the rotor swept zone). Within the study area, 1 roseate tern was observed flying at approximately 75 feet, 49 common terns were observed flying at approximately 80 feet, and 50 mixed terns were observed at an altitude higher than 81 feet. Of these 100 terns observed within the rotor swept zone, none were observed within the boundary of the proposed Project Site on Horseshoe Shoal. Another flock of terns was estimated to be flying at 110 feet (33 meters) asl. They were flying in a southeasterly direction approximately 1 mile (2 km) off of Cape Poge on September 13, 2002 and were identified as Common Terns. Mass Audubon observed very few terns flying within the rotor swept zone on Horseshoe Shoal during their field surveys. (Perkins et al 2003 and Perkins et al 2004).

In 2002, altitude estimates from both the aerial and boat surveys totaled 1,813 individuals, of which only 47 were above 60 feet with all located within the rotor swept zone. In 2003, altitude estimates from the aerial and boat surveys totaled 3,299 individuals, of which only 56 were above 60 feet with 3 of which were below rotor height.

Also during 2003, MAS estimated heights of 222 flying terns from a boat: 8 (3.6%) were above 60 feet (6% if foragers excluded), confirming that relatively few of these birds fly above 60 feet during the entire season when these birds are present. For all these observations, Common Terns were most often identified and there were large numbers of “Common/Roseate” types, and identified Roseates were in a minority. During boat surveys (by Cape Wind and by Mass Audubon), which are better suited for recording altitudes, most all flying terns observed were well below rotor height with the exception of 47 common terns observed at rotor height during the Cape Wind boat surveys. During Cape Wind boat surveys, 34 observations were made of flying Roseates (197 individuals) and 113 of flying Commons (698 individuals) and Mixed terns (1,380 individuals). Almost all of these were observed flying at or below 33 feet (10 m) asl. Only three were above that height, and they flew no higher than 66 feet (20 m). Flocks of foragers numbered from 1 to 33 individuals. During August 2002, Mass Audubon observers during two boat surveys, made six observations of 42 terns (one definitely identified as Roseate) and they were all below 50 feet (15 m) asl.

Several land-based observations (by J. Hatch) indicate that both species may fly higher than 100 ft (30 m) when over land, these included commuting birds, those returning to colony or roost. Terns, some carrying fish, have been seen over Falmouth on several occasions, evidently returning towards Bird Island from Nantucket Sound, flying well above 100 ft (30 m). At dusk in late August 2001, individuals of both species approached the roost on South Beach, Chatham from the north (over the beach) flying at about 120 feet (37 m, estimated from below). On September 17, 2002, similar flights over South Beach were measured at 200 feet (60 m), with a clinometer at known range.

On the other hand, observations of commuters at sea showed no differences in altitude from daytime travelers in the area. On August 1 and 15, 2002, during boat surveys, numerous individuals of both species were observed flying near dusk towards a roost site on an exposed sandbar ("Fernando's Fetch") near Muskeget Island. Altitudes of 133 terns close to the boat, including 2 Roseates and 74 Roseate/Common were below 30 feet (10 m). Many additional birds were too distant for estimates of altitude but none appeared to be flying higher than the daytime flocks. Near dusk on June 2, 2002 two roseate terns were observed from the boat survey flying just above the water surface towards Fernando's Fetch.

High flights during courtship occur at the colonies throughout the season but none were seen during any of the surveys, boat or plane.

3.2.7 Summary

From the studies/surveys conducted in 2001 - 2003, it is apparent that Roseate Terns forage in Nantucket Sound throughout their residence in Massachusetts (May to September). However, repeated sampling during several seasons by both Cape Wind and Mass Audubon showed that the numbers observed at the proposed site for a Wind Park on Horseshoe Shoal during standardized surveys are small relative to other parts of the Sound. Furthermore, terns observed in Nantucket Sound flew primarily below the height of the turbine rotors (75 feet (23 m)). The data collected by both Cape Wind and biologists working for a non-profit conservation organization both indicate that terns very rarely fly over the sea at altitudes at which they might be at risk of collision. Moreover, the vicinity of the proposed landfall is not reported to be used by terns for nesting.

4.0 POTENTIAL IMPACTS TO THE PIPING PLOVER AND ROSEATE TERN

4.1 Introduction

This section discusses potential biological and physical impacts of the proposed project to the two bird species addressed in this Evaluation. For each species, the potential effects during the three phases of the project (construction, operation/maintenance, and decommissioning) will be considered in relation to the following four components: (1) habitat modifications, which include transient effects during construction and decommissioning, as well as alterations for the duration of the project; (2) construction/operation activities and vessel traffic; (3) disturbance/displacement by the turbines and ESP; and (4) collision with the turbines. The first two components are present in all three phases of the project while the last two components are only applicable to the operation phase. These categories address the same concerns as a recent analysis based on extensive experience with offshore and onshore windfarms in Europe (Langston and Pullan 2003). The equivalent headings in the European document are: direct habitat loss/damage; disturbance/displacement; barrier to movement; collision.

Construction

The proposed landfall for the project is on the northeastern side of Lewis Bay in Yarmouth, at the end of New Hampshire Avenue. This vicinity is not reported to be used by the Roseate Tern or Piping Plover for nesting or roosting. The intertidal area contains a concrete and stone seawall and very little open sand. This site is 0.8 mi (1.3 km) from the nearest reported nesting sites of Piping Plover on the opposite (seaward) side of Great Island, and 1.5 mi (2.4 km) from those at Kalmus Beach/Dunbar Point, Hyannis (Fig. 1). The site is over 20 miles (32 km) from the nearest nesting colonies of Roseate Terns in Buzzards Bay. No work is being proposed on Great Island, Kalmus Beach or in Buzzards Bay. Construction techniques will minimize disruption of the intertidal zone through the use of Horizontal Directional Drilling (HDD) to make landfall for the submarine cable system. For more information, see Section 4.3.4 of the DEIS-DEIR.

The buried cables will pass within approximately 820 feet (250 m) of Kalmus Beach/Dunbar Point and approximately 1,210 feet (369 m) of Great Island where piping plovers are known to nest. The jet plow embedding procedures are expected to have only transient and negligible effects on the shoreline feeding areas used by the plovers because almost all of the sediment (sand) will be deposited within 200 ft of the trench and the increase in TSS will be transient (< one hour) and localized (about 20 mg/liter at 1500 feet from the trench. See sediment modeling information in DEIS Appendix 5.2-C). Workboats will be present near Egg Island during the installation for a short duration approximately 5 days and will not differ appreciably from the current boat traffic in and outside of the navigational channels. Cape Wind has agreed that a seasonal restriction along the proposed submarine cable route would be appropriate. Cape Wind has proposed during the Energy Facilities Siting Board process, that a seasonal restriction from mid-March to mid-to-late April be imposed for the protection birds, and bird habitat. Offshore construction work is anticipated to take approximately 14 months spread over two construction seasons and will involve technologies of pile-driving hammers for installing monopile foundations and jet plow embedment for burying the submarine cable system and inner-array cables (Section 4.3.4). These techniques will minimize the area on Horseshoe Shoal affected by a temporary increase in suspended solids that might influence fish and foraging terns. The limited duration and localized extent of the disturbance will be as described above. The construction vessels will travel to the project site from Quonset, Rhode Island. If conditions require the use of helicopters to transport personnel, it is anticipated that they will travel to the project site from either New Bedford or Barnstable Airports.

Operation

The cable system is a three-core solid dielectric AC cable design, which was specifically chosen for its minimization of environmental impacts and its reduction of any electromagnetic field. The proposed cable systems for the Project will contain grounded metallic shielding that effectively blocks any electric field generated by the operating cabling system. Since the electric field will be completely contained within those shields, impacts are limited to those related to the magnetic field emitted from the submarine cable and inner-array cables (See Section 5.13 of the DEIS-DEIR). These cable systems are not expected to have any effects on birds.

The WTG site will consist of 130 WTGs, the ESP and array of cables describe in section 2.1. Impacts to Roseate Terns during operation may result from collision with turbine blades (during courtship displays, foraging and commuting). Piping Plovers may be similarly affected if commuting or migrating across the Sound. An in depth analysis of impacts is addressed below in Section 4.2.

Decommissioning

Decommissioning will entail removal of all cables and, within the WTG site, all infrastructure to the level of the seabed. Effects on water quality and noise are expected to be similar to the anticipated effects during construction.

4.2 Analysis of Impacts

4.2.1 Habitat Modification

The primary water quality concern will be elevated concentrations of Total Suspended Solids (TSS) associated with construction and decommissioning of the project. Sustained elevated concentrations of TSS may dispel terns which would result in a potential direct effect if their prey is made invisible, or an indirect effect by potentially changing prey populations or local distribution. However, as indicated below, construction and decommissioning activities are expected to result in only temporary and localized increases in TSS and therefore will have minimal impacts to the listed species.

In total, about one percent of the Project Area is expected to receive temporary impacts from construction: this comprises about 0.04 percent of Nantucket Sound. In addition, the Project Area is situated in a naturally dynamic environment that is subject to higher suspended sediment concentrations at the seabed/water interface as a result of relatively strong tidal currents and wind and storm generated waves, particularly in shoal areas. Therefore, marine organisms in this area are adapted to mobile bed and high suspended sediment concentrations due to natural conditions and populations are expected to recover rapidly from a temporary elevation of suspended sediment levels from Project activities. Mobile organisms are expected to opportunistically recolonize the disturbed sediments from adjacent areas (see Sections 5.3 and 5.4 of the DEIS-DEIR for details).

It is anticipated that the WTGs will be installed in approximately 13 strings, each comprising 10 WTGs with associated inner-array cable and scour mats. Completion of each string and installation of the ESP are each anticipated to take approximately one month to complete. The installation of the submarine cable system from the ESP to the landfall via jet plow embedment is anticipated to take approximately two to four weeks to complete. Construction activities associated with installing the monopile foundations, scour protection mats, and submarine cables will result in a temporary and localized increase in suspended sediment concentrations. The vibratory or pile driving hammer and jet plow technology that will be used to install the monopile foundations and the submarine cables, respectively, were selected specifically for their ability to keep disturbance of sediment to a minimum. As discussed above (Section 4.1- Construction), the majority of disturbed sediments are expected to settle and refill cable trenches and areas immediately surrounding these trenches shortly after installation (generally minutes to less than one hour at any fixed location) (see Appendix 5.2-C). The majority of sediments suspended during foundation installation are conservatively expected to settle within the immediate vicinity of the foundations within one to two tidal cycles because the volume of sediment that would be suspended during the pile driving is expected to be minimal. This expectation is based on the predominance of sand sized sediments in the Wind Park area and the fact that the volume of sediment suspended by pile driving would be much less than the sediment volume suspended by jet plow embedment of the submarine cables (refer to Section 5.2 and Appendix 5.2-C for information on expected settlement rates associated with jet plow embedment). In addition, because the monopiles are hollow and open-ended, subsurface sediments would be encased within the monopile, providing additional structural support and minimizing disturbance of sediment from installation activities.

Sediment suspension during construction and decommissioning activities is expected to last no longer than a few tidal cycles and will not result in long-term elevations in water column TSS. Zooplankton or fish species may be temporarily affected or displaced in the immediate vicinity of the area of the activity; however, they are likely to return rapidly to these areas once construction in the specific area is ceased or completed. Most avian species that may be present in the vicinity of the Project Area during construction are not expected to be adversely affected by temporary increases in TSS because they can move to other areas; the exception is the Piping Plover that feeds within a restricted territory and cannot shift to new areas while it is nesting. A temporary increase in TSS might affect the food available, either increasing it or decreasing it and any such effect would occur too rapidly for any local response in mitigation to be effective. The plovers potentially affected will be those nesting on either side of the entrance to Lewis Bay. Since the submarine cable system will be located approximately 1,210 feet (369 m)) and approximately 820 feet (250 m) respectively, from Great Island and Kalmus Beach/Dunbar Point, any potential impact to these nesting sites will probably be very small and confined in occurrence to a single breeding season but its exact magnitude is unknown.

Another potential direct and cumulative effect could be bioaccumulation of chemical contaminants. Recent studies, however, indicate that there is little potential for birds to bioaccumulate chemical contaminants in their tissues from consuming prey in the Project Area during the brief period of construction. Analysis of 27 sediment core samples obtained from the Project Area indicated that sediment contaminant levels were below established thresholds in reference sediment guidelines. All of the chemical constituents detected in the sediment core samples had concentrations below Effects Range-Low (ER-L) and Effects Range-Median (ER-M) marine sediment quality guidelines (Long et al., 1995). The ER-L and ER-M guidelines use numerous modeling, laboratory, and field studies to establish values for evaluating marine and estuarine sediments. Concentrations below the ER-L represent a concentration range in which adverse effects are rarely observed. Section 5.1 of the DEIS-DEIR has more detailed information on sediment quality in the Project Area.

Based on the absence of potentially harmful chemical constituents in the marine sediments analyzed for this project, the temporary and localized disturbance and suspension of these sediments during project construction and decommissioning activities is not expected to adversely affect marine water quality conditions and fish populations in these areas of Nantucket Sound and thus is not expected to have an effect on the Roseate Tern or the Piping Plover. Any small amount of contaminants that might be present in suspended sediments is likely to remain adsorbed to sediment particles and be rapidly redeposited onto the bottom as the particles settle. It is unlikely that measurable increases in concentrations of some chemicals in the water column will occur, and thus, no direct or cumulative adverse affects on avian species that may be present in the vicinity of project construction and decommissioning are expected.

