OCS Study
BOEM 2012-076

Compendium of Avian Occurrence Information for the Continental Shelf Waters along the Atlantic Coast of the United States: Final Report (Database Selection – Shorebirds)

April 2011

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U.S. Department of the Interior
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Patuxent Wildlife Research Center

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Compendium of Avian Occurrence Information for the Continental Shelf Waters along the Atlantic Coast of the United States: Final Report (Database Section - Shorebirds)

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In cooperation with the
U.S. Department of the Interior
Bureau of Ocean Energy Management,
Regulation and Enforcement (BOEMRE)
Headquarters

PROJECT COOPERATION

This study was procured to meet information needs identified by the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), now called the Bureau of Ocean Energy Management (BOEM), in concert with the U. S. Geological Survey.

DISCLAIMER

REPORT AVAILABILITY

This report is available at the Environmental Studies Program Information System (ESPIS) online at http://www.gomr.boemre.gov/homepg/espis/espismaster.asp?appid=1.

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1. INTRODUCTION AND BACKGROUND

Wind power is increasingly recognized as an accessible, carbon-emission-free energy source, which can help meet growing energy requirements while mitigating the environmental impacts of fossil fuel-based energy generation (Allison et al. 2008, Snyder and Kaiser 2009, American Wind Energy Association [AWEA] 2010). Mounting interest in wind power has recently made it competitive with other power sources (Kuvlesky et al. 2007), and it is now one of the fastest-growing segments of the electricity market in several countries, including the United States (Stewart et al. 2007, Snyder and Kaiser 2009). Despite these advantages, the rapid expansion of wind development has led to concerns over its detrimental impacts on birds, including mortality from turbine collisions, blocking of flight pathways, and alteration of habitats (Drewitt and Langston 2006). In the United States, regulatory agencies are tasked with evaluating and mitigating threats to bird populations on public lands, under laws such as the Migratory Bird Treaty Act and the Endangered Species Act (Allison et al. 2008). This responsibility also pertains to waters within the U.S. Atlantic Outer Continental Shelf (OCS) zone, where construction of numerous wind facilities is planned (O'Connell et al. 2009).

Some studies have evaluated the effects of offshore wind facilities on marine birds in Europe, where over 900 turbines (located > 5.6 km off the coastlines of eight different countries) have begun operating in the last 15 years, and several thousand more are planned or under construction (Desholm and Kahlert 2005, Allison et al. 2008, EWEA 2011). Findings have varied greatly by location, species, and study design (Drewitt and Langston 2006, Stewart et al. 2007). Thus, the extent of risk that birds face from offshore wind development remains unclear, particularly in the U.S., where no turbines have been constructed in the marine environment (Allison et al. 2008, AWEA 2010). As a first step in evaluating the frequency of such interactions and the potential risks posed by them, there is a need to collect information on the distribution and behavior (e.g., flight heights, direction, timing) of birds occurring in offshore areas where wind facilities may be sited (Richardson 2000, Allison et al. 2008, O'Connell 2009). This information can be used to generate models to predict impacts of future offshore wind turbines, serve as a baseline for comparisons with post-construction species monitoring efforts, and identify subsequent research and conservation priorities for species that may be most affected by offshore wind development (Drewitt and Langston 2006, O'Connell et al. 2009, Burger et al. 2010). While birds with largely offshore ranges, including seabirds and marine waterfowl, are thought to have the greatest chance of interacting with offshore wind facilities (Allison et al. 2008, Desholm 2009), there is also a need to examine interactions between offshore wind development and other avian taxa that regularly utilize marine environment, such as shorebirds.

"Shorebirds" are comprised of two closely-related clades within the avian order Charadriiformes (Patton and Baker 2006, Baker et al. 2007). These clades include the suborders Scolopaci (sandpipers, phalaropes and allies) and Charadrii (avocets, stilts, oystercatchers, and plovers), as well as two others (Thinocori, Chionidi) not found in North America (Hayman et al. 1986, Patton and Baker 2006, Baker et al. 2007). Many shorebird species use coastal and near-coastal habitats during substantial portions of their lifecycles (Hayman et al. 1986). While few studies have examined shorebird use of offshore and marine environments (Burger et al. 2010), their extensive distribution in near-coastal waters, and highly migratory behavior, including multiple reports of over-ocean flights (Hayman et al. 1986, Poole 2010), suggest shorebirds could be exposed to offshore wind facilities, increasing their risk of disturbance and mortality.

Here we review existing occurrence information, movement patterns, and flight behavior for shorebirds in the OCS zone. Our report is associated with the Compendium of Avian Occurrence Information for the Continental Shelf Waters Along the Atlantic Coast of the United States (hereafter "Offshore Atlantic Bird Compendium"), which addressed seabird occurrence (O'Connell et al. 2009).

Our objectives were to:

1) **Identify, inventory, and summarize available shorebird occurrence data for the OCS zone**

2) **Review and summarize ancillary information pertinent to assessing shorebird conflicts with offshore wind development in the OCS zone, including seasonal ranges, flight patterns, and flight altitudes of western Atlantic shorebird species**

3) **Compile and map existing datasets of shorebird locations in the OCS zone using a Geographic Information System**

4) **Identify gaps in distribution data and relevant ancillary information (e.g., flight altitude and pathways) for shorebirds in the OCS zone**

5) **Examine shorebird conflicts with existing offshore wind facilities in Europe, and wind facilities along the North American Atlantic coast to predict potential conflicts at facilities to be sited in the OCS zone**

6) **Recommend future research and/or monitoring activities to adequately assess the impact of offshore wind development on Atlantic shorebirds in the OCS zone**

This report compiles the majority of occurrence and behavior information currently available for shorebirds in the OCS zone. Results and recommendations contained herein provides regulatory agencies, such as the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), additional information for evaluating and minimizing shorebird conflicts with proposed offshore development projects. BOEMRE is responsible for regulating offshore wind development beyond State waters, which begins at three nautical miles (about 5.6 km) from shore along the Atlantic Coast. For the purposes of this report, "OCS zone" refers specifically to these waters. States have authority over development nearer to shore. We use the term "offshore" more generally, to refer to marine waters at an unspecified distance off the coast (including the OCS zone). In this report we use a "weight-of-evidence" approach (Burger et al. 2010) to draw conclusions from available data, prioritize research and conservation activities, and recommend methodologies for carrying out future work.

2. METHODS

2.1. Seasonal Ranges, Migratory Paths, Population Estimates, and Conservation Status of Shorebirds in the U.S. Atlantic

We identified all shorebird species regularly occurring in the U.S. Atlantic and determined approximate extents of their coastal and offshore ranges by season (winter, spring migration, breeding, and fall migration) using life history accounts in the Birds of North America (BNA) series (http://bna.birds.cornell.edu/bna). For species occurring in the U.S. Atlantic during fall and/or spring migrations, we also used BNA to determine whether migratory paths were primarily coastal, oversea, or interior. BNA is the most current and comprehensive life history reference available for North American birds (Poole 2010) and is widely cited in avian studies. For a few species, research conducted since BNA accounts were published provided us with updated information about seasonality or migration routes. These sources are indicated in the results.