4.2.1.1 Effects of Underwater Structures

The presence of 130 WTGs and the ESP piles in Nantucket Sound has the potential to cause a localized change from a non-structured system to a structure-oriented system, with potential localized changes to benthic and finfish community assemblages. Both pelagic and more demersal finfish species (including small schooling species upon which terns feed) may tend to congregate around the WTGs more frequently than if a structure was not present (see Section 5.4).

Since the individual towers within the array will be spaced approximately 0.34 nautical mile by 0.54 nautical mile (0.63 km by 1.0 km) apart, substantial changes from pre-Project conditions are not anticipated. Any changes will likely be localized and it is unlikely that these isolated structures will impact (either positively or negatively) the overall environment or species composition of the Project Area or Nantucket Sound. In the immediate vicinity of the monopiles there may be changes in the fish community that affect tern prey positively (e.g. new species), or negatively (e.g. new predator), but the scale of these effects will be very small in the context of the whole 560 square mile Sound. Please refer to Sections 5.3 and 5.4 of the DEIS-DEIR for more details. Piping Plover habitat should not be impacted by presence of the WTGs because plovers do not occur offshore except when traveling to new feeding areas (as at the end of the breeding season) or migrating.

4.2.1.2 Effects of Project Infrastructure used for Perching/Roosting

Although the turbine towers will give no sites for birds to perch below the nacelle, a pre-fabricated access platform and service vessel landing located around each tower at about 30-35 feet (9-11 m) from MLLW and the centralized electric service platform (ESP) will provide potential resting sites for terns, gulls, cormorants, and other species. For some birds familiar with the turbines this may be beneficial, enabling more efficient use of foraging time. However, terns commonly initiate courtship flights from such resting areas (not only near the colony), which bring them to the range swept by the rotors, thus increasing risks of collisions. Piping Plovers are unlikely to be affected by the WTG platforms and ESP because they appear to cross the site only rarely and are not known to frequent offshore structures.

Birds reported using offshore turbines in Europe for roosting/resting include gulls on nacelles and cormorants on landing platforms (Langston and Pullan 2003). While these species appear to raise no issues for this Evaluation, a species that does deserve scrutiny is the Peregrine (*Falco peregrinus*). Migrant Peregrines could perch on the nacelles and prey on terns foraging or travelling nearby. This is unlikely to be a noteworthy problem because the falcons typically travel along shorelines, pausing to hunt where prey (including terns) are numerous (as at South Beach). Furthermore, most migrant Peregrines reach Massachusetts in late September and October (Veit and Petersen 1993), after the bulk of the Roseates have left.

In order to reduce the risks to terns and other bird species, these platforms will incorporate elements designed to prevent birds from perching upon them.

Each WTG and the ESP will be equipped with an avian deterrent system to discourage terns and other avian species from perching on the railings and deck areas. The system will be passive and incorporate stainless wire and vision restriction. In addition to the passive deterrent, the WTG's will be operating most of the time resulting in vibrations and low level noise that may also discourage usage by avian species.

Each WTG has a transition piece on top of the pile that has an access ladder and boat fender system connected to a deck. The deck is round through 180 degrees and has an extended section on one side. The diameter of the transition piece is 5.39 m with a deck that is 8 m diameter with the extension section of 7.4 m from the centerline of the transition piece. The deck will have a railing on the outer perimeter covered with an aluminum chain link fence. The deck overhangs the ladder.

The deterrent system consists of the fence to prevent access from the side, a stainless wire on top of the railing and a 0.65 m solid panel to restrict visibility of any avian species from the deck. This system will take advantage of the preferences of web-footed birds to perch on near-flat surfaces with views of their surroundings.

The wire will be 3 mm stainless steel marine wire with swage lock terminals and turnbuckles to connect it to posts at appropriate locations and maintain it taught. The spacing between the rail and the wire will be 3 cm. The size selected was to allow visibility of the wire to various species while being too small to perch upon. Birds, including terns, attempting to perch on the rails would not be at risk of colliding with or being entangled in the wire because it is very close to the rail. Birds attempting to land on the rail would undoubtedly decelerate to a point where their airspeed would be nearly zero, thereby negating the potential for collision injuries. Other injuries, such as oiling from fluids in the gear boxes of the WTGs (the only fluids in wind turbines) are improbable because gearboxes on modern wind turbines are not known to leak but are designed to contain any fluids if leaks do occur (see Section 4.6.1 of the DEIS). The ESP will also utilize fluids but will have sealed, leak-proof decks, which will act as fluid containment. It is likely that birds may initially be attracted to the WTGs for perching, but effective deterrents will likely limit the number of times terns do this. Once they learn that they cannot perch, they will be unlikely to attempt to perch on turbines further.

The electric service platform (20,000 ft^2 (1858 m^2)) is likely to be used frequently by birds because it will not be continuously manned. Maintenance visits to the Wind Park are likely to occur on about 250 days per year and night time use will be minimal (see Section 4.4 DEIS-DEIR). Two potential bird uses of the ESP are pertinent to this Evaluation: 1) individual Common Terns will use various perches around the edges of the platform as vantage points from which to watch for prey below and as the base for feeding territories from which to drive other terns. Foraging terns are generally below the height of the rotors so that any such increases in foragers are unlikely to represent risks and need not be discouraged; and 2) numerous species of birds, not only Roseate and Common Terns, are likely to use any suitable flat surfaces of the upper decks as places to rest by day and perhaps also by night (roosting). From such resting flocks of terns in May and June, potential pairs initiate high courtship flights during which they could drift downwind to a nearby turbine (distance 1,640 feet (500 m) or more) where they would be at risk of collision. The platform is likely to attract terns throughout their residence in the Sound (April – September) and other birds, notably gulls and cormorants, throughout the year. Some birds might nest there if a suitable site were available.

The ESP has an overall size of 60 m x 30 m consisting of a building like superstructure sitting on a 6 pile structural support. The superstructure overhangs the support. The bottom of the superstructure is 11.5 m from MLLW and the top of the heliport deck is 30 m. The top deck will have a perimeter railing. The deterrent system used for the ESP will be the same as the WTG's in that all ladders and railings will have the same treatment of stainless steel wire, chain-link fence and solid panels. Birds will be deterred from perching on the ESP as much as possible however, some amount of perching is likely to be unavoidable.

A final, complete deterrent design will be based on the success of this approach on the existing Cape Wind Scientific Measurement Devices Station (SMDS) as well as existing literature and recommendations from USFWS, USDA and consultants or vendors of bird deterrent technology. Bird deterrent methods have been proven effective on the SMDS that is currently situated in Nantucket Sound. Prior to "bird-proofing" this tower in June 2003, terns were observed resting on the fence and the decking of the platform. None have been observed since the installation of the bird deterrents.

4.2.2 Disturbance from Construction and Vessel Traffic

Neither noise nor visible activities from construction at reasonable distances are likely to affect the Roseate Terns or Piping Plover. Other terns (e.g. Least, Arctic) and plovers (Killdeer) are known to nest successfully in close proximity to airports. In areas managed for plovers, buffer zones of 150 ft (46 m) have been used successfully around birds nesting on beaches (Blodget and Melvin, 1996). This suggests that offshore work in conjunction with the project will not disturb Piping Plovers on shore but no data have been found on responses to seaward disturbance.

Vessel traffic will be greatest during construction and will continue during the operational phase, when maintenance trips are expected on about 250 days per year, which would include one crew boat from Falmouth and the maintenance support vessel from New Bedford. In addition an occasional second round trip from Falmouth could take place in times of fair weather or for emergency service. These estimates are based upon the calculations derived from the Operations and Maintenance (O&M) Plan (see Section 4.4 of the DEIS-DEIR). At expected distances, the presence of vessels would have negligible effects on foraging by terns or plovers. Helicopters will be used occasionally and may have effects on birds over a greater range than boats, but these effects are local and ephemeral. The helicopter-landing platform will allow for crews to be deployed to the ESP during periods when wind and wave conditions are unsuitable for boat transfers, and in case of emergency.

4.2.3 Disturbance-Displacement by Turbines

Disturbance-displacement by turbines and barrier effects of lines of turbines that exclude individuals from certain areas, leading to habitat loss, are thought to have direct impacts on some birds, especially those species that inhabit open landscapes and tend to avoid tall vertical structures, e.g. grassland species (Leddy et al. 1999). Disturbance-displacement by turbines and barrier effects of lines of turbines that exclude individuals from certain areas, leading to habitat loss, are thought to have direct impacts on some birds, especially those species that inhabit open landscapes and tend to avoid tall vertical structures, e.g. grassland species (Leddy et al. 1999; Langston and Pullan 2003). However, for terns, there is no evidence to suggest adverse displacement effects from the proximity of turbines; lines of turbines were no barrier to movements of terns and gulls nesting nearby (van den Bergh et al. 2002). No displacement from habitat is expected for the Roseate Tern. Piping Plover habitat will not be impacted at the WTG site because plovers do not occur offshore except when traveling to new feeding areas (as at the end of the breeding season) or migrating.

4.2.4 Collision with Turbines and other Infrastructure

Collisions of terns and plovers with the monopoles or the ESP are most unlikely to occur. These species are agile flyers and very rarely collide with large stationary objects such as lighthouses, bridges, light poles, or communication towers, or with large moving objects such as ships, even when they are brightly lit. Few records of such collisions are known from Massachusetts (Veit and Petersen 1993) or elsewhere, even from Great Point Light in Nantucket Sound, and there seems to be little reason to expect that offshore objects will differ greatly. A recent example from a long-term study at Long Point Lighthouse in Lake Erie is instructive in indicating that terns and plovers are not likely to collide, even with an illuminated structure: during the period 1960 – 2001 a total of 18,158 dead birds were recorded, of which 2 were Common Terns and 54 were shorebirds (Jones and Francis 2003; Jones pers. comm. 2004). This example is by no means definitive because numbers at risk are unknown, although thousands of terns nest on the Great Lakes and many thousands of shorebirds pass that way every year. These same types of birds are present along the Atlantic Coast where there are a large number of lighthouses, communication towers (including Coast Guard loran and other towers), bridges, etc., yet searches through the published avian literature for examples or even anecdotes regarding collisions did not reveal that large or significant numbers of these birds collide with man-made structures.

It is widely known that certain types of lighting attract birds, principally songbirds migrating at night and especially in inclement weather. However, lighting should have minimal impact on terns and plovers, not only because the proposed lighting is much less than a lighthouse but also because terns and shorebirds have not been demonstrated to be attracted to the lighting on communication towers (Shire et al. 2000, Avery et al 1980), lighthouses, bridges, buildings, or other man-made structures equipped with any kinds of lights. Also, the lighting scheme proposed for the WTGs will have characteristics that have not been demonstrated to attract even night migrating songbirds (Kerlinger, 2004). See Section 5.12 of the DEIS-DEIR for a description of the proposed lighting scheme. Thus, the risk of collision mortality of terns and plovers at turbine towers or at the ESP appears to be negligible.

Collisions with turbine blades do cause some avian mortality. Reports of terns or shorebirds killed in collisions at wind farms are very rare. In part, this results from few turbines being installed where terns and shorebirds are numerous; their active avoidance may also be important. A recent summary of information on such avian mortalities from the United States identified no terns and only one shorebird, a Killdeer (Erickson et al., 2001), but these data are only suggestive because most wind farms are at inland sites where such birds are usually much less common than in nearshore marine habitats. In Europe, there is greater experience with coastal and offshore wind farms and some data are available for some birds, although none are available for terns or shorebirds at large offshore wind farms. At one coastal wind farm with 23 small and medium-sized turbines (200-600 kW), at Zeebrugge in Belgium (part of which was located amongst nesting Little Terns (*Sterna albifrons*)), five terns (3 Common, 2 Little) were reported as killed in year 2001 (Everaert et al., 2002). These collisions are examined further below, in 4.2.5.1. Most of the terns observed at this site flew below rotor height (49-164 feet (15-50 m) rotor-swept area). During daylight hours very few of the Little Terns flying past the turbines at rotor height (or above) visibly reacted to them (5 reacted/850 observed). For Common Terns, which nested further away, at 1.1 mi (1.8 km)), on the other hand, 17/90 reacted, to avoid the turbines. Such data suggest that terns both detect the presence of the turbines and become accustomed to them. Migrants and other naïve birds will likely avoid coming close to wind turbines. The findings at this wind farm are not appropriate for direct extrapolation to Nantucket Sound for numerous reasons, of which two are particularly significant: the proposed rotor-swept area will be much higher (75 - 417 feet (23 – 127 m)) and there will be no resting areas nearby and the closest nesting sites for Roseates are 16 miles (26 km) away, at Monomoy, so the likelihood of Roseate collisions in Nantucket Sound is much lower (see 4.2.5.1). Other factors may be important, in addition, but cannot be predicted.

A second coastal wind farm located in an area frequented by terns is at Blyth, Northumberland, in northeastern England (Painter et al., 1999, 2002). At this site nine 300 kW turbines were erected on a breakwater in 1992, and two 2 MW turbines were constructed about 1 km offshore in December 2000. This wind farm is 13.7 mi (22 km) from tern colonies that include some Roseates at Coquet Island. Monitoring that began in 1991 (pre-construction) and continues post-construction has included regular coast-based observations of bird movements by day and night and beach surveys for dead birds. Terns have been seen near the turbines by day but not by night and very small numbers were encountered in the beach-carcass surveys; none of the latter were identified as collision mortalities. During the seven-year period since the wind farm was commissioned, only about 3 percent of the bird corpses found on the beaches were attributed to the wind farm and a majority of those were gulls. One shorebird species of special concern in Europe, the Purple Sandpiper (*Calidris maritima*), occurred at the site. Its winter roost adjacent to the turbines was unaffected.

The observations of flight altitudes of terns and plovers reported in this evaluation did not include conditions of poor visibility when the risk of collision may differ. It was not possible to establish the frequency of sufficiently adverse conditions because they are so patchy. The radar data could not be used to distinguish terns from other birds.

In conclusion, while some collision mortalities may occur, these are unlikely to be detected. Possible numbers are examined in the Section 4.2.5; they will be very low (too low to measure precisely) and are unlikely to affect significantly the populations (local or regional) of the Roseate Tern or Piping Plover.

4.2.5 Modeling Collision Mortality and Population Impacts

This section has been prepared at the request of USACE, with the goal of estimating potential collision mortality and possible effects on tern and plover populations. The modeling quantifies potential impacts while recognizing the very large uncertainties resulting from the limitations of available data and the absence of suitable precedents. Three steps are involved:

1) Projection of potential fatalities: the numbers are based on conservative estimates and the narrative is intended to lead the reader to provisional conclusions rather than to derive firm predictions.

2) Computer simulations: these are used to examine the likely effects of a range of possible additional mortalities on the populations in question, applying the procedures known as Population Viability Analysis (PVA).

3) Evaluation of the results from 1) and 2) to determine the biological significance of the possible fatalities attributable to the Project; that is to say, asking whether the population can sustain the additional mortality.

Mortality rates are affected by two main variables:

1) Numbers: the occurrence of birds where they are vulnerable to collision, i.e., within the Wind Park and at the height of the turbine rotors. This zone of vulnerability is the Rotor Swept Zone (RSZ). Note: the space below the

rotors is not included in the zone of vulnerability for this Project because, as noted earlier, terns and plovers are agile flyers and unlikely to collide with large stationary objects (towers, ESP) so the rotors alone define the height-range of the zone.

2) Avoidance Factor: this refers to the extent to which birds in the RSZ collide with the rotor blades, which is affected by passively missing them as well as actively avoiding them. The proposed turbines will be very widely spaced, 629 to 1000 m apart, so that the 130 rotors will occupy less than 1% of the volume of the RSZ. (At any moment a rotor occupies a plane, but the wind may come from any direction, as may a tern, so that the rotor effectively occupies a sphere). Thus, passively missing the rotors makes a large contribution to minimizing collision frequencies at modern wind farms, and calculations indicate that many birds that do encounter the rotors would pass between the blades even without making any active response (Tucker 1996).

4.2.5.1 Roseate Tern

In principle, Roseate Terns may cross Nantucket Sound in two contexts: (a) in the course of long-distance migratory movements which might occur at turbine-height, and/or (b) while locally-resident and foraging at Horseshoe Shoal or traveling near Cape Cod,

For (a), the relevant numbers are unknown because no such migrants were identified in the Cape Wind surveys and no other reports are known. Possible collisions of migrating terns are here estimated as zero because they appear not to cross the Project area in the course of long migratory flights. Some migrants may arrive directly at the colony-sites in spring after a long over-ocean flight, but many first arrive at the Muskeget-to-South Beach area and spend some time there before dispersing to breeding colonies. This conjecture is based on dates of arrival and nesting at diverse colonies (J. Spendelow, pers.comm.) Direct routes between winter quarters and this staging area lie to the east of Horseshoe Shoal. A similar pattern, but in reverse, occurs in fall: the occurrence of staging terns on Cape Cod from all over the range is well-known at that season. Roseates nesting north of Nantucket Sound that pass Cape Cod on their way north or south are likely to pause in a similar manner. Thus, the risk of collisions with WTGs will be estimated by assuming that all Roseates are present in the Project area in the manner revealed by the Cape Wind field surveys and addressed in (b).

For (b), as noted above, mortality rates are affected by two main variables:

1) Numbers: the occurrence of terns within the Wind Park and at the height of the turbines: these are derived from the fieldwork quantifying numbers and behavior of terns in Nantucket Sound, and specifically at Horseshoe Shoal. During the period May through September, the average density of terns observed on Horseshoe Shoal was 4.8/km^2 in 2002 (8.6 in 2003), of those identified to species 15/97 (16%) (2/180 or 1% in 2003) were Roseates. As indicated above, in 3.2.6.2, only 2% of the terns fly at the height of the rotors.

2) Avoidance Factor: this refers to the extent to which terns in the rotor-swept zone collide with the rotor blades, which includes passively missing them as well as actively avoiding them. Active avoidance is very high for traveling terns, not distracted by social interactions or foraging, in conditions of good visibility (giving a vanishingly low value for the factor by day). Empirically-established Avoidance Factors for night migrants (values 0.0014 to 0.0008) are described below (Section 4.2.5.2).

Without knowing the number of encounters with turbines, as well as the occurrence of poor weather conditions, when collisions may be more frequent, directly calculating the number of collisions is not possible. Instead, we can roughly estimate annual mortality per turbine by comparing the prospective situation on Horseshoe Shoal to a known situation where terns collide with wind turbines (Everaert et al. 2002). At the East dam in Zeebrugge, in Belgium, 23 small to medium-sized turbines were operating in 2001 within about 4 km of 2250 pairs of nesting Common Terns (other nesting terns included 200 pairs of Little Terns nesting below the turbines and 1550 pairs of Sandwich Terns, but this discussion will be confined to Common Terns because they are most similar in size to Roseates). Collision victims in 2001 included 3 Common Terns. After correcting for search area, search efficiency and scavenging, the total kill in 2001 was estimated as 28 Common Terns. Based on traffic rates, measured for 2 days in September, the collision rate in that month was estimated at 1 in 600 (0.002) for Common Terns passing at rotor height (15 – 49 m) and the estimated annual mortality was 1.2 Common Terns per turbine. In 2002 similar numbers were found; in 2004, larger numbers (estimated as 80 - 100) were killed apparently because many Common Terns nested very close to the turbines following development of their previous site (Everaert, pers. comm.): this increase supports the suggestion that birds involved in social behavior are more likely to collide with turbines. These collisions could have occurred at any time, day or night, and in diverse weather conditions.

At Horseshoe Shoal (HSS) the mortality rate from collisions is expected to be much lower than at Zeebrugge (Z), the factors involved are listed below and the relative values shown as "HSS/Z = ". Some of these values are speculative in the magnitude but not in the direction of the difference: they can be combined by multiplication. Each estimate is followed by a provisional range of values in parentheses: these can be similarly combined to indicate a range of uncertainty.

- fewer Roseates at HSS than Commons at Z = 0.01 (0.005 – 0.1)
- higher turbines, so smaller fraction of terns at rotor height: 0.02/0.2 = 0.1 (0.05 – 0.2)
- wider spacing of turbines, so increased passive avoidance: 1/(800/100) = 0.14 (0.1 – 0.2)
- colony remote, so less distracting social behavior (and high flights) = 0.1 (0.05 – 0.2)
- colony remote, so less activity at night, when collision more likely = 0.1 (0.01 – 0.4)

The preceding provisional analysis suggests that collision frequencies of Roseate Terns at the proposed Wind Park on Horseshoe Shoal would be very much lower than those of Common Terns at the Belgian colony, by a factor of x 0.0000014. This suggests a total annual mortality at the proposed Wind Park of 130 x 1.2 x 0.0000014 = 0.0002 Roseate Terns per year.

To explore worst-case possibilities, we consider that the collisions at Zeebrugge could have been underestimated (principally from more terns falling into the surrounding water and not being found than are addressed in the correction for "search area"). Extreme values for the collisions at Zeebrugge would be 1 to 12 per turbine per year. Combining this high value with the most conservative extremes for every one of the six factors at HSS yields an upper estimate of 0.5 Roseate Tern collisions per year. The lower estimate yields an extremely low probability of less than 1 in a million. It is important to recognize that these numbers indicate a range of collision possibilities in the face of great uncertainty, and not a prediction.

4.2.5.2 Piping Plover

For Piping Plovers, the numbers of birds at risk are given by those potentially traveling across the Wind Park at turbine height because they do not forage at sea. These birds are the 28% of the population that nest north of Nantucket Sound and may cross the Project area during annual migrations (S. Melvin, pers.comm.). The number of flights each year is 2 per adult (neglecting mortality during the summer) and 1 per fledged young; thus 5.2 per pair (assuming productivity of 1.2 fledglings): 2,458 total movements. The fraction that enter the rotor-swept zone is unknown because the routes taken and altitudes of flight have not been documented. The fraction crossing the Project area could be as high as 0.5 if all plovers travel along the coast within 10 miles of shore, or as low as 0.3 if plovers travel on a broad front across land and ocean. If the plovers are strictly coastal, flying from beach to beach, then none (0.0) would be likely to cross the Project area. As an initial value 0.4 was selected as the fraction crossing the Project area. The fraction flying at rotor height would be 0.05 if evenly distributed from sealevel up to the mean altitude of shorebirds migrating over the Atlantic near to shore (2000 m) reported by Richardson (1979). A provisional estimate of 0.1 has been selected. Thus, the fraction entering the RSZ is conservatively estimated as 0.4 x 0.1, or 0.04. (Taking rather less conservative estimates of 0.1 for the fraction crossing and 0.08 for fraction at rotor height gives 0.1 x 0.08 = 0.008 for the fraction at risk.)

Likewise, the Avoidance Factor (AF) is unknown but, as explained for the Roseate estimates (above), the turbines occupy <1% of the volume of the RSZ so that few plovers crossing the Wind Park will encounter turbines. The plovers may cross by night or by day. Empirical data for the AF for nocturnal migrants (principally passerines) have been obtained in The Netherlands (Winkelman, 1994) and Oregon/Washington (Erickson, 2004) by counting the numbers passing and the numbers killed. The values for the AF were 0.0014 and 0.0008, respectively. (Winkelman observed that 15.7% of birds passing through the rotor swept area were killed; the rotors occupy 0.9% of the RSZ; 0.157 x 0.009 = 0.0014). These are conservative values for plovers, which fly faster than most nocturnal migrants (lower risk) and may travel by day when collision-rates are very much lower than by night.

For the purpose of the present initial estimate an AF of 0.0008 is selected. (A less conservative value would be 0.0004.)

Annual collisions = Number of migratory movements x fraction entering the RSZ x Avoidance Factor
= 2,458 x 0.04 x 0.0008
= 0.08 plovers per year

(If the less conservative estimated values are used, the predicted number of fatalities each year is 2,458 x 0.008 x 0.0004 = 0.008, or less than one plover in 100 years)

If all Massachusetts plovers, including those nesting to the south, make similar movements this would double the predicted number of collisions.

4.2.5.3 Population Viabilities

The modeling of population viabilities presented in Attachment 1 uses well-established approaches involving computer simulations to develop probabilistic trajectories (numbers/time) for populations with demographic parameters that have specified values and variability. Such models enable evaluation of the effects of a change in a parameter, in this case additional mortality potentially attributable to the Project for a period of 20- or 40-years. Such mortality would be additive and not compensatory, for the purposed of this model. Realistically, however, an unknown portion of the potential mortality to these birds would be compensatory because some individuals would have died of other causes. In each case a range of additional deaths ("takes") are entered into the model to determine likely effects on outcomes such as probabilities of recovery or extinction (as well as stasis at current levels) of the population within a specified time horizon. For convenience of modeling, and by convention, such models commonly are constructed for females only.

The Roseate Tern model incorporates, in addition to the usual demographic parameters, features that address the female-biased sex ratio (unusual in a monogamous species) and the occasional catastrophic mortality-events (such as Hurricane Bob in August 1991). As expected for a long-lived species, the model shows that population growth is most sensitive to Adult Survival (Proportional Sensitivity = 0.607). Under existing conditions, the median projected time to recovery of the population is 17 years. This predicted outcome is almost unaffected by extra deaths of as many as 5 females per year and there is zero probability of extinction. Above that rate the effects increase relatively slowly.

The population addressed in the Piping Plover viability model was that in New England, which had stabilized above the subgoal of 600 pairs in the late 1990s. The model is complicated by a change in demographic parameters (decline in productivity in recent years not attributable to habitat saturation) at about that time (after the 1994 PVA in the Recovery Plan). Population growth is sensitive to Adult Survival (Proportional Sensitivity = 0.49), but to a lesser extent than the Roseate Tern. Possible impacts of additional fatalities depend strongly on assumptions about growth rates. The No Growth scenario (current conditions), even with zero take, yields substantial risk of the population declining below 600 pairs. Additional mortality of one Female (= 2 takes/yr) does not increase this risk significantly (3% by 20 years). The Intermediate Growth scenario (average performance since 1989) yields predictions of negligible chances of decline below the recovery threshold even with additional mortalities of as many as 10 females per year, and non-zero chances of extinction only at 50 deaths or more.

4.2.5.4 Population Impacts

The very low estimates of collision mortalities presented above are based on limited information and a lack of variability for a number of model inputs and thus contain a degree of imprecision resulting in a wide range of possibilities. However, it seems most unlikely that errors (or chance) would be sufficient to bring the estimates to a level sufficient to affect the populations of either species. The population modeling indicates that the possible annual takes, even under the pessimistic scenarios that were examined, will not have significant effects.

For the Roseate Tern, the potential fatality rate attributable to collisions in the Wind Park, estimated in 4.2.5.1 above, is an average of 0.0002 individuals per year, and the highest rate in the range of possibilities identified, is 0.5 per year. These are well below the level of 5 females per year at which effects become important.

For the Piping Plover, the potential fatality rate attributable to collisions in the Wind Park, estimated in 4.2.5.2 above, is an average of 0.08 individuals per year. A take of ten birds per year (= five females) is unlikely to affect the New England population.