We obtained estimates of population size (Morrison et al. 2006) and noted the conservation status (U.S. Shorebird Conservation Plan 2004) of shorebird species (or subspecies and subpopulations) regularly occurring in the U.S. Atlantic. Population estimates for many species included individuals with non-Atlantic distributions, and did not distinguish among seasons. Thus, BNA accounts were further used to provide a rough estimate of regional Atlantic abundance by season, when information was available. The following abundance approximations were used: “very small” (< 500 birds), “small” (500 to 2,500 birds), “moderate” (2,501 to 10,000 birds), “large” (10,001 to 50,000 birds), “very large” (> 50,000 birds), and “data deficient” (no information provided in BNA). We stress that abundance estimates are based on the best available data and are intended for purposes of comparison rather than accuracy and precision.

2.2. Comprehensive Literature Search and Review

We comprehensively searched published and unpublished (“gray”) literature for information pertaining to occurrence, abundance, and behavior of shorebirds in offshore waters, with a focus on the U.S. Atlantic. We also searched for literature about avian interactions with wind generation facilities, with a focus on shorebirds and offshore wind facilities. Some literature was further examined to identify potential shorebird datasets with offshore location data.

We employed a systematic and replicable literature search methodology (Stewart et al. 2007), using the following search-terms and/or combinations of search terms: “shorebird(s)”, “seabird(s)”, “bird(s)”, “Atlantic”, “United States”, “U.S.”, “offshore”, “ocean”, “marine”, “abundance”, “distribution”, “location(s)”, “range”, “movement patterns”, “wind facility”, “wind farm”, wind turbine”, “wind development”, “wind”, “flight”, “behavior(s)”, “migration”, “path”, “track”, “radar”, “ascent”, “climb”, “descent”, “altitude”, “angle”, “take-off”, “landing”, "tower", and "collision". We queried search terms using the Web of Knowledge (http://www.isiwebofknowledge.com/), GoogleScholar (http://scholar.google.com/), Searchable Ornithological Research Archive (http://elibrary.unm.edu/sora/), National Renewable Energy Laboratory (http://nrelpubs.nrel.gov/Webtop/ws/avianlt/www/web_data/SearchForm), U.S. Fish and Wildlife Service Online Conservation Library (https://intranet.fws.gov/conservation_library/litsearch/index.html), and JSTOR (http://www.jstor.org/) search engines and literature archives.

Our literature search produced several hundred potentially relevant citations. We reviewed information from relevant articles and reports and summarized them in a Microsoft Excel spreadsheet. In some cases, authors were contacted to inquire about access to datasets and unpublished reports, or as part of our survey of professionals (see section 2.3 below).

2.3. Survey of Professionals

We contacted biologists, ecologists, and conservation professionals from the United States and Canada with demonstrated expertise in 1) shorebird distribution and behavior, 2) bird-wind facility interactions, and/or 3) offshore bird occurrence in the U.S. Atlantic. These professionals represented federal, state, and local governments; non-profit and academic institutions; and biological consulting firms. We provided these professionals with the following list of questions:

- Have you participated in studies that have examined offshore movements of shorebirds along the North American Atlantic coast? If so, do you have access to data sources from these studies? If not, can you recommend any pertinent studies or people to ask about such information?

- Do you have knowledge of behaviors for specific shorebird species that would be relevant to evaluating whether shorebird - wind development conflicts are likely to occur in the OCS zone (e.g., flight heights, flight direction, etc.), or know of any relevant reports/studies on this topic?

- Based on what you know of existing information, how frequently do you believe shorebird-offshore wind development conflicts are likely to occur in the OCS zone, and are there particular species you are concerned about?

- What sort of information or study design do you believe would be most informative for investigating whether shorebird - wind development conflicts are likely to occur in the OCS zone?

Answers to these questions were summarized and entered into a Microsoft Excel spreadsheet. Literature, contacts, and data sources recommended by those who answered our survey were pursued, frequently leading to additional information.

Other professionals were surveyed less formally and opportunistically if encountered at conferences, meetings, or during the course of other research activities. These interactions often involved discussion of datasets or relevant projects that they were involved in.

2.4. Compiling and Mapping Atlantic Shorebird Location Data

We obtained access to a small number of repositories of bird occurrence data for offshore and/or coastal areas, and queried them for spatially-explicit shorebird records. During the course of literature searches (see 2.2) and surveys of professionals (see 2.3) we also attempted to find associated datasets containing shorebird locations. We compiled geographic coordinates (latitude-longitude), species identifier, number of individuals observed, time, and date in a Microsoft Excel spreadsheet for shorebird data records within offshore and nearshore areas.

Each spreadsheet of shorebird records was imported into an ArcGIS v.9 (ESRI, Redlands, CA) Geographic Information System as an ESRI geodatabase featureclass, and overlaid on a map of the U.S. Atlantic coast and offshore waters. Related shorebird species groups were displayed as separate color icons:

White - plovers
Purple - oystercatchers and stilts,
Blue - sandpipers of genus Tringa,
Orange - godwits and whimbrels,
Yellow - sandpipers of genus Calidris,
Green - other sandpiper species (Spotted Sandpiper, Ruddy Turnstone, dowitchers)
Red - phalaropes
Black - unidentified shorebird species

We intended to account for disparate levels of sampling effort among datasets to provide a more meaningful interpretation of distribution patterns across the study area (O'Connell et al. 2009). However, this calculation was not practical given the scarcity of shorebird location data existing for offshore areas (see results).

3. RESULTS

3.1. Shorebird Occurrence in the U.S. Atlantic Region

3.1.1. Seasonal ranges, migratory paths, population estimates, and conservation status

Thirty-five species of shorebirds regularly occur in coastal and/or offshore areas of the U.S. Atlantic (hereafter, "U.S. Atlantic region"; Poole 2010; Table 1). Nearly all of these species are found in the U.S. Atlantic region during spring (late March to early June) and/or fall (mid-July to late October) migrations, while few species (5 of 35) occur here during the breeding season (most are arctic or subarctic breeders). Twenty-four of 35 species are found in the U.S.

Atlantic region during the winter, primarily in southern states. The greatest numbers of shorebirds also occur during migrations. Species with the largest reported numbers of migrants in the Atlantic region include Black-bellied Plovers (*Pluvialis squatarola*), Semipalmated Plovers (*Charadrius semipalmatus*), Ruddy Turnstones (*Arenaria interpres*), Red Knots (*Calidris canutus*), Sanderlings (*Calidris alba*), Semipalmated Sandpipers (*Calidris pusilla*), Least Sandpipers (*Calidris minutilla*), Dunlin (*Calidris alpina*), and Red Phalaropes (*Phalaropus fulicarius*).

Birds of North America species accounts include very little information about numbers and locations of shorebirds in the OCS zone. However, apparent migratory paths have been identified for several species using a combination of band-resight, seasonal survey, and tracking data (Table 1). This information can be used to predict whether offshore waters are likely to be used during this period. Plovers, oystercatchers, stilts, avocets, and yellowlegs are generally thought to migrate along the coast, rarely venturing into offshore waters. However, there is evidence that migrants including Piping Plovers (*Charadrius melodus*), Wilson's Plovers (*Charadrius wilsonia*), Black-necked Stilts (*Himantopus mexicanus*), and both species of yellowlegs (*Tringa melanoleuca, T. flavipes*), travel over the open Atlantic (and thus, the OCS zone) to reach Caribbean islands, where they are regularly recorded (see Table 1, note e). Other shorebird species including Whimbrels (*Numenius phaeopus*), Hudsonian Godwits (*Limosa haemastica*), Red Knots, Semipalmated Sandpipers, Least Sandpipers, Red-necked Phalaropes (*Phalaropus lobatus*), and Red Phalaropes fly primarily oversea migration routes during one or both migrations, particularly in fall. Individuals of some of these species skip over the U.S. Atlantic region from staging grounds in Canada on their way to winter in Central and South America. Migrating populations of most other shorebirds in the U.S. Atlantic region use some combination of coastal and offshore paths.