4.3 Summary/Conclusion of Impacts

Based upon the analysis of potential impacts, it is unlikely that biologically significant adverse effects to the two listed avian species will result from the construction, operation/maintenance, and/or decommissioning of this Project.

The disturbance and suspension of marine sediments during project construction and decommissioning are not expected to have significantly adverse effects on water quality from the very low levels of potentially harmful chemicals present in those sediments. The effect of suspended solids on feeding areas is predicted to be temporary. Habitat changes resulting from the presence of the turbines are not expected to have net adverse effects on the food supply of Roseate Terns, nor will the turbines exclude terns from foraging habitat. Piping Plover habitat will not be impacted at the WTG site because plovers do not forage offshore and only occur there when traveling to new feeding areas (as at the end of the breeding season) or migrating. Although vessel traffic will increase slightly during the period of the project, this will have a negligible effect on foraging Roseate Terns or Piping Plovers.

The risk of mortality or injury from collisions with rotors or towers has been estimated to be small so as to not be biologically significant (0.0002 Roseates/year and 0.08 plovers/year). The WTG access platforms and the ESP may provide opportunities for terns to perch and thus increase chances of collisions during courtship flights: deterrents will be used to minimize or eliminate perching, as discussed in Sections 5.3 and 5.4 below.

5.0 MANAGEMENT PRACTICES/MITIGATION

The following paragraphs address the alternative locations for the Wind Park as well as some features of the turbines that have been adopted as potential mitigation or prevention of potential impact to birds.

5.1 Location

As agreed upon with USACE, three possible sites for the Wind Park in Nantucket Sound have been identified: the proposed Site (Alternative #1) is on Horseshoe Shoal, with alternatives to the northeast (Alternative #2, named Monomoy/Handkerchief Shoal), and south (Alternative # 3, Tuckernuck Shoal). The study area for the Cape Wind quantitative field studies covered all three alternatives and bird observations were compiled for each of the three areas. For the two listed species, Alternative Site #1 is preferred for reasons of potential and observed use. For potential use by Roseate Terns, site #1 is remote from their nesting colonies in Buzzards Bay (although it is the closest of the three), and it is the most distant from roosting sites and staging areas. The largest of these pre-migratory aggregations is on South Beach, but several sites on the south edge of the Sound are also important (Eel Point (Nantucket), Tuckernuck, Muskeget, and Fernando's Fetch). The observed use of the alternative areas by terns during May - August is given by data from the Cape Wind summer aerial surveys in 2002 (6 flights) and 2003 (8 flights), respectively, from Appendixes 5.7-F, -K, and -L. The measured tern densities as terns/sq km/ survey in the two years were as follows; Site #1- 0.77, 1.03; Site #2- 0.71, 0.51; Site #3- 0.82, 0.51. Few terns used the sites and there were no large differences between the sites.

For Piping Plovers, Site #1 is approximately 12.5 mi (20 km) from the main nesting and staging areas on Monomoy and South Beach, whereas site #2 is less than 6.2 mi (10 km) from Monomoy and South Beach. Although Site #3 is the furthest from Monomoy, it is in close proximity to Nantucket, Tuckernuck and Muskeget Islands, which are significant nesting habitat for plovers. For both species, Alternative #1 has advantages.

5.2 Turbines

Although no quantitative comparisons have been made at offshore sites, it is likely that the proposed 3.6 MW turbines are to be preferred to smaller turbines on lower towers, because higher turbines are expected to reduce risks of collision for terns that generally fly close to the surface of the sea. The towers are tubular, rather than lattice, which reduces perching opportunities. It is likely that birds may initially be attracted to the WTGs for perching, but effective deterrents will likely limit the number of times terns do this. Once they learn that they cannot perch, they will be unlikely to attempt to perch on turbines further.

5.3 Turbine Access Platforms

Near the base of each turbine tower there will be access for servicing the WTG. The standard model includes a flat platform about 30-35 feet (9-11 m) above MLLW that may be a convenient resting place for terns, gulls, cormorants, and other species. As discussed in Section 4.2.1.2, this could be beneficial to some species by offering a resting area, but may increase the risk of collision with the WTGs for terns during courtship flights.

However, the fence on the perimeter of the platforms will be equipped with bird deterrent devices to deter terns from perching as noted in Section 4.2.1.2. A final, complete deterrent design will be based on the success of this approach on the existing Cape Wind Scientific Measurement Devices Station (SMDS) as well as existing literature and recommendations from USFWS, USDA and consultants or vendors of bird deterrent technology. Bird deterrent methods have thus far proven effective on the SMDS that is currently situated in Nantucket Sound. Prior to "bird-proofing" this tower in June 2003, terns were observed resting on the fence and the decking of the platform. None have been observed since the installation of the bird deterrents.

5.4 Electric Service Platform

The ESP (20,000 ft^2 (1,858 m^2)) is likely to be used frequently by birds because it will not be continuously manned. Maintenance visits to the Wind Park are likely to occur on about 250 days per year and night time use will be minimal (see Section 4.4 DEIS-DEIR). The platform is likely to attract terns throughout their residence in the Sound (April – September) and other birds, notably gulls and cormorants, throughout the year. Some birds might nest there if a suitable site were available. In order to reduce the risk to terns that may initiate high courtship flights from the ESP, the ESP will be constructed with deterrents (see Section 4.2.1.2) so as to be unsuitable for use by birds. Deterrent methods included securing wire above the top of the platform fence and other areas where birds may perch. This method has proven successful on the existing SMDS. The turbine platforms and ESP will be monitored closely post-construction to ensure that the opportunity for birds to perch is not available. Recommendations by the USFWS, USDA, consultants and vendors of bird deterrent technology will also be employed.

5.5 Lighting

Currently, design plans call for lighting the WTG towers with the lowest possible intensity white flashing lights in daytime and red flashing lights at night to meet FAA and USCG safety requirements. The proposed WTG lighting does not possess the characteristics that are known to attract night migrating birds and includes some of the features recommended by the USFWS in Guidelines for Communications Towers, for reducing potential bird problems on land. The most recent research has shown that these lights do not attract night migrating songbirds and the body of research on towers, turbines, buildings, bridges, ships, and other man-made structures has never suggested that shorebirds or terns are attracted by lights (Kerlinger, 2004). Furthermore, preliminary evidence for the breeding season suggests that terns are not often active at sea at night so lighting of the WTGs would pose little risk to the Roseate Tern. The Piping Plover would be unlikely to be affected by lighting of the WTGs because it rarely crosses the turbine field. Too little is known about migrating birds for any firm conclusion, but it is likely that most departures entail the birds rapidly climbing to high altitudes, well above the WTG lights. For further detail on the lighting design and potential effects on other bird species, see Section 4.0 and Section 5.7 of the DEIS-DEIR.

6.0 CONCLUSION

Evaluation, which includes the management practices discussed above, finds no evidence that the Cape Wind project is likely to jeopardize the continued existence of, or present biologically significant risks to, either Piping Plover or Roseate Tern, or will adversely modify designated critical habitat. Some infrequent collision mortality is possible but this very small risk will not adversely affect overall population levels of either species.

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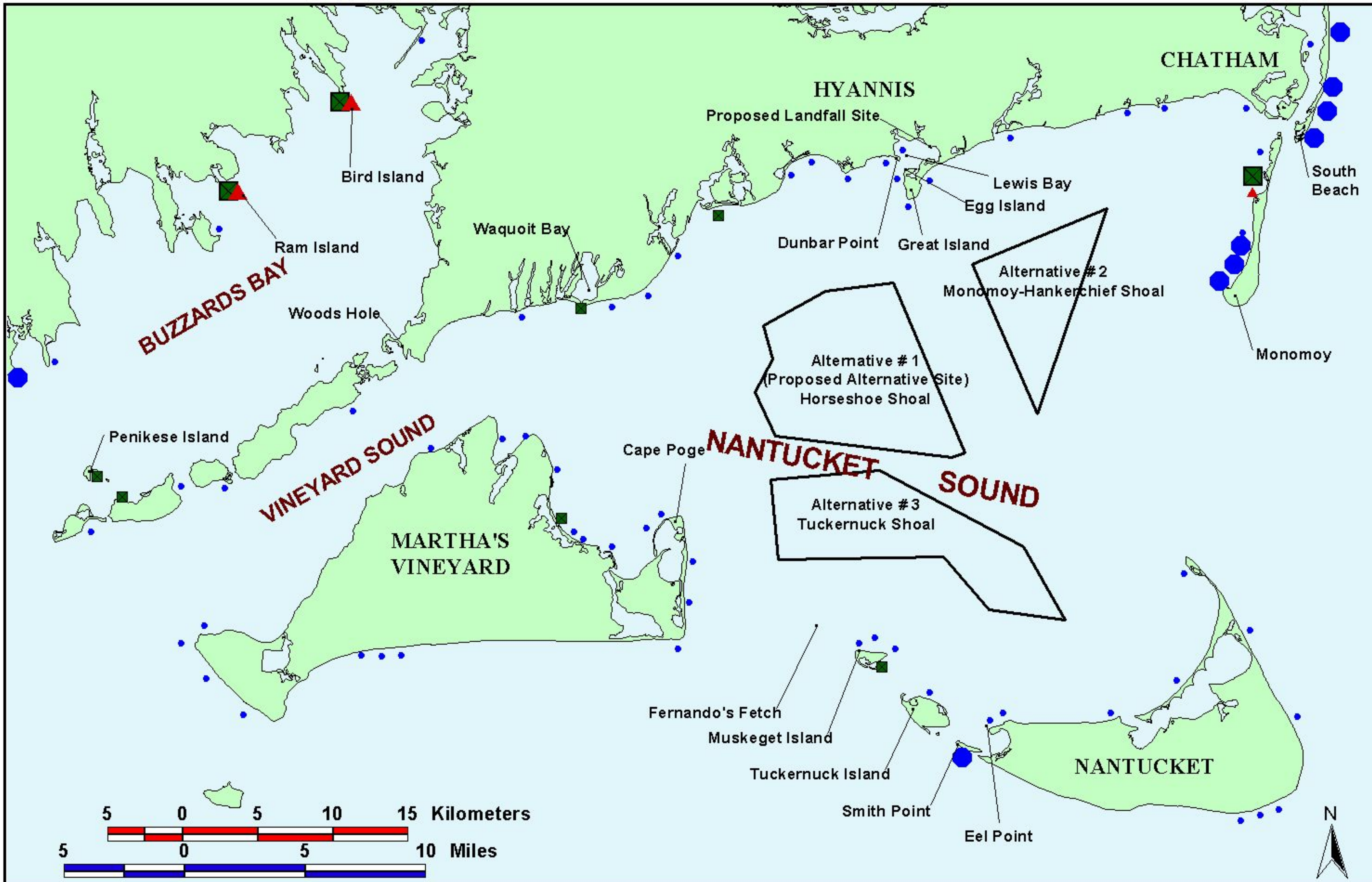
Figures



Cape Wind™ Energy for Life.

Legend:

Roseate Tern Colony	Common Tern Colony	Piping Plover Nests (Schematic)
Large	Large	1-3
Small	Small	10

Figure:

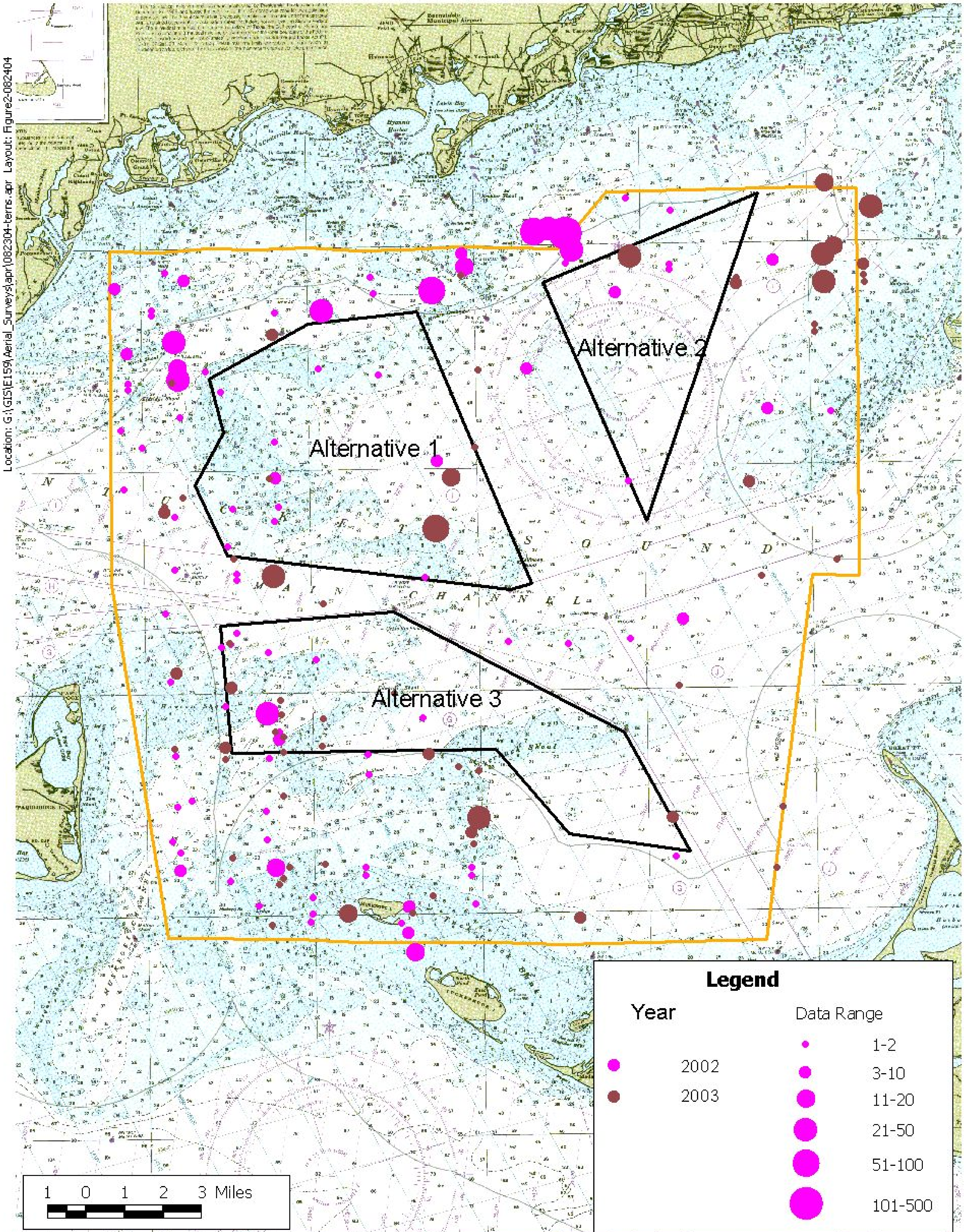
2002 Piping Plover, Common and Roseate Terns Nesting Sites.

January 10, 2003

Source: MassGIS 1991

ESS Group Inc.

Location: G:\GIS\E159\Aerial_Surveys\apr\082304-terns.apr Layout: Figure2-082404



ESS Group Inc.
Engineers
Scientists
Consultants

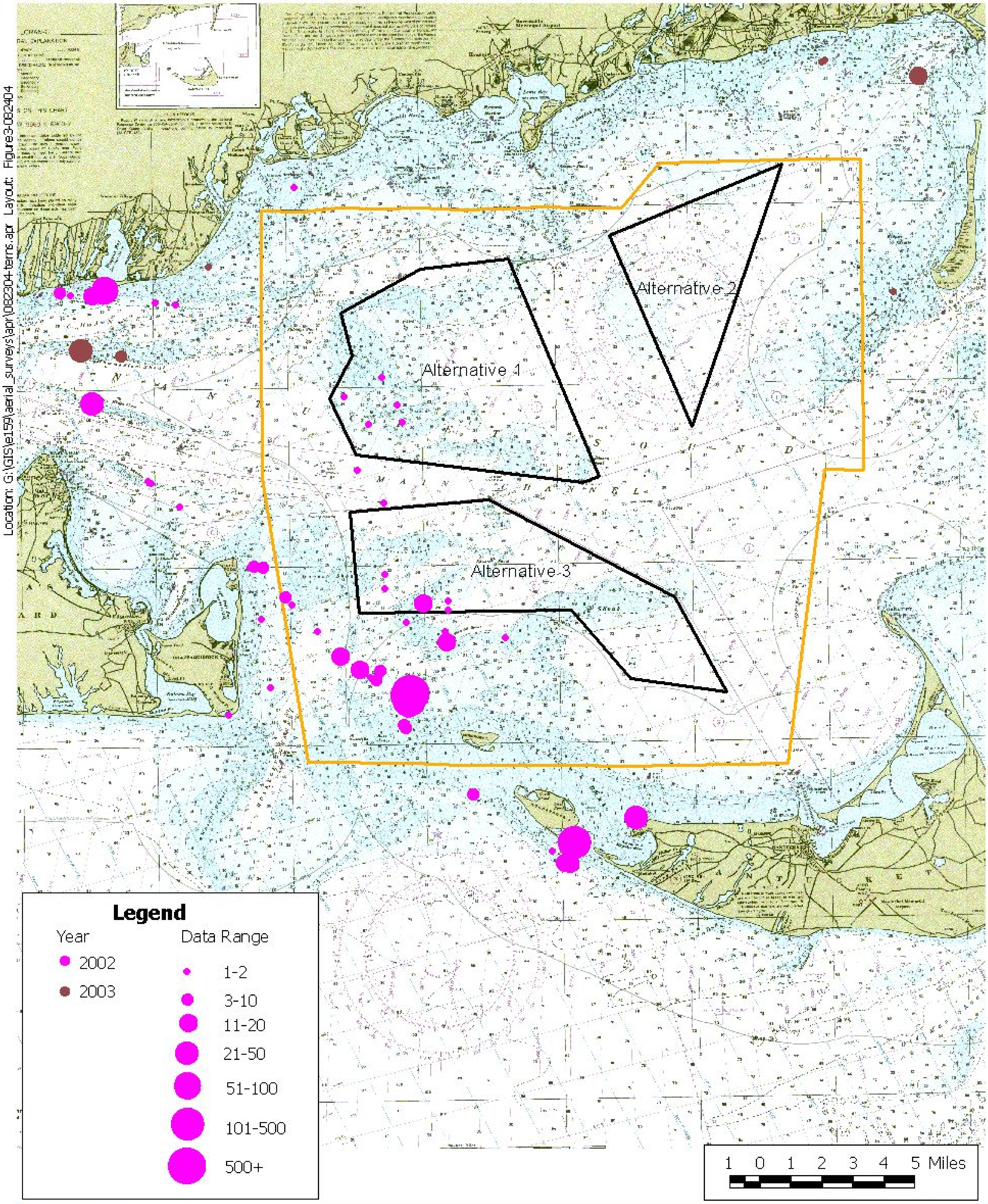
Cape Wind LLC
Nantucket Sound

Scale: 1" = 20,000 ft

Source: 1) MassGIS

Aerial Survey Data-
Roseate and Mixed Terns

Figure
2



Engineers
Scientists
Consultants

Cape Wind LLC
Nantucket Sound

Scale: 1" = 25,000'

Source: 1) MassGIS

Boat Survey Data-
Roseate and Mixed Terns

Figure
3

ATTACHMENT 1

Population Viability Analysis For Roseate Terns and Piping Plover 2004

POPULATION VIABILITY ANALYSES FOR ROSEATE TERN AND PIPING PLOVER 2004

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Jennifer M. Arnold, Auburn University, Auburn AL

INTRODUCTION

The models presented here were constructed to represent the life history and demographic features of two populations of species of conservation concern nesting in the northeast U.S: the endangered roseate tern and the threatened piping plover. The questions asked of the models in this analysis pertain to the listed status of these species: What would be the effects of additional fatalities due to a wind farm in Nantucket Sound on the persistence of these populations, in other words, on their risks of extinction? By how much would these fatalities increase the time to recovery of these populations, that is, the time it would take each of them to reach a size allowing de-listing under the Endangered Species Act? Model-based investigations of such questions are generally called Population Viability Analyses (PVA; Morris and Doak 2002).

A model, by definition, is a simplified depiction of a real system; how well it mimics this reality depends on what features are used as its key elements in relation to the goals of the analysis. More biologically realistic models are desirable, but also complex; in the case of the two species at hand, we are limited by what quantitative data are available. Life history parameters (such as fertility, survival rate, maturation rate) necessary for a PVA can only be quantified through lengthy field studies, which are limited to one or a handful of nesting sites across the whole population. A number of assumptions common to the analyses of both species were made. The life history parameter estimates available, although from geographically restricted studies, were assumed to be representative of the whole population. We modeled only the female segment of the population. In the roseate tern, there exists a well-documented sex-ratio imbalance, with more females than males at both hatching and breeding ages (Nisbet and Hatch 1999, Szczys 2004); we account for this in the model, because of its effect on the rate of production of female offspring. The models are stochastic; they incorporate available information on how variable the parameters (fertility, survival rates, etc.) are from year to year. As a consequence, model results are presented in terms of risk, or probability, of a specific event happening within a given time horizon: "risk of extinction" is the chance that the population will become extinct (fewer than 1 female) within one hundred years, taking into account the year-to-year variability in breeding success and survival rates. Similarly, "time to recovery" is the time it takes to reach the goal population size by at least 5%, 50%, or 95% of the simulation runs.

The potential effect of the wind farm on the two populations was investigated using a range of female fatalities additional to natural mortality. We applied these "takes" annually over 20 years, the expected life of the wind farm, and over 40 years, assuming that the wind farm activity is sustained.

ROSEATE TERN MODEL

Introduction

We considered for this analysis that the whole northeastern population of Roseate Terns was potentially at risk from takes from collisions with the WTGs because dispersal is substantial and Nantucket is an important staging area for these birds prior to migration. Historical and current population status were obtained from Gochfeld et al. 1998, Lebreton et al. 2003, and J. Spendelow *pers. comm.* We used the "peak period numbers" for population size; this value underestimates the total number of breeders. Recovery scenarios were based on a recovery goal of 5000 breeding pairs outlined in the Endangered Species Recovery Plan for the Roseate Tern.

Model Description

We used information on roseate tern life history from Gochfeld et al. 1998, Lebreton et. al. 2003, and J. Spendelow *pers. comm.* The software used was Aves Modeler Beta version (Auburn U. and USGS), a package developed for the study of avian demography in presence of perturbations. Our model structure can be represented as shown in Figure 1; it follows the fate of female birds only. We used a pre-breeding census perspective, i.e. the population is evaluated yearly as if the birds were counted just before breeding. The circles represent age/stage groups of females, the arrows represent all the possible events happening to individuals in a given stage from one year to the next. For example, Stage 2 females (circle labeled "2") must survive (at a rate s_2) in order to become either Stage 3 females or Breeders the following year; a portion become Breeders with probability m_2 , the rest move to a second year of juvenile status (Stage 3) with probability $1 – m_2$. Each of the pre-breeder stages 2-4 has an arrow pointing to the

Breeder stage, indicating that individuals become reproductively mature between the ages of 3 and 5 years of age. Most adult females breed every year. However, a small fraction skip a breeding year, modeled here as an additional adult Non-breeder stage N. The reproductive output of breeders B from a given year *t* is measured at the end of that year, just before the *t+1* breeding season, as the number of female offspring per breeding pair.

The model uses the parameters of Figure 1 to map the transition of the population from year t to year t+1 in the recursive equation:

$$\mathbf{n}_{t+1} = \mathbf{A}\,\mathbf{n}_t$$

where the vector **n** contains the number of individuals in each stage, and the transition matrix **A** modifies the numbers in these stages according to the life-cycle graph of Fig. 1 (Caswell 2001). By applying this equation recursively, a trajectory of population size over time can be constructed.

The matrix **A** can also be analyzed to obtain directly the rate of increase of the population (i.e. how quickly a population can grow; equivalent the interest rate in a bank account), the proportion of the population in each stage, and how sensitive the rate of increase is to changes in the parameter values. This sensitivity analysis (Caswell 2001) is a useful “what if” experiment, measuring the change in rate of increase when each of the parameters is modified. A large sensitivity value associated with a vital rate means that a change in this rate will greatly affect the capacity of the population to recover from a perturbation. This allows a qualitative evaluation of the likely effect of changes in fertility or survival rates on population recovery. The means for each of the parameter values in Table 1 were used for this analysis.

Choice of Parameter values

Life history parameter values used in the model are shown in Table 1. The proportions of 2 to 5 year-old females that reproduce for the first time (rates of accession to breeding) is from Lebreton et al. (2003) and J. Spendelow *pers. comm*., modified to account for effects of female-biased sex-ratios and differences in behavior between males and females on this rate; estimates of variation about these proportion are from Lebreton et al. (2003). No females breed before 3 years of age, and all breed by age 5. The proportion of breeders that take a year off after a breeding attempt was estimated as 0.02 based on observational and mark-recapture data (J. Hatch *pers. comm*).

For roseate terns studied at Bird Island, Massachusetts, the sex ratio of females to males at fledging is 1.22 (excess females; Szczys 2004), and the sex ratio of breeders is 1.27 (Nisbet and Hatch 1999). We have applied both these sex ratios in the model, thus assuming that this sex ratio exists for the whole population, and for the entire time period of the model. The percent of adult females that actually enter the breeding population and are considered to form reproductive units ("breeding pairs") is determined by those that can find a male mate plus those that can find a female mate (a pair of females only counts as 1 breeding female). (The reference to female-female pairs here includes a diversity of multi-female associations, described by Nisbet and Hatch (1999)). The fecundity measure is a mean of fledglings produced by female-female pairs and female-male pairs combined. The contribution of Breeders to Stage1 thus incorporates their sex ratio, fertility, and breeding success, as well as the sex ratio and survival rate of their offspring through year *t*.

Survival rate estimates over the first 2 years of life and of breeding females were taken from Lebreton et al. (2003) and Nichols et al. (unpubl. ms.). No estimates exist at present for the survival rates of non-breeders older than 2 years; we opted to use the estimates from adult breeders. These pre-breeding stages tend to have higher survival rates than younger birds in many other species and often have higher survival than breeding adults, thus this is a conservative estimate.

Using the vital rates described above and outlined in Table 1, we obtain a rate of population increase, 1.02 (= 2% increase per year), equal to the current rate of increase from measured annual census values from 1998-2003.

The stochastic simulations were conducted by allowing some of the vital rates to vary from year to year (Table 1). The potential for variation of a parameter is modeled by creating a distribution of values, the range of which is based on the observed mean and standard deviation for the parameter. We used a beta distribution for the survival rates and proportion of breeders among Age1 females because this distribution was shown to best describe the range of variation in vital rates that are limited between zero and one (Morris and Doak 2002); for fertility distributions, maximum fertilities values were used to rescale the upper limit of their beta distributions. The parameters A and B of the beta distribution for each of the model parameters were calculated from their mean and standard deviation. In each year of a simulation, the value of a parameter was picked at random from its model distribution, and used to fill the **A** matrix entries. The initial number of breeders in all simulations was 3,500 breeding pairs. This is the approximate estimate for 2004 for the Northeast U.S. population (not including Canada). Because other, non-breeding, stages also exist the total population is larger than this. Females were allocated to each of these stages according to the stage distribution calculated analytically from the basic model (using Table 1 mean values).