Population estimates for shorebirds in the U.S. Atlantic region vary considerably among species (Table 1), from under 3,000 for Piping Plovers to over 3,000,000 for Western Sandpipers (*Calidris mauri*), though there is uncertainty in some estimates (Morrison et al. 2006). Although we tried to include population estimates specific to subspecies or populations in the U.S. Atlantic region, they were often unavailable. Thus, for several of the 35 species, most of the estimated population occurs outside the region (see Table 1, note g). However, six species or subspecies that have comparatively small total populations are known to occur largely or exclusively within the U.S. Atlantic region: Wilson's Plover (6,000), Piping Plover (Atlantic subspecies, *C. m. melodus,* 2,900), American Oystercatcher (*Haematopus palliatus,* 11,000), Whimbrel (subspecies *N. p. hudsonicus*, 31,000), Red Knot (subspecies *C. c. rufa,* 20,000), and Purple Sandpiper (2 subspecies, *Calidris maritima maritima* & *C. m. belcheri,* 15,000 combined). Thus, the U.S. Atlantic is a key region for these shorebird populations. Sixteen of the 35 shorebirds occurring in the U.S. Atlantic region are considered species of "high concern", or "highly imperiled" by the U.S. Fish and Wildlife Service (Table 1; U.S. Shorebird Conservation Plan 2004). Additionally, 19 of 35 species are known or suspected to be declining within the region or across the species' range (Table 1, downward arrows; Morrison et al. 2006). Total species population estimates, proportion of the population occurring within the region, conservation status, and population trends can be collectively evaluated to determine regional shorebird conservation priorities.

3.1.2. Occurrence in the OCS zone

3.1.2.1. Literature and reports on shorebird occurrence

Our comprehensive review of over 50 published articles and unpublished reports produced scant occurrence information for shorebirds in the OCS zone. Very few studies have collected offshore location data for shorebirds. Those that did generally collected data secondarily to primary objectives, limiting its rigor. The information we located was restricted to few species, an unidentified suite of species, a brief study period, and/or very localized study areas. In the following paragraphs we summarize available information.

Radar tracking: Several studies in the 1960s and 1970s used coastal, island, and offshore surveillance radar (as defined in Desholm et al. 2006) to track birds over the western Atlantic Ocean, primarily during migrations. Study locations included Puerto Rico, South Florida, New England, and southern Atlantic Canada (Drury and Keith 1962; Nisbet 1963; Richardson 1973, 1974, 1979; Williams et al. 1977). Shorebirds were sometimes able to be distinguished from other bird types through interpretation of radar echo intensities, flight speeds, and flight heights (Drury and Keith 1962, Richardson 1979), though techniques for distinguishing among avian groups were less sophisticated than they are today (e.g., wingbeat analysis; Desholm et al. 2006). Some studies reported greater offshore numbers of migrating passerines than shorebirds (Drury and Keith 1962, Richardson 1974, Williams et al. 1977), which is representative of the relatively high abundance of migratory passerines as a whole (B. Andres, U.S. Fish and Wildlife Service, pers. comm.). Offshore abundance of shorebirds varied within a season, with densities peaking during light winds and tail winds, and clear weather (Drury and Keith 1962, Richardson 1979). During fall migration, many groups of shorebirds travelled from stopovers in New England and Eastern Canada, directly over the Atlantic Ocean, later turning south toward the Caribbean and South America (Drury and Keith 1962, Richardson 1979). Over-water flights during fall migration regularly occurred at high altitudes (see 3.2.1. Flight Behavior) and often skipped the U.S. coast. In rare cases, low flying radar-tracked fall migrants, presumably ascending to migratory flight altitudes off New England, were able to be identified by observers on the ground. Sightings included Black-bellied Plovers, Semipalmated Plovers, Greater Yellowlegs, Lesser Yellowlegs, Hudsonian Godwits (*Limosa haemastica*), Red Knots, White-rumped Sandpiper (*Calidris fuscicollis*), Pectoral Sandpiper (*Calidris melanotos*), and Short-billed Dowitchers (*Limnodromus griseus*; Drury and Keith 1962). In New England, shorebird migration patterns differed in spring, with fewer over-water and more coastal migrants (Richardson 1979). During one winter, Drury and Keith (1962) used radar to track birds off of Cape Cod and found very few shorebirds.

Banding and resighting: Large-scale shorebird banding studies have used a broad network of land-based resighting areas along the Atlantic coasts of North and South America, and the Caribbean to infer migratory paths of tens of thousands of banded birds (McNeil and Burton 1977, Meyers et al. 1990). This information is limited in its ability to document specific routes, particularly over the ocean where there is no resighting effort. However, band-resight studies have found strong evidence that many shorebird species, including Semipalmated Sandpipers, Red Knots, and Least Sandpipers, fly over-water paths from New England and Canada to the Caribbean and South America during the fall (McNeil and Burton 1977). Band-resight studies have also determined that migratory paths of many species vary between fall and spring, with fall routes to the east of spring routes, and often over the ocean (McNeil and Burton 1977, Meyers et al. 1990). In some species, individuals of the same breeding or wintering populations use several different migratory paths, making those paths difficult to generalize (Meyers et al. 1990). This finding warns against making assumptions about migratory patterns based on small samples of occurrence data.

Surveys: The need for better understanding of shorebird and seabird occurrence in the OCS zone prompted the initiation of three comprehensive aerial and ship-based bird surveys of areas where offshore wind turbines are being planned.

The Massachusetts Audubon Society was contracted to conduct regular offshore surveys of Nantucket Sound (south of Cape Cod, MA) between 2002 and 2006 as part of an Environmental Impact Statement for the Cape Wind Project. While the primary objective of the surveys was to document locations of Federally-listed species, including Piping Plover, location data was collected for other shorebirds, seabirds, and marine waterfowl. Only a very small number of shorebirds, and no Piping Plovers, were observed during surveys (USFWS 2008). These shorebird locations are included in our GIS mapping effort (see 3.1.3. below).

Between January 2008 and November 2009 Geo-Marine, Inc. conducted shipboard transect surveys in offshore waters of southern New Jersey, as part of the New Jersey Department of Environmental Protection's (NJDEP) Wind Power Ecological Baseline Study. Transects ("double sawtooth" design) ran perpendicular to shore from the 10m isobath to 20 nautical miles from the coastline, an area primarily within the OCS zone. At least 16 shorebird species were documented. However, numbers and encounter frequencies were low for all shorebirds. According to the final report (http://www.nj.gov/dep/dsr/ocean-wind/report.htm; Appendix C), released in July 2010, total counts of the two most abundant shorebirds, Least Sandpiper (n = 28) and Short-billed Dowitcher (n = 18), were over two orders of magnitude smaller than the most abundant seabird (Northern Gannet, *Morus bassanus*, n = 8,844) and diving duck (Surf Scoter, *Melanitta perspicillata*, n = 4,782) species (NJDEP 2010). Raw location data for the offshore New Jersey surveys were not yet available at the time of this writing, and therefore are not included in our GIS mapping effort.

Bird surveys were conducted in offshore waters of Rhode Island between January 2009 and July 2010 (Paton et al. 2010). Work was carried out by researchers from the University of Rhode Island (URI) as part of the Rhode Island Special Area Management Plan (SAMP). Monthly ship-based transects (straight-line and "sawtooth") were conducted within 4 x 5 nautical mile grids, situated largely (approx. 80%) within the OCS zone. According to the SAMP Interim Technical Report (http://seagrant.gso.uri.edu/oceansamp/pdf/appendix/11-PatonAvianReptV3_reduced.pdf), which includes data through mid-February 2010, 49 shorebirds of six species were observed during the ship-based surveys. Red-necked Phalarope was the most abundant species (n = 24 individuals), followed by Short-billed Dowitcher and Whimbrel (n = 5 individuals per species). These numbers are one to three orders of magnitude smaller than the most abundant diving duck (Common Eider, *Somateria mollissima*, n = 294) and seabird (Wilson's Storm-petrel, *Oceanites oceanicus*, n = 1,511). No shorebirds were seen during winter ship-based surveys. Only 17 individual shorebirds were observed during 10 aerial transect surveys (24 strip transect lines covering the entire 3,800 km^2 study area) conducted between November 2009 and February 2010[1]. Aerial transects were located primarily (approx. 90%) within the OCS zone. All shorebirds seen from the air were in flight, likely migrating, but could not be identified to species due to their relatively small size. Raw shorebird location data for the OCS zone, collected during the SAMP surveys, were not yet released at the time of this writing, and therefore are not included in our GIS mapping effort. However, URI researchers have agreed to provide data after their final report is completed (likely by mid-2011), which will be incorporated into the Offshore Atlantic Bird Compendium (O'Connell et al. 2009).

Aside from recent surveys related to offshore wind development, only a handful of sources of shorebird location data for the U.S. Atlantic region are known to exist. Most come from unpublished Atlantic seabird, marine mammal, and fisheries surveys. These data were compiled in the Offshore Atlantic Bird Compendium (O'Connell et al. 2009), and included in our GIS mapping effort (see 3.1.3. below).

Tag tracking: A small number of studies have attached satellite tags or geolocators to shorebirds to track their movements across the annual cycle. This method allows researchers to continuously log offshore locations of tagged individuals. Since 2008, the Center for Conservation Biology at the College of William and Mary and the Nature Conservancy have attached satellite transmitters (each weighing 9.5 g) to 14 Whimbrels at a migratory stopover site on the Delmarva Peninsula (http://ccb-wm.org/programs/migration/Whimbrel/whimbrel.htm). Some of these birds have been tracked for over a year. Existing satellite tracks have confirmed that Whimbrels regularly migrate over the OCS zone during a few days of each year, and return to their Delmarva Peninsula stopover annually. Tracking maps show variation in over-water routes among, and even within individuals. However, little published information is yet available for this project, as data are still being collected and analyzed.

In May 2009, 47 geolocators were attached to Red Knots at one of their primary migration stopovers in Delaware Bay (Niles et al. 2010). The light weight (1 g) of geolocators allows them to be used on smaller shorebirds. Geolocators log data frequently, which can be used to track migration routes, but do not transmit the data remotely. Thus, birds must be recaptured to retrieve the data device. Three birds with geolocators were recaptured in May 2010, and movement data was retrieved and analyzed. Data showed that the birds used the Delaware Bay and Cape Cod as stopovers during fall and/or spring migrations, each flew over the OCS zone during spring and fall migration flights, and storms likely affected migration paths. Broad conclusions about offshore use of Red Knots await the collection of more data. Two hundred additional geolocators have been deployed on Red Knots since the original 2009 capture period (Niles et al. 2010). As of March 2011, 14 more geolocators had been recovered from birds captured in the field. Data is currently being analyzed, and further recapture efforts continue (L. Niles, Conserve Wildlife pers. comm.).

Although these tag tracking studies documented offshore migration routes for Whimbrels and Red Knots, neither satellite tags nor geolocators provided flight altitudes for these areas. Knowledge of flight altitudes is one important component of determining the propensity of

[1] The SAMP project also recorded shorebird locations within state waters (outside BOEMRE jurisdiction) during land based seawatches and coastal boat surveys. These surveys accounted for over 98% of shorebirds counted.

shorebirds to fly within the rotor swept zone of turbines in the OCS zone, which could increase collision risk[2] (Burger et al. 2010). The small number of tagged species and low sample sizes of tagged birds also prevents robust conclusions about occurrence in the OCS zone from being drawn from current data, particularly given the variability in observed movement patterns among individuals and within species. Further, both technologies are subject to error of over 100km, which is insufficiently precise for evaluating exposure risk to turbines on a local scale. However, broad scale movement data from tag tracking have proven invaluable, and cannot be obtained in other ways. Tag tracking is a relatively recent methodology, and as the technology improves it will only increase in utility.

Other information: Red Knot geolocator tracking is one of several projects currently underway as part of an effort by Pandion Systems, Inc. to better understand the risks that proposed wind development in the OCS zone poses to "highly imperiled" species, including Red Knot, and Piping Plover. Other Pandion shorebird projects use limited existing data to evaluate risks to Red Knots and Piping Plovers. In one study, all available coastal Atlantic location data were compiled for the two species, and a geospatial analysis of the data was performed (Forcey et al. 2010). From abundance distributions, researchers aim to determine whether large bodies of water, such as the Delaware and Chesapeake Bays, are being crossed ("short-cutters") or skirted ("coast-huggers") by Red Knots and Piping Plovers. A final report, which will detail findings of the study, is currently in revision.

Burger et al. (2010) used available literature and personal knowledge of the habits of Red Knots and Piping Plovers to create a conceptual model for evaluating their exposure to, and risk from potential offshore wind development in the OCS zone. A lack of quantitative information for the species necessitated use of a weight-of-evidence approach in which qualitative and limited quantitative data are used to assess risk to the best degree possible. The model evaluated risk at three scales "macro" (does the species occur in the area?), "meso" (does the species fly at wind turbine height?), and "micro" (given behavioral capacity for avoidance, will the species collide with turbines?). Piping Plovers were predicted to face less exposure (and thus less risk) to turbines in the OCS zone than Red Knots, though neither species were predicted to be at high risk of collision. However, even though Red Knots and Piping Plovers are well-studied compared with other shorebirds, there was much uncertainty in the conclusions, and further study was recommended.

Methods employed by both studies described above are broad enough to be applied to other shorebird species. Such studies could provide useful information for prioritizing and informing future research efforts, depending on the amount of data available for the species.

3.1.2.2. Survey of professionals about shorebird occurrence

Fourteen of 20 professionals responded to our survey. These individuals are affiliated with the following groups: ABR, Inc.; Audubon Alaska; Canadian Wildlife Service; Conserve Wildlife Foundation; Manomet Center for Conservation Sciences; New Jersey Audubon; Oregon State University; Pandion Systems, Inc.; Trent University; U.S. Fish and Wildlife Service;

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[2] Other important factors affecting collision risk include behavioral capacity of birds to avoid turbines in their path; see section 3.2.1.1 below

and U.S.G.S. Biological Resources Division. Twelve of 14 have served as principal investigators on projects studying shorebird distribution, interactions between wind development and birds, and/or offshore Atlantic seabird distribution. We also discussed offshore Atlantic shorebirds less formally with five additional professionals.

Eight of 14 respondents had no specific knowledge of shorebird location data for the OCS zone or did not respond to the question. The six other respondents told us that they believed that they had knowledge of most data sources available for the U.S. Atlantic region, and that very little offshore location data existed for shorebirds. Five of these professionals had a history of leading shorebird or research projects in the region. As part of the overall effort to develop the Offshore Atlantic Bird Compendium (O'Connell et al. 2009), all available sources of offshore bird location data were used in our mapping effort (see 3.1.3. below).