Simulations

We simulated losses of females for 20 and 40 years, and each simulation was run over 100 years, from an initial population size of 3,500 female breeders. The stochastic simulations were conducted by allowing the rates to vary from year to year according to their distributions. In each year of a simulation, the value of a parameter was picked at random from its model distribution, and used in the matrix equations. Several scenarios were modeled, with different assumptions about the number of females colliding with the wind turbine generators (WTGs) resulting in mortality, and about what stages were at risk (Table 1). Each scenario was made up of 1,000 or 500 simulation runs. The time it took for 5%, 50% and 95% of runs to reach the Recovery Plan Population Goal (PG; 5,000 breeding pairs) in a given scenario measured the time to recovery. Additionally, we specified the probability of recovery at 20 years (the proposed lifetime of the windfarm) and 100 years for each scenario. We recorded the probability of extinction (population size less than 1 female) at 20 years for relevant scenarios.

The scenarios we ran were the following:

0. Status quo: baseline model and simulations without any added mortalities.
1. Added mortalities of 1, 2, 5, 10, 20, 50, 100, 250 females taken annually **for the first 20 years**; assuming that all individuals (in any stage) are equally at risk of collision with WTGs, i.e. the proportion taken from each stage was dependent on the stable stage distribution.

2. Added mortalities of 1, 2, 5, 10, 20, 50, 100, 250 females taken annually **for the first 20 years**; assuming that no one-year old females are taken, i.e. the proportion taken from each stage was dependent on the stable stage distribution, except that no 1 year olds were taken. Young birds are likely to remain in their wintering grounds before they reach 2 years of age, thus remaining out of the Nantucket area until then.
3. Added mortalities of 1, 2, 5, 10, 20, 50, 100, 250 females taken annually **for the first 40 years**; assuming that all individuals (in any stage) are equally at risk of collision with WTGs, i.e. the proportion taken from each stage was dependent on the stable stage distribution.
4. Added mortalities of 1, 2, 5, 10, 20, 50, 100, 250 females taken annually **for the first 40 years**; assuming that no one-year old females are taken, i.e. the proportion taken from each stage was dependent on the stable stage distribution, except that no 1 year olds were taken. Young birds are likely to remain in their wintering grounds before they reach 2 years of age, thus remaining out of the Nantucket area until then.

Results

Assuming that conditions for the Roseate Tern population in the Northeast U.S. do not change from the current ones, there is a 50% chance of reaching the Recovery Goal of 5,000 breeding pairs within 17 years, and a 95% chance within 80 years (range 72 to 80), under a scenario of No Take (Table 2). This scenario also projects a zero probability of extinction.

Adding annual fatalities of 1 to 5 females increases the median time to recovery by no more than 2 years, and does not change the time to 5% probability of recovery. Wind farm mortalities of 10 or 20 have a slight impact on recovery time, but still the time to a 5% probability of recovery is only changed by about 1 year and the time to a 50% chance of recovery is changed by 5 years or less. This holds true for all scenarios, over 20 and 40 years of wind farm operation. Extinction probability is still zero for this range of fatalities. A notable increase in time to recovery is found at or above 50 female takes per year. Median recovery time increases by 6 or more years compared to the No Take scenario, and 11 or more years under a 40-year period of wind farm operation. However, extinction risk is still nil. The risk of extinction is non-zero with very high annual takes, an unlikely scenario. At takes greater than 100, 250 and 500 takes per year, the recovery goal is never reached in the 100-year horizon and there is a 5% probability of extinction as early as 20 years from the initial take.

Discussion

Times to recovery for various scenarios are rather imprecise. This is suggested by the fact that the time to a 95% probability of recovery for a 1 mortality scenario may take less time than a 0 mortality scenario. Several runs of 1000 simulations for the 0 mortality scenario suggest a range of times to a 95% of recovery from 72 to 80 years. This difference is due to the variance in the vital rates for the population.

The model results were very consistent across scenarios, showing that a mortality of 10 or fewer females per year, if distributed across the different life stages of the population, is unlikely to reduce the capacity of the population to reach the PG. This is true whether the fatalities span a 20-year or a 40-year period, indicating that this level of take is unlikely to have long-term effects on recovery. The sensitivity results in Table 1 help explain why excluding birds younger than 1 year from risk of fatality (scenarios 2 and 4) yields the same results as when all ages are at risk. Fatalities are distributed among age classes according to the proportion of birds in these stages at breeding time. One-year-old females are a relatively small fraction of the population, and they are of lesser value than older females in terms of their future effect on population growth (i.e. lower reproductive value); moreover, in the first year of life they already are subjected to a high mortality, so shifting fatality "burden" to the rest of the age classes is unlikely to affect population growth. If fatalities due to the wind farm were to be mostly of breeders however, time to recovery will be more seriously affected. The sensitivity analysis shows the rate of increase being much more sensitive to changes in adult mortality than to mortality of any other stage. If fatalities due to the wind farm were to be mostly of adult females, time to recovery may be more seriously affected.

As discussed in the general Introduction, a model is only a representation of the real world. The output of a model is only as accurate as the data that go into the development of the model. This model was developed using data from published literature and from personal communications with members of the Endangered Species Act recovery team. Much of the potential impact of environmental stochasticity on vital rates has not been thoroughly explored in this model, and several of the vital rates have been extrapolated from a single population, or inferred based on behavioral observation. These factors contribute to current uncertainty in model projections. The model is designed to give a rough estimate of the impacts of potential wind farm mortalities.

Where possible, we have attempted to err on the side of conservatism (testing the more risky possibilities), and with this, have found that a number of fatalities 0-10 females per year is unlikely to hinder the time to population recovery. Due to the nature of projections, the further into the future, the wider the confidence intervals become. For this reason we have also provided times for 5% and 50% probabilities of recovery and extinction, because these occur earlier in the simulation, and so will have a lower variance.

Table 1. Parameter values used in the roseate tern model. Symbols are the same as in Figure 1. All parameters with a standard deviation are modeled as stochastic, using the mean and standard deviation as parameters for the beta distribution; remaining parameters have constant values. Proportional sensitivities (= elasticities) measure the change in population rate of increase if each parameter in turn is modified by a same proportion. Proportional sensitivity to adult survival rate is the largest value, indicating that small changes in adult survival will cause large shifts in population growth, compared to any other parameter.

Parameter	Symbol	Mean	Standard Deviation	Proportional Sensitivity
Yearling survival rate*	s_0	0.616	0.086	0.109
Stage 1 survival rate *	s_1	0.616	0.086	0.109
Stage 2 survival rate*	s_2	0.870	0.095	0.109
Stage 3 survival rate*	s_3	0.870	0.095	0.050
Stage 4 survival rate*	s_4	0.870	0.095	0.004
Breeder survival rate*	s_B	0.870	0.095	**0.607**
Non-breeder survival rate*	s_N	0.870	0.095	0.010
Breeder fertility	f_B	0.605	0.109	0.109
Proportion females breeding	br_2	0.893	--	0.109
Probability Stage2 becoming breeders	m_2	0.50	0.116	0.060
Probability Stage3 becoming breeders	m_3	0.90	0.207	0.047
Probability Breeders becoming Non-breeders	m_B	0.02	--	0.010
Probability Non-breeders becoming breeders	m_N	1.0	--	0.010

* these rates assume the probability of a severe hurricane that causes extreme adult mortality as occurred in 1991 (Lebreton et al. 2003) to occur at a frequency of once every 100 year.

Table 2. Recovery and pseudo-extinction under scenarios 1 and 3. Scenarios 2 and 4 are not shown as the results do not significantly differ from those of scenarios 1 and 3. These scenarios are presented assuming constant conditions over the time period of the model projections.

A. Scenario 1: An equal probability of loss is assumed for individuals in each stage, thus losses are calculated based on the age distribution produced by the model.
Losses are applied for 20 years, the proposed lifetime of the wind farm.

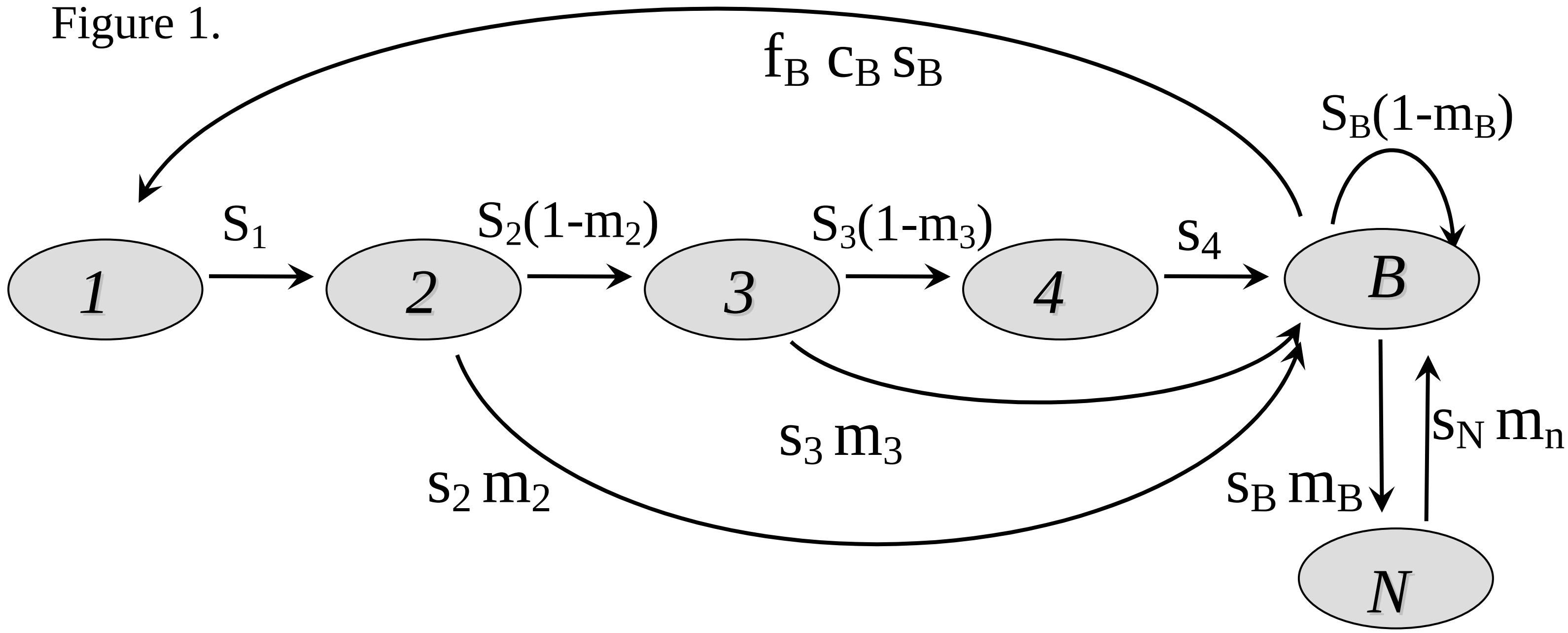
Probability of Recovery	***5%***	***50%***	***95%***			
*Number of annual **	*Years to recovery (based on 1000 simulations)*			*Probability of extinction at 20 years*	*Probability of Recovery at 20 years*	*Probability of recovery at 100 years*
0	6	17	72	0	0.57	0.98
1	6	19	74	0	0.55	0.98
2	6	19	72	0	0.56	0.98
5	6	19	73	0	0.52	0.98
10	7	22	82	0	0.48	0.98
20	6	20	78	0	0.51	0.97
50	7	26	96	0	0.37	0.95
100	9	35	107	0	0.23	0.94
250	31	88	>300	0.07	0.01	0.59

B. Scenario 3: An equal probability of loss is assumed for individuals in each stage, thus losses are calculated based on the age distribution produced by the model.
Losses are applied for 40 years, the sustained wind farm activity

Probability of Recovery	***5%***	***50%***	***95%***			
*Number of annual mortalities**	*Year to recovery (based on 500 simulations)*			*Probability of extinction at 20 years*	*Probability of Recovery at 20 years*	*Probability of recovery at 100 years*
0	6	17	74	0	0.56	0.98
1+	6	19	72	0	0.53	0.99
2	6	20	71	0	0.5	0.99
5	7	18	67	0	0.53	0.98
10	6	20	86	0	0.5	0.96
20	7	21	85	0	0.49	0.98
50	7	29	99	0	0.36	0.95
100	9	53	172	0	0.21	0.8
250	70	>300	>300	0.07	0.01	0.08

*Note this projection assumes no losses other than natural mortality and the prescribed mortality for the scenario. It is assumed that conditions are constant over time.
+This scenario is based on 1000 iterations.

Figure 1.