Ten of the 14 respondents suggested literature or other contacts. The last professionals to respond to our survey generally recommended sources that others had already suggested, or that we had located independently. Thus, we are confident that we located most information available for shorebirds in the OCS zone.

3.1.3. Shorebird datasets and location mapping

Nearly all shorebird datasets located for this project were contained in either the Compendium of Avian Occurrence Information for the Continental Shelf Waters Along the Atlantic Coast of the United States (O'Connell et al. 2009) or the Avian Knowledge Network (http:// www.avianknowledge.net). These databases are compilations of dozens of datasets from multiple sources. Both are updated as participants volunteer their data.

3.1.3.1. Compendium of Avian Occurrence Information for the Continental Shelf Waters Along the Atlantic Coast of the United States

The Offshore Atlantic Bird Compendium was created and is currently maintained by USGS Patuxent Wildlife Research Center, and includes the majority of known modern location data for seabirds and shorebirds in the OCS zone. Shorebird locations came from 36 different datasets in the database. Most data were collected between 1978 and 2009. Sources of data included ship-based and aerial seabird surveys, marine mammal surveys, fisheries surveys, and pelagic bird watches. Additional information about the database is available in O'Connell et al. (2009).

Twenty-five of 35 shorebird species regularly occurring in the U.S. Atlantic region were observed. Shorebirds (n = 2,552) comprised < 0.6% of all location records currently in the database. Nearly 200,000 individual shorebirds were reported. Over 94% of individuals were phalaropes, primarily Red Phalaropes, which are reported to be the most pelagic of North American shorebird species (Brown and Gaskin 1988). All shorebird locations are mapped in Figure 1. The small amount of occurrence data did not allow us to correct for variable observation effort among datasets throughout the mapping area. Thus, densities of bird locations on the map may be confounded by survey effort.

3.1.3.2. Avian Knowledge Network

The Avian Knowledge Network (AKN), maintained by Cornell Lab of Ornithology, is comprised of 54 datasets collected by government, academic, public, and private organizations, which volunteer bird observation data from throughout the Western Hemisphere. The AKN includes a massive quantity of bird locations from professional and citizen science projects that can be queried via the internet (www.avianknowledge.net/akntools/download). Data are standardized, and validated by AKN personnel.

Several datasets within the AKN are specific to areas outside the U.S. Atlantic and do not contain locations for the region. Other datasets do not include shorebird records, or only include land-based shorebird records. We limited our query to ten AKN datasets that contained shorebird records for U.S. Atlantic Region between 1990 and 2010, and potentially had offshore locations. The majority of locations came from e-Bird (http://ebird.org/content/ebird/), a citizen science project managed by Cornell Lab of Ornithology, which includes nearly 42 million bird locations (by far the largest dataset within the AKN). We omitted all location records that were listed as "non-valid" by AKN staff, or did not include precise coordinates (i.e. a reporting area > 10 miles or 1000 acres).

Our query of the AKN resulted in over 240,000 shorebird observation locations, comprised of all 35 species that regularly occur in the U.S. Atlantic Region (Figure 2). Despite the large number of locations, our query returned few shorebirds in the OCS zone (Figure 2). This result was predicted, as relatively few datasets included in the AKN have an offshore focus. Further, we did not query the two datasets within the AKN that contain primarily offshore bird locations, Manomet Center for Conservation Science Cetacean and Seabird Assessment Program and the Canadian Wildlife Service (CWS) Programme Integre des Reserches sur les Oiseaux Pelagiques (PIROP), because the data are also included in the Offshore Atlantic Bird Compendium (see 3.1.3.1. above).

3.1.3.3. Other data sources.

During 2008 and 2009, Geo-Marine, Inc. recorded nearly 150 shorebird locations along offshore shipboard transects that ran perpendicular to the New Jersey coast (from the 10m isobath to 20 nautical miles off the coastline). Surveys were part of the NJDEP Wind Power Ecological Baseline Study. NJDEP has recently provided USGS with data from the study which will soon be added to the Offshore Atlantic Bird Compendium.

A small number of shorebird locations (n < 100) were recorded in 2009 and 2010 during ship-based and aerial transect surveys conducted for the Rhode Island SAMP. These transects were performed in waters south of Rhode Island, perpendicular to the coastline. Northern boundaries of some transects were located within State waters. However, the majority of transect coverage was within the OCS zone, with some transects falling entirely within the OCS zone (Figs. 23, 24, and 27 in Paton et al. 2010). URI has agreed to make SAMP data available to USGS later this year for inclusion in the Offshore Atlantic Bird Compendium.

In addition to PIROP (see 3.1.3.2 above), the CWS has conducted surveys of birds in offshore waters of eastern Canada and the northeastern U.S. since 2005. These surveys have been combined with PIROP as part of the CWS's Eastern Canadian Seabirds at Sea program. Surveys are conducted regularly throughout the year. Besides a few hundred phalaropes, only 35 shorebirds have been observed since 2006, and most locations fall within Canadian waters. While PIROP locations in the OCS zone were mapped as part of the Offshore Atlantic Bird Compendium (Figure 1), we did not include recent CWS survey locations in our mapping effort.

3.2. Shorebird Flight Behavior and Other Ancillary Information

Here we report relevant ancillary information about shorebirds, including flight behaviors such as migration altitude. We also describe studies that have examined the effects of existing wind facilities on shorebirds in areas outside of the OCS zone. Although this information cannot directly determine whether interactions will occur between shorebirds and proposed offshore wind facilities in the OCS zone, it can be used to provide a best estimate of whether shorebirds are likely to be at risk, and can guide future research efforts.

3.2.1. Shorebird flight behavior and wind development

3.2.1.1. Literature and reports on shorebird behavior

Flight altitude: Birds flying between approximately 20m and 135m above sea level (i.e., the "rotor swept zone") may be exposed to offshore wind turbines in their path, and risk collisions (USFWS 2008, Burger et al. 2010). Several studies have examined flight altitudes of shorebirds off the coasts of eastern North America and Europe, using coastal and offshore radar, primarily during migration periods. Most of these studies reported that migrating shorebirds fly at higher altitudes ($\bar{x} \geq$ 1,000m) than the majority of other avian taxa (Drury and Keith 1962, Richardson 1974, 1979, Alerstam and Gudmundsson 1999, Green 2004). Green (2004) used modern X-band tracking radar, with the capacity to automatically track small avian targets and determine air speeds, to record mean flight altitudes of several shorebirds flying over the Baltic Sea, off Sweden. Size, air speeds, flight heights, and flight directions of radar targets were used to identify species or species type, in accordance with known migratory patterns of species in the area. The identities of birds tracked during daylight were visually confirmed by coastal- or sea-based observers using field telescopes. Flight heights (± SD) were determined for the following shorebirds: Black-bellied Plover = 1,726m ± 685m, n = 8; Red Knot = 393m and 426m, n = 2; Dunlin and Sanderling combined = 2,294m ±711m, n = 4; Bar-tailed Godwit 2,223m ± 481m, n = 13. These species, most of which also occur in the U.S. Atlantic region, all flew considerably higher than marine waterfowl (297m ± 125m, n = 27), which were also tracked in the study.

A small number of studies have tracked and/or visually observed migratory shorebirds flying at lower elevations offshore, ranging from 0m to 400m (Noer et al. 2000, Gudmundsson et al. 2002, Chamberlain et al. 2006, Paton et al. 2010). Paton et al. (2010) reported that all shorebirds observed during boat-based surveys offshore of Rhode Island flew below 10m in altitude (n = 26 individuals of 6 species); well below the rotor swept zone. Gudmundsson et al.

(2002) noted that nearly 25% of fall migrant shorebirds radar-tracked near the Northwest Passage of the Arctic Sea flew < 250m, including phalaropes and Semipalmated Sandpipers. However, unlike Paton et al. (2010), this study and several others that have documented low-flying shorebirds, found great variability in flight altitudes of shorebirds, even among members of the same species (see 'Variability in behavior' below). It is possible that Paton et al. (2010) were limited in their ability to detect high-flying migrants using visual detection methods, though migrants in the upper range of the rotor swept zone should have been detectable if present.

Avoidance: Flight altitude alone is not an accurate predictor of collision risk because it does not take into account the capacity of birds to avoid turbines in their path, or detour around wind facilities entirely (Chamberlain et al. 2006). Rates of avoidance, measured for several terrestrial avian species encountering land-based wind turbines, were high, ranging from 0.950 to 0.998 (Chamberlain et al. 2006, USFWS 2008). A lack of correlation between exposure rates to turbines and mortality rates of terrestrial bird species at Altamont Wind Resource Area in California supports the idea of high avoidance rates (Smallwood et al. 2008).

Very little information exists about wind facility avoidance behavior of shorebirds, and avoidance rates have not been quantitatively examined (USFWS 2008). Visual acuity of most shorebirds is thought to be very high, and most are agile flyers which have evolved the capacity to avoid aerial predators in flight (Burger et al. 2010). Thus, it is likely that shorebirds would avoid turbines at a high rate. In a literature review examining offshore wind energy in the North and Baltic seas, Exo et al. (2003) reported that Eurasian Curlews (*Numenius arquata*) and Eurasian Golden Plovers (*Pluvialis apricaria*) avoided wind facilities by > 500m. Avoidance of offshore wind facilities has also been documented in Little Terns (*Sterna albifrons*) in the U.K. (Perrow et al. 2006) and marine waterfowl off of Denmark (Desholm and Kahlert 2005). However, as with flight heights, avoidance behavior is highly variable depending on the species and both environmental and physiological factors (see 'Variability in behaviors' below).

Although avoidance of wind facilities reduces the risk of turbine collisions, long and/or frequent flights around large concentrations of offshore wind turbines could deplete body energy reserves of individual birds, leading to negative fitness consequences and adverse population effects (Drewitt and Langston 2006). While energetic costs of such avoidance have not been studied in shorebirds, work with seabird species suggests that energetic costs associated with infrequent detours (1-2 times/year) around offshore wind facilities during migration are insubstantial and have little impact on populations (Drewitt and Langston 2006, Masden et al. 2009). Some species also regularly encounter offshore wind facilities at other times of year, largely during foraging trips (e.g., winter and breeding season; Masden et al. 2010). Energetic models have found that the additional costs of turbine avoidance during this period vary among species depending on morphology (e.g., wing loading) and life history (e.g., the proportion of daily energy expenditure committed to flight), and may interact with variable environmental conditions (Marsden et al. 2010). Birds adapted to sustained flight with low wing loadings, such as most shorebirds, suffer a lower energetic cost relative to overall daily energy expenditure (Masden et al. 2010). Moreover, as few shorebirds use the OCS zone regularly for foraging (with the notable exception of wintering phalaropes), the affects of avoidance are likely to be lower for shorebirds than for most marine bird species. Still, as no data exist for shorebirds, cumulative impacts of offshore turbine avoidance and displacement cannot be thoroughly evaluated, and are expected to vary among species, and with density and location of turbines.

Variability in behavior: Flight behavior of birds, which influences their capacity to avoid wind turbine collisions, varies greatly depending on environmental and physiological factors. Flight activity of migratory shorebirds is usually reduced in poor weather, including strong headwinds, rain, dense clouds, and fog (Drury and Keith 1962, Richardson 2000, Green 2004, Huppop et al. 2006). Thus, the number of birds aloft likely decreases during bad weather, lowering exposure to offshore wind facilities. However, shorebirds encountering poor weather conditions while in flight often fly at lower altitudes, and could experience greater risk of collision with turbines if bad weather affects flight performance and visibility (Richardson 2000, Exo et al. 2003). Migrant shorebirds encountering poor weather while in the midst of a long overwater migratory flight may not have the immediate option to land (i.e., "fallout"), wait out the weather, and then continue along the same route after the weather clears. Instead, shorebirds may have to alter migration patterns to avoid the weather system or backtrack to shore (Niles et al. 2010), potentially increasing the risk of exposure to, and collision with offshore wind turbines.

Peak numbers of migratory shorebird departures usually occur near sunset (Drury and Keith 1962, Huppop et al. 2006) and collision risk increases with lower flight visibility during darkness (Exo et al. 2003). However, there is evidence that most birds fly at higher altitudes at night, thus decreasing exposure (Richardson 2000, Desholm and Kahlert 2005). Artificial illumination (e.g., navigation warning lights) on land-based towers and sea-based energy platforms have been shown to attract and disorient several species of nocturnal bird migrants, by interfering with navigation cues, particularly during fog, rain, and dense clouds (Poot et al. 2008, Kerlinger et al. 2010). While little information exists for shorebirds, it is possible that individuals migrating at night could face a risk from lights placed on offshore turbines (Drewitt and Langston 2006). Recent studies have determined that the effect of tower, turbine, and platform lighting on birds is greatly minimized or eliminated by substituting solid red or white lights with flashing red lights, and/or lights in the blue end (higher wavelength) of the spectrum (Poot et al. 2008, Kerlinger et al. 2010).

Tides may also affect the number of shorebirds aloft, and thus, exposure to offshore wind facilities. The greatest number of migratory shorebird departures occurs during high tide (Richardson 2000).

Flight behavior and abundance of birds aloft varies among season. Shorebirds are most likely to embark on long offshore flights during migration, and may face the highest risk of exposure to offshore wind facilities during this period, particularly in adverse weather (Richardson 2000). However, predicting timing of exposure is difficult, as peak migration density varies among shorebird species; among individuals, depending on age, sex, and condition (Richardson 2000); and with weather and predation risk (Drury and Keith 1962, Lank et al. 2003). Given that shorebirds generally fly at a high altitude during most of their migratory flight (see "Flight Altitude" above), the greatest risk of exposure to wind turbines likely occurs during takeoff and landing. Shorebirds rapidly ascending to, or descending from the coastline during takeoff and landing would only be expected to fly at lower altitudes near shore, reducing the chances of interaction with turbines in the OCS zone. However, there have been few studies of migratory ascent and descent behavior in shorebirds, and there is evidence that flight heights are highly variable, even after takeoff and landing (Richardson 2000). Thus, the possibility of interaction between migratory shorebirds and turbines in the OCS zone cannot be ruled out.

Although shorebirds are likely to make over-water flights during migration (Poole 2010), some behavior could expose shorebirds to wind facilities even during non-migratory periods. Studies of wintering Dunlin from Europe and the west coast of North America have reported that wintering flocks may fly offshore for several hours during high tides to escape aerial predators (Hoetker 2000, Dekker and Ydenberg 2004). Hudsonian Godwits have also been reported to fly for prolonged periods over water when disturbed by predators on their South American wintering grounds, though remaining near to the shore (B. Andres, USFWS pers. comm.). Proximity and placement of offshore wind facilities in relation to large concentrations of breeding and wintering shorebirds may further affect the likelihood of exposure (Drewitt and Langston 2006).