Roseate Tern model stages:

Stage 1: fledging-1 year-old
Stage 2: 1-2 year-old juveniles
Stage 3: 2-3 year-old juveniles
Stage 4: 3-4 year-old juveniles
B: Breeding Adults
N: Non-breeding adults

Model parameters:

$s_1 - s_4$: annual survival rate of Age 1 – Age 4 females

s_B , s_N : annual survival rate of breeding and of non-breeding adults

f_B : annual fertility of breeders (number of female offspring per female (a cohort is 55% female at fledging))

c_B : proportion of breeding adults that contribute to reproduction (are females in female-male pairs, or females in female-female pairs)

m_B : probability of breeders becoming non-breeder in the following year

m_2, m_3, m_N : probability of non-breeder stages becoming breeders in the following year

PIPING PLOVER MODEL

Introduction

A Population Viability Analysis (PVA) for the piping plover was done in 1994 by Melvin and Gibbs (1994), and is available on the USFWS website for the Piping Plover Atlantic Coast Population (pipingplover.fws.gov) in Appendix E of the species' Atlantic Coast Recovery Plan. That analysis used information on productivity (number of chicks fledged per breeding pair) from the 1989-93 census data, and on survival from a 1985-88 banding study. In the 1994 PVA document, the authors' recommendations for management with the goal to remove the species from the Endangered Species list included increasing the breeding population to at least 600 for New England, and maintaining mean productivity at 1.5 chicks fledged per pair through long-term management programs. Since that study, the New England breeding population has seen a period of rapid increase up to the mid-1990s, and has since stabilized at or somewhat above the 600 breeding pair goal (Figure 1). The current plateau in NE population size appears to be a consequence of increased hatchling and fledgling mortality at the nesting sites, caused by predator activity around nesting sites. In the current analysis, our goal was to update the model conditions to reflect the demographic changes that have occurred since the 1994 PVA, and determine the consequences of increased fatalities under this new regime.

Model description

We used the general model structure of the 1994 PVA:

- 3 age classes: (1) From fledging to 1 year of age, (2) 1 to 2 year olds, and (3) Adults 2 years old and older;

- Modeling only the female portion of the population, assuming a 1:1 sex ratio;
- Simulations of annual population changes using stochastic vital rates (i.e. values for fertility, survival and maturation rates that are picked randomly from distributions of values);
- Using the same survival probability information as in the 1994 PVA (no new values since 1994);
- But using productivity information updated through 2003 from the USFWS website for the Piping Plover Atlantic Coast Population (pipingplover.fws.gov)

Basic model parameter values are presented in Table 1. To ease comparison with the 1994 PVA, we also used a post-breeding census perspective, i.e. the population is evaluated yearly as if the birds were counted just after chicks are fledged.

The software used was Aves Modeler Beta version (Auburn U. and USGS), a package developed for the study of avian demography in presence of perturbations. Our model structure is presented in Figure 2. The circles represent age/stage classes, the arrows represent all the possible events happening to individuals in a given stage from one year to the next. Adults counted just after fledging of their chicks can be counted again the following year if they survive (at a rate s_a); they will produce new chicks the following year according to their fertility f_a, if they survive through the year and if they attempt to breed (the proportion of adults breeding is br_a).

Yearlings (age class 0), counted as chicks, need to survive through their first year to be counted as one year-olds (age class 1) in the following year. A portion *br1* of the females first reproduce at age 1; all others need to survive through another year, to first breed at age 2. All females aged 2 years and older are in stage class *a* (adults). The life-cycle diagram above translates to the matrix model (set of linear equations; Caswell 2001):

$$\begin{bmatrix} n_0 \\ n_1 \\ n_a \end{bmatrix}_t = \begin{bmatrix} 0 & (s_1 \cdot f_1 \cdot br_1) & (s_a \cdot f_a \cdot br_a) \\ s_0 & 0 & 0 \\ 0 & s_1 & s_1 \end{bmatrix} \bullet \begin{bmatrix} n_0 \\ n_1 \\ n_a \end{bmatrix}_{t+1}$$

This matrix equation allows the individuals *n* in each stage in year *t* to "move" through a yearly interval *t* to *t+1*; the central matrix (the transition matrix **A**) modifies the numbers in these stages according to the life-cycle graph of Fig. 2. By applying this equation recursively, a trajectory of population size over time can be constructed.

The matrix A can also be analyzed to obtain directly the rate of increase of the population (i.e. how quickly a population can grow; equivalent to the interest rate in a bank account), the proportion of the population in each stage, and how sensitive the rate of increase is to changes in the vital rates (Caswell 2001). This sensitivity analysis is a useful "what if" experiment, measuring the change in rate of increase when each of the vital rates is modified. A large sensitivity value associated with a vital rate means that a change in this rate will greatly affect the capacity of the population to recover from a perturbation. The means for each of the parameter values in Table 1 were used for this analysis.

Choice of Parameter values

The recent changes in trends of population size in New England (Figure 2a; increasing at 13% per year (rate of increase of 1.13) between 1986 and 1995, then stationary in later years) complicate the task of choosing an appropriate range of variation for the parameters. To explore the equivalent of a "high risk" and "intermediate risk" scenarios, we have opted to depict two scenarios of potential population status:

(1) **No growth**: assuming that the population will remain under the current conditions for the foreseeable future, with **stationary breeding population size** under no additional fatalities;

(2) **Intermediate growth**: assuming that the population will be exposed to conditions ranging from the period of growth of the mid-1990s to the current period of no growth. The mean rate of increase from 1990 to 2002 was of 8.9 % per year, so the scenario under no additional fatalities will approximate this **positive rate of increase**, with a scope for variation from very low growth (rate of increase close to 1) to very high growth (rate of increase close to 1.13).

The potential for variation of a parameter was modeled by creating a distribution of values, the range of which is based on the observed mean and standard deviation for the parameter (Table 1). We used a beta distribution for the survival rates and proportion of breeders among Age1 females because this distribution was shown to best describe the range of variation in vital rates that are limited between zero and one (Morris and Doak 2002); for fertility distributions, maximum fertilities values were used to rescale the upper limit of their beta distributions.

Fertility

During the population growth period average fertility was of 0.77 female offspring/female (mean productivity of 1.54 chicks/pair); in the current stationary level, it averages 0.65 female offspring/female (Figure 2). In the 1994 PVA, fertility was reduced to 0.5 chicks per pair when the population would reach the recovery goal, to mimic the effect of reduced management activity at nesting sites. However, the observed decline in productivity is more likely due to increased predation than human disturbance (S.Melvin, *pers.comm.*). In terms of the model, either source of mortality would translate in a lower observed productivity at time of census, as predation on chicks would have been ongoing between onset of nesting and census time. The fertility values used are the means and standard deviations of field-measured fertilities for 1996-2002 (No Growth scenario) and for 1990-2002 (Intermediate Growth scenario) for New England breeding sites.

We have included an annual variation in the proportion of Stage2 (i.e. 1-2 year-old) females becoming breeders, unlike the less realistic fixed rate in the 1994 PVA. Given that no data exist, but that 1-year olds are commonly seen as breeders, the distribution of breeding propensity used for the Stage2 females is centered at 0.60, with a standard deviation of 0.1. All females above 2 years of age will breed annually.

Annual Survival

The increased mortality of young at the breeding sites would also cause a lowered first year survival rate, because mortality of fledglings after a census can only be measured at the next census, one year later, in terms of number of one-year old (Stage 1) female survival.

Survival parameters in the 1994 PVA, were from a banding study of piping plovers nesting on Cape Cod, MA, from 1985 to 1989 (MacIvor, Griffin and Melvin, unpubl.; cited in Melvin and Gibbs 1994). No new estimates have been calculated since then for this area, so this is also our source of information. Melvin and Gibbs, the authors of the 1994 PVA, noted that the survival rate values obtained in that study were likely underestimates, because the analysis did not separate out actual mortality from movement of birds out of the study area (emigration) or from band loss; in this case, a fraction of birds deemed “dead” would still be alive, but not be observed by the researchers. Although MacIvor et al. made efforts to obtain sightings of banded birds from outside their study area, under-reporting remains a cause for downward bias in survival rate estimates. This is important, because of the high sensitivity of the model results to survival (see below, under Basic Results). We assumed that the marked birds alive in a given year but not sighted increased the apparent mortality rate by 10%, for all stages. The assumed “true” survival rates that we used were therefore higher than those estimated from the banding study, but the standard deviation estimates remained the same (Table 1). Additionally, for the No Growth scenario, we allocated some of the predator-caused mortality on young birds to the first-year (Stage1) survival rate, as discussed above; we assumed a first-year mortality increased by 10% (Table 1).

Simulations

The stochastic simulations were conducted by allowing the rates to vary from year to year according to their distributions. In each year of a simulation, the value of a parameter was picked at random from its model distribution, and used in the matrix equations. All simulations had an initial number of 650 breeding pairs, approximately the breeding population plateau of the last several years (pipingplover.fws.gov site). Each simulation was run over 100 years, and each scenario was made up of 1,000 runs. The proportion of these 1,000 runs with fewer than 1 female after 100 years measured the probability of extinction. The probability of recovery to the Recovery Plan Population Goal (600 breeding pairs for the New England region as a whole) at a given year was the proportion of runs at or above 600 breeding pairs on that year. The total female population size needed for 600 breeding females was calculated based on the stage distribution calculated from the parameter matrix under No Take (stable stage distribution; Caswell 2001).

We assumed that all birds in New England (Connecticut to Maine) are equally at risk from the effects of fatalities in the wind farm area, so that birds were taken in proportion to their numbers in each stage. Fatalities attributed to the wind farm in the simulations are a constant number of females every year of wind farm operation, i.e. 20 years; after 20 years, all scenarios revert to conditions of no take.

The scenarios we ran were the following:

No Growth

- Baseline: simulations without any added mortalities.
- Added annual takes of 1, 2, 5, 10, 50 females over the first 20 years;

Intermediate Growth

- Baseline: simulations without any added mortalities.
- Added annual takes of 1, 2, 5, 10, 50, females over the first 20 years, the planned life of the wind farm

Results

Basic analysis

Using the parameter values listed in Table 1, the model yielded a population rate of increase of 1.006 (0.0067% growth per year) for the No Growth scenario and of 1.063 (6.3% per year) for the Intermediate Growth scenario. To obtain the annual rate of 13% observed in the 1990s, the high productivity of that period is not sufficient; yearling and/or adult survival must be higher as well. Similarly, the zero growth of the recent years cannot be obtained from the observed decrease in productivity alone; an additional decrease in yearling (Stage1) survival rate is necessary.

The sensitivity analysis results are shown in the right-hand column of Table 1. These are proportional sensitivities (elasticities) of the population rate of increase to changes in each of the parameters, evaluated for the No Growth scenario; results for the Intermediate Growth scenario are very similar. The largest value, for adult survival rate, indicates that population growth is most sensitive to changes in this parameter; any factor causing a change in this parameter will have a strong influence on population growth. However survival rate of the other stages, as well as adult fertility, also have a substantial influence on growth. These sensitivity results are representative of species with a relatively fast life cycle, i.e. with high mortality rates, early maturation and high fertility, and contrast with those of the Roseate Tern. In essence, this means that populations will have a fast response time to environmental changes, positive or negative.

Fatality Scenarios

Results from the simulations (Table 2, Figure 3) show the profound difference between the two scenario groups. The No Growth scenario, even with zero take, yields a substantial risk of population decrease below 600 breeding pairs, the minimum level for recovery of the New England population recommended by Melvin and Gibbs (1994) in the 1994 PVA. An additional fatality of 1 female per year does not increase this risk significantly, with a 3% increase by 20 years and a 1% increase by 100 years. All other levels of additional fatalities increase the risk of crossing this population threshold by more than 5% relative to the zero-take level. However, none of the levels of fatality tested caused any risk of extinction.

Figure 3 also illustrates the effect of takes on the risk of decline. The 5, 10 and 20 female fatality lines have a clear change in slope at 20 years, when takes stop occurring, indicating recovery from these increased mortality regimes. The effects of 20 years of heightened mortality remain visible to the end of the 100-year period.

The Intermediate Growth scenario results in population increase from the current level for all levels of additional take tested, a zero risk of decline to below 600 breeding pairs for all but the first 2-3 years of the simulations, and a zero risk of extinction.

Discussion

The sharp difference between the results of the two scenarios makes clear how crucial it is to sustain management action at the nesting sites to reduce mortality of young. The major difference between the two scenarios, in terms of parameter values, is the increased mortality of young, either as chicks (through reduced fertility) or as fledglings after census (through reduced Stage1 survival). The amount of difference in these parameters between scenarios is remarkably small, and within the range of observed or estimated variation. The sensitivity analysis makes the same prediction of high sensitivity of population growth rate to relatively small changes in several parameters.

The impact of additional mortalities on probabilities of piping plovers remaining above recovery level depends very strongly on the growth rate assumption for the population. Under an assumption of intermediate growth around 6% per year, the risk of decline below the recovery threshold is negligible unless a very large (and improbable) annual take occurs. Only if more than (10) additional females die will there be a significant risk of decline below the threshold; only if more than 50 additional females die is there a non-zero risk of population extinction. While the No Growth scenarios also yield zero risk of extinction for all below the 20-take level tested, an annual take of very few females can slow down recovery. This scenario thus describes how the effect of a potential mortality factor can be mitigated through management of other aspects of the ecology of a species.

Under the assumptions of our model, fatalities between 1 and 5 female piping plovers per year are unlikely to increase the risk under the current no-take condition, and will not cause a risk of extinction, if applied to the New England population alone. The No Growth scenario was chosen to represent conditions, among those observed in this species in the last 20 years, under which added fatalities would have the strongest influence on population growth. It represents a "risky" set of conditions, where higher mortality could "tip the balance" toward a return to pre-recovery levels. A number of caveats must be given, however. The only hard data available for the current period are from annual nesting site censuses. The mortality rate differences between the two scenarios are theoretical; obtaining new values would require a new mark-recapture study. A slightly different combination of mortality levels between young and mature females will cause large differences in the dynamics of this species, and these two scenarios should be expanded to a larger range of alternative assumptions. Lastly, many other changes in the birds' ecology are possible; in particular the risk of loss or degradation of wintering range habitat. The results presented hinge on the assumption of no change in conditions for the course of the simulation period, and thus the projected effects must be interpreted with this assumption in mind.