As behavior varies greatly among shorebirds, so do the risks of exposure and collision with turbines in the OCS zone. Some shorebirds, such as phalaropes, are primarily marine species (Brown and Gaskin 1988), while others, such as Piping Plovers, rarely fly offshore (USFWS 2008). Within species, flight behavior varies among age classes and between sexes (Poole 2010), which may result in further individual variation in risks posed by offshore wind facilities. The high degree of behavioral variability among shorebirds, depending on environmental and physiological factors, indicates that the risks of wind facilities to shorebirds may be most adequately evaluated on a case by case basis for the suite of species that occur in the specific area of proposed development (Drewitt and Langston 2006, USFWS 2008).

3.2.1.2. Survey of professionals about shorebird behavior

Qualitative information and opinions about shorebird behavior for the OCS zone was provided by seven of 14 respondents from our survey of professionals (see 3.1.2.2. above). According to the opinion of the majority of respondents, most shorebird flights in the OCS zone will likely occur well above the height of planned wind turbines (often >1 km), and migratory periods will be the primary, or only windows of exposure. Additionally, the exposure window will probably be brief, occurring during migratory takeoffs (which usually peak around sunset) and landings (D. Mizrahi, New Jersey Audubon, pers. comm.). This contrasts to a much larger exposure window for seabirds, which spend more time in waters of the OCS zone. Many respondents indicated that shorebird vulnerability to wind development in the OCS zone will probably vary widely by bird species, age, sex, and weather during migratory flights, but that available data are insufficient to methodically evaluate risk. Three respondents identified phalaropes (*Phalaropus spp.*) as being particularly at risk of exposure to wind developments in the OCS zone due to their marine distribution.

3.2.2. Shorebird interactions with operational wind facilities outside the OCS zone

No offshore wind facilities have yet been constructed in North America. Thus, it is currently impossible to evaluate localized interactions between shorebirds and wind development in the OCS zone. However, within the last decade, a few small-scale coastal and island wind facilities have been installed along the northeast coast of North America, and are generating electricity. Additionally, as of late December 2010, 904 turbines (range: 1 - 100 per facility) are operating at 23 offshore facilities (sited > 5.6 km offshore) in Europe, generating a total of 2,391 megawatts (mW; range: 2.3 - 300 mW) of electricity (EWEA 2011). A small number of studies have been conducted at some of these offshore wind facilities in Europe and at a few coastal/island facilities in northeast North America to examine avian interactions with turbines. Results from these studies provide a broad assessment of the degree of risk shorebirds may face from wind development in the OCS zone (primarily from collisions).

3.2.2.1. North American Atlantic coastal and island wind facilities

We were able to locate study information for three operational wind facilities in coastal areas of eastern North America. Shorebirds likely frequent coastal areas more than offshore areas during most of the year (see 3.1 "Shorebird Occurrence"), so they might be expected to face greater exposure to coastal wind facilities than offshore wind facilities. Several of the same shorebird species found in the U.S. Atlantic region also occur in areas where these coastal wind facilities operate. The Jersey Atlantic Wind Farm began operating five turbines (7.5 total mW) along the coast of Southern New Jersey in 2005. Regular point counts and carcass surveys found that shorebird species are far less common than gull species near the facility, and noted that only three of 33 fatal turbine collisions were shorebirds compared with 11 gulls (1 Dunlin, 1 Short-billed Dowitcher, and 1 unidentified; N.J. Audubon 2008, 2009).

We examined two other coastal North American wind projects, both in Atlantic Canada. Pubnico Point Wind Farm operates 17 turbines (30.6 total mW) on the southern coast of Nova Scotia. No shorebird fatalities were documented during a two-year point count and carcass survey, despite the fact that 10 species of shorebirds were observed near operational wind turbines (Matkovitch 2007). On Sable Island, located 180 km southeast of Nova Scotia, five wind turbines (37.5 mW) have operated intermittently for the past several years. Sable Island hosts a number of shorebirds species including a small breeding population of Least Sandpipers. Only one shorebird fatality was documented within the vicinity of the wind facility, and the cause of death was unknown (Z. Lucas, Sable Island Green Horse Society, pers. comm.; USFWS 2008). Although monitoring has been sporadic at this remote location, carcasses of other avian taxa, such as seabirds, have been found in much greater numbers (A. Boyne, Canadian Wildlife Service, pers. comm., Z. Lucas, Sable Island Green Horse Society, pers. comm.).

3.2.2.2. European offshore wind facilities

Despite the increasing number of operational offshore wind facilities in Europe, we found few sources that examined avian interactions with turbines, and none that specifically examined shorebird interactions. The scarcity of published data likely reflects the difficulty of determining avian collision rates and observing avian behavior in the marine environment (Drewitt and Langston 2006, Snyder and Kaiser 2009). Some accounts, primarily literature reviews of waterfowl data, were available and are covered here. However, standardized avian monitoring protocols and detailed reporting metrics are lacking, making comparisons of avian risk across wind facilities problematic (Drewitt and Langston 2006, Kuvlesky et al. 2007). Existing quantitative estimates of collision risk with offshore turbines, based on observations at operational wind farms, were generally low for all species reported (Table 2). At the 72-turbine (166 total mW) Nysted Wind Farm in Denmark (10 km offshore), less than 0.02% of all birds observed within the facility's boundaries, using tower-mounted thermal imaging technology, collided with turbines. Another study found few shorebird interactions with an offshore German marine research platform, while monitoring it with a combination of radar and thermal imaging to predict collision rates at proposed wind facilities in the area (Huppop et al. 2006). Although 10% of calls captured with acoustic recorders were shorebird species (including Red Knots), only one of 442 observed collisions was a shorebird (Dunlin). A small number of sources gave descriptive estimates of low collision risks with offshore turbines, but did not include metrics (Table 2). Other studies noted that marine birds avoided offshore marine wind facilities when they were encountered (Noer et. al. 2000, Drewitt and Langston 2006). However, only one of the studies presented metrics to this effect. Guillemette and Larsen (2002) conducted research at Tunø Knob in Denmark, showing that Common Eiders were 80% less likely to use areas within 100 m of wind turbines, compared to areas that were 300 - 500 m away from turbines.

4. CONCLUSIONS AND RECCOMMENDATIONS

4.1. General Conclusions

This report offers a synthesis of current knowledge about shorebird use of the OCS zone based on available literature, the expertise of shorebird professionals, and the compilation and mapping of most available location data. Based on this information, we offer the following conclusions about shorebird occurrence, and the potential for interactions with offshore wind development in the region:

(1) Minimal information is currently available on shorebird occurrence and behavior within the OCS zone.

(2) Few shorebirds have been documented in the OCS zone, though several species may pass over or through it en-route to/from the coast during migration flights

(3) Most shorebird species (with the notable exception of phalaropes) should face a narrow window of exposure to wind turbines in the OCS zone compared to species that spend most of the year in offshore areas, such as seabirds and marine waterfowl.

(4) The window of exposure for shorebirds should primarily be migratory periods, when shorebirds are most likely to fly offshore. However, we stress that behavioral information and distribution data in the OCS zone are largely lacking for other seasons, particularly winter.