Conditions for the piping plover in New England have improved since the 1994 PVA, and its current population size, above the 600-breeder threshold recommended as a result of that PVA , and its consequent near-zero risk of extinction show the extent of the change. Still it is apparent that under the present stationary growth regime a return below that threshold is likely. The 1994 PVA also addressed extinction risk for piping plovers of the whole Atlantic Coast, with nesting grounds from Canada to North Carolina. We restricted our work to a single region, New England, because the different subpopulations show strikingly different growth patterns, and because only birds migrating to areas north of New York and New Jersey are likely to be at risk from fatality in the Nantucket Sound wind farm. If birds from other areas, especially the Atlantic Canada subpopulation, were included in the analysis we would be looking at the same number of potential annual fatalities, but applied to a larger number of birds. Although a metapopulation model is warranted to study piping plovers, fatalities from the projected wind farm are unlikely to bring about higher risks of extinction to the Canadian subpopulation unless most birds taken are from that subpopulation.

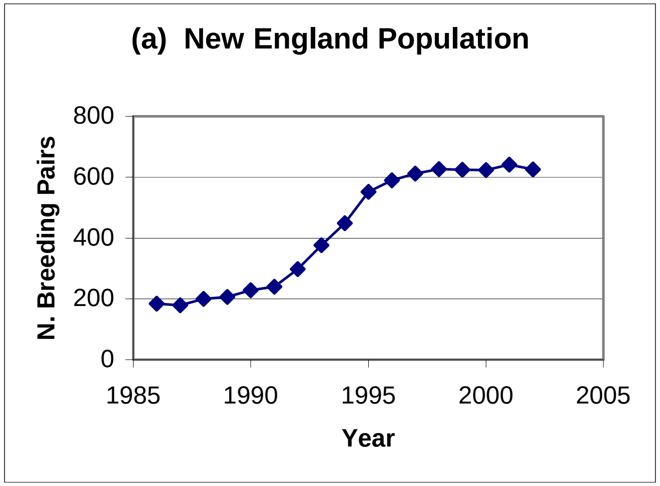
Table 1. Parameter values used in the piping plover model, for the two scenarios, without additional fatalities (takes). Proportional sensitivities (= elasticities) measure the change in population rate of increase if each parameter in turn is modified by a same proportion. Proportional sensitivity to adult survival rate is the largest value, indicating that small changes in adult survival will cause large shifts in population growth, compared to any other parameter.

Parameter	**Symbol**	**No Growth Assumption (No Takes)**		**Intermediate Growth Assumption (No Takes)**		**Proportional Sensitivity**
		Mean	Standard Deviation	**Mean**	**Standard Deviation**	
Age1 survival rate	$\mathbf{s_1}$	0.48	0.075	0.58	0.1	0.18
Age2 survival rate	$\mathbf{s_2}$	0.77	0.06	0.77	0.06	0.15
Adult survival rate	$\mathbf{s_a}$	0.77	0.06	0.77	0.06	**0.49**
Age2 fertility (female/ breeding female)	$\mathbf{f_2}$	1.38	0.16	1.52	0.24	0.03
Adult fertility (female/ breeding female)	$\mathbf{f_a}$	1.38	0.16	1.52	0.24	0.15
Proportion Age2 breeders	$\mathbf{br_2}$	0.7	0.1	0.7	0.1	0.03
Proportion adult breeders	$\mathbf{br_a}$	1	--	1	--	--

Table 2. Probability that the breeding population **decreases below 600** pairs, measured after 20 and 100 years. Dashes indicate no results for that scenario and take level. Extinction probability is 0 for all but the Intermediate Growth scenario with 100 takes, where a 5% risk of extinction is reached by 19 years.

	No Growth Assumption		Intermediate Growth Assumption	
Added Fatalities (Takes) Levels	Probability at 20 yrs	Probability at 100 yrs	Probability at 20 yrs	Probability at 100 yrs
0	.27	.22	0	0
1	.30	.23	0	0
5	.43	.28	0	0
10	.58	.35	0	0
20	.84	.53	--	--
50	--	--	.18	0
100	--	--	.97	.58

Figure 1. (a) Population trends and (b) Productivity trends in New England. From USFWS Piping plover website.



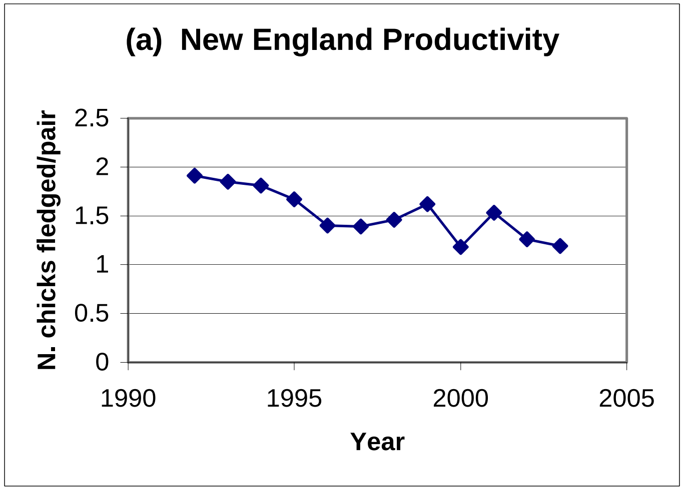
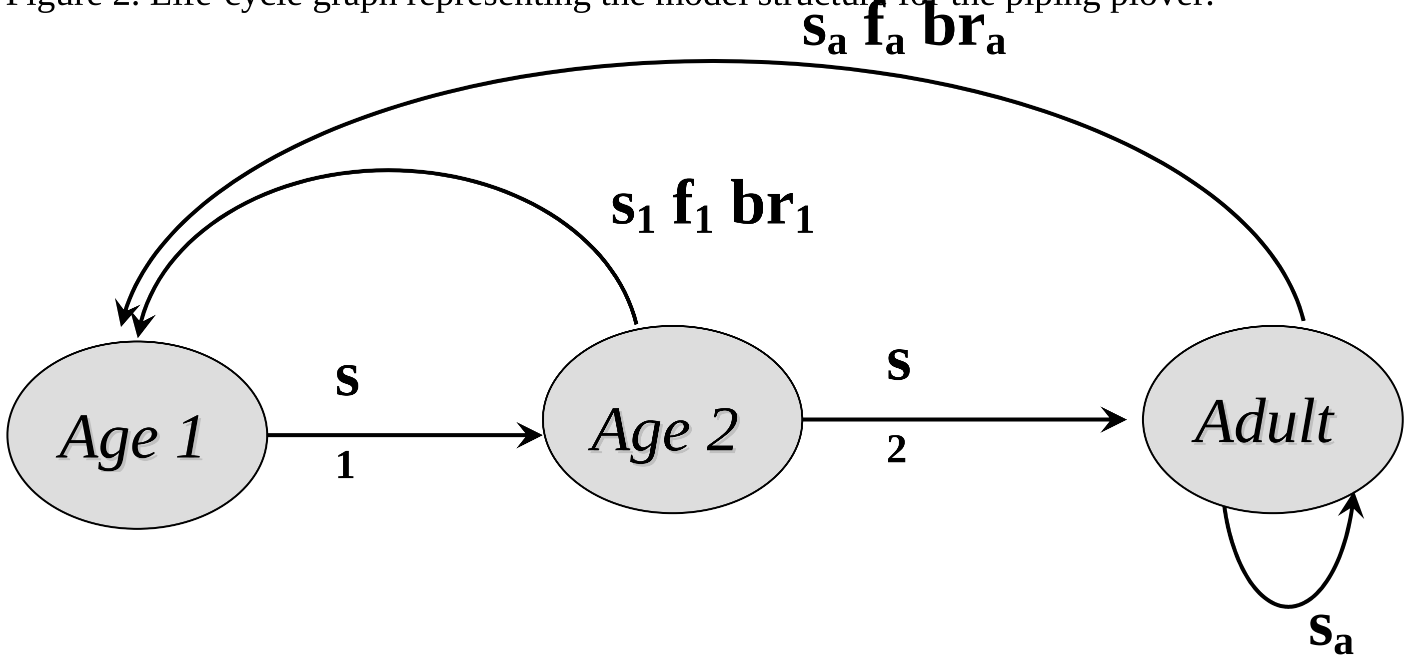


Figure 2. Life-cycle graph representing the model structure for the piping plover.



Piping Plover model stages:

Age1: chick to 1-year-old
Age 2: 1-2 year-old females
Adult: females 2 year-old and older

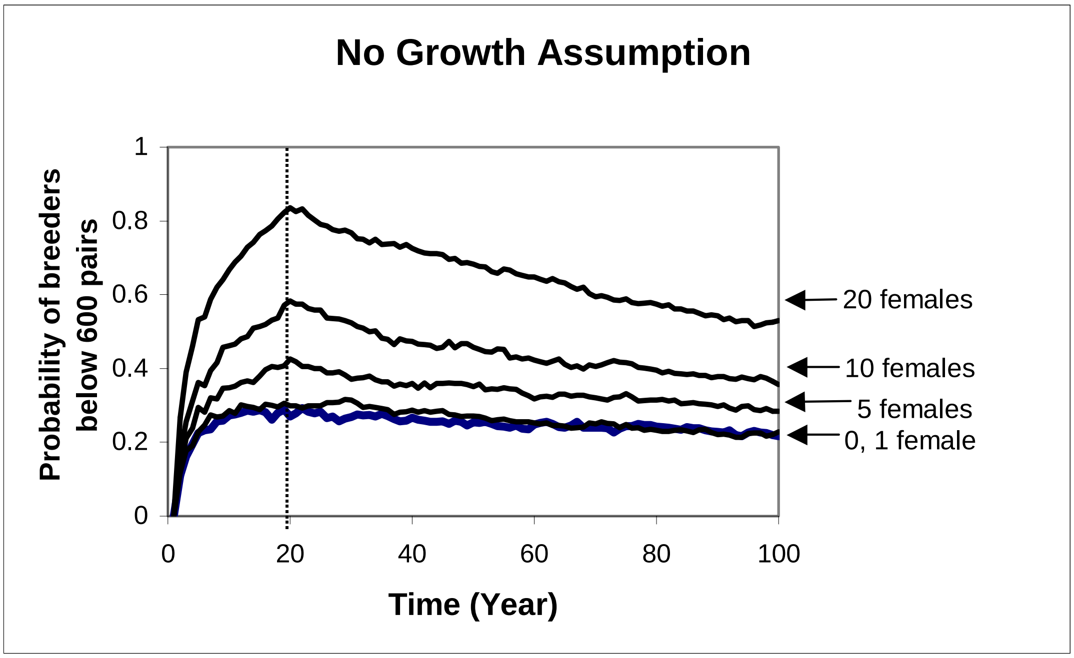
Post-breeding census

Model parameters:

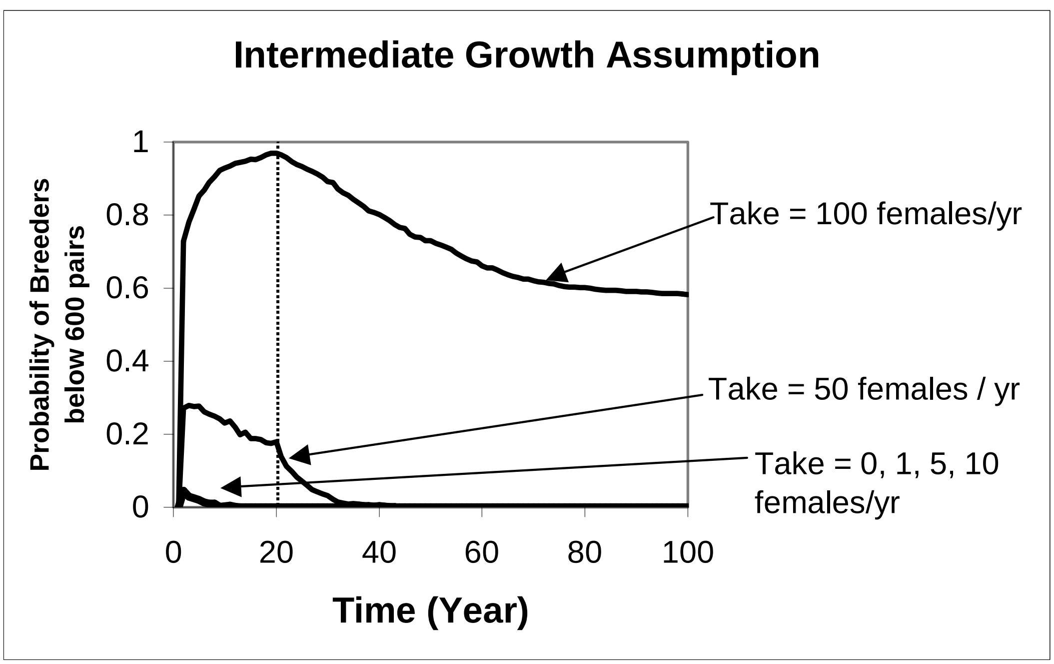
$s_1 – s_2$: annual survival rate of Age1 and Age2 females
s_a : annual survival rate of breeding adults
f_a: annual fertility of adults (number of female offspring per female)
f_2: annual fertility of Age2 females (number of female offspring per female)
br_a: proportion of breeding adults that contribute to reproduction
br_2: proportion of Age2 females that contribute to reproduction

Figure 3. Probability that the size of the breeder population falls below 600 pairs in the next 100 years, under a) No Growth assumption, b) Intermediate Growth assumption. Arrows indicate the take level associated with each curve; dotted line indicates the 20th year, at which point all scenarios revert to zero takes/year for the rest of the simulation.

a)



b)



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