(5) Under ideal conditions, shorebirds should fly at altitudes well above the rotor swept zone during migratory flights. However, there is evidence for several avian species that flight altitudes are reduced during takeoffs and landings, bad weather, and poor visibility (fog, heavy cloud cover, etc.). Further work is needed to quantify the

reduction in shorebird flight altitude related to adverse environmental conditions, and determine how rapidly shorebirds ascend and descend from migratory altitude.

(6) If exposed to wind developments, shorebirds should have the behavioral capacity to regularly avoid turbines in their path, but this capacity will be reduced during poor weather and darkness.

(7) Substantial variability exists in shorebird occurrence and behavioral patterns within time and space, depending on species, environmental conditions (e.g., weather and time of day), season, micro- and macro-habitat characteristics, and physiology (e.g., age class, sex, and condition). This will result in variable risk of exposure and collision with turbines in the OCS zone.

4.2. Data Gaps

Occurrence data for shorebirds is limited in the U.S. Atlantic region, particularly in offshore areas. Data documenting interactions between shorebirds and offshore wind development in the OCS zone are not available because no offshore wind developments have yet been constructed there. We highlight several of the most prominent gaps in data needed to adequately evaluate interactions between shorebirds and offshore wind development:

(1) Offshore distribution and abundance of shorebirds.

• Offshore distributions (including migratory routes) and abundances of most shorebird species are entirely lacking, or are based on a few anecdotal observations.

• Data about seasonal variation in offshore distribution of shorebird species, and suites of species found in specific offshore areas are lacking (e.g., several shorebird species have been observed along the southeast coast of the U.S. during winter, but their use of the OCS zone is unknown).

• The effect of environmental variables, such as weather and time of day, on species distributions is not well understood within the marine environment.

(2) Offshore behavior of shorebirds.

• Offshore behavior, including flight altitudes (particularly after take-offs and before landings) and nocturnal flight patterns, are entirely lacking, or based on a few anecdotal observations for most shorebird species.

• Data about seasonal variation in offshore behaviors of shorebird species, and suites of species found in specific offshore areas, are lacking.

• The effect of environmental variables, such as weather and time of day, on offshore behavior is not well understood (e.g., Do migrating birds descend in altitude in response to storms?).

• Variation in offshore behavior (e.g., flight agility) among species and/or individual condition (e.g., age, sex class, fitness) has not been well examined.

(3) Shorebird interactions with offshore wind development.

• The risk of shorebird exposure to wind facilities in the OCS zone is unknown, due to a lack of long-term, systematically collected distribution and abundance data for shorebirds in the area.

• The risk of collision faced by shorebirds in the vicinity of a wind facility is not known, as rates of avoidance have not been collected for shorebird species found in the U.S. Atlantic region.

• Fitness consequences to shorebirds from avoidance of wind facilities have not been thoroughly examined for any species in either terrestrial or marine environments.

• Population-level impacts of shorebird displacement and/or collisions with offshore wind turbines have not been assessed, even in Europe.

4.3. Recommendations for Improving Understanding of Distribution and Behavior of Shorebirds in the OCS Zone

(1) Prioritize locations, species, and time periods to study.

Limited information on offshore distribution and population abundance is available for shorebirds in the U.S. Atlantic region. However, using a weight-of-evidence approach (Burger et al. 2010), even limited information can be used to determine which species and subspecies are most likely to be exposed to proposed wind developments in the OCS zone. A thorough examination of existing information may also identify which species/subspecies are most likely to be threatened by adverse affects of wind facilities at a population level (i.e., how abundant is the species/subspecies, what proportion of the total population could be exposed, and how resilient is the species/subspecies to decline?). Focal shorebirds should be those species/subspecies that are most exposed and at risk from a proposed wind development.

Focal study areas should include OCS locations where a high concentration of wind facilities are planned, where the greatest density and diversity of shorebirds are found, and/or where shorebird species of conservation concern are known to occur. New Jersey Department of Environmental Protection’s Wind Power Ecological Baseline Study (2010) serves a good example of a study area with multiple proposed wind facilities, and a high abundance and diversity of species, including species of concern.

Future research should be conducted during times of the year when species/subspecies are known to be present in the U.S. Atlantic region. For many shorebirds this would not include the breeding season. Research must also be of sufficient duration to account for variability in shorebird distribution and behavior. Although sufficient duration is likely to vary depending on species, location, and study objective, some authors have suggested a minimum avian monitoring period of three years associated with offshore wind development projects (Allison et al. 2008).

(2) Make the most of available information.

A thorough review of all existing distribution and behavior information for study species and locations of interest can guide future research and monitoring efforts, and be used to evaluate proposed methodologies (e.g., Burger et al. 2010, this study).

Additionally, geospatial analysis of existing shoreline and nearshore occurrence data and/or color-band resighting data may be of use in determining preferred shorebird migratory routes over large bays and inlets (C. Gordon, Pandion, Inc., pers. comm.). Wind facilities sited in water-bodies crossed annually by large numbers of migrating shorebirds could present a higher collision risk.

(3) Initiate studies using advanced monitoring and tracking technologies.

There are currently several technologies that can be used to monitor distribution and track movement of shorebirds to better understand their offshore occurrence and behavior. With these technologies, individuals can be monitored at all times, even during darkness and bad weather (periods when shorebirds likely face the highest risk of collision with turbines).

• RADAR AND OTHER REMOTE MONITORING DEVICES: Ship-board and coastal surveillance radar has been used to track bird movements for nearly half a century (e.g., Drury and Keith 1962). Modern surveillance radar tracking techniques (e.g., combination vertical-horizontal scanning units) can be used to detect individual birds and determine flight altitudes, although they are often unable to distinguish among species (Desholm et al. 2006). X-band tracking radar, which has been used widely in European bird tracking studies, allows the user to analyze wing-beat signatures for differentiating bird types, sometimes to species (Desholm et al. 2006, Bruderer et al. 2010, D. Mizrahi, NJ Audubon, pers. comm.), but lacks some of the benefits of surveillance radar. A third type of radar, doppler, has the capacity to identify fine-scale differences in bird flight velocity (Desholm et al. 2006). Depending on study objectives, radar technologies are probably most effectively for determining distribution of shorebirds and other birds in the OCS zone when used in combination. Radar can also be used to monitor post-construction offshore wind facilities.

Drawbacks to using radar to track birds in the marine environment include radar signal interference from refraction off of waves ("wave clutter") and rain, a poor capacity to detect slow or stationary (floating) birds, and the prohibitive cost of tracking radars (Kelly et al. 2009). Several recent advances in radar data processing techniques have been developed to reduce wave clutter and rain interference, and modifications to radar scanning techniques allow radar to better detect slow-flying or stationary individuals (Kelly et al. 2009). However, many of these techniques are proprietary and would require contracting consultants, which could raise costs. New radar technology, such as the solid state Kelvin-Hughes radar-antennae system, has been designed to reduce wave clutter (TetraTech 2011). Other radar technology has recently been developed to replace expensive tracking radar, without losing data-gathering capacity (e.g., analyzing wing-beat frequencies; Kelly et al. 2009). Renting radar systems may be a cost-effective solution to purchasing them, depending on the duration of anticipated use. As the use of radar in wildlife applications has increased in recent years, more companies have begun renting radar (e.g., DeTect, Inc.).

Remote thermal imaging devices have been developed in the last several years to monitor bird activity in the vicinity of operational offshore turbines in Europe. These devices are mounted to wind turbine towers to record collisions and determine flight altitudes of individual species, providing critical information for calculating avoidance rates and predicting collision risk (Desholm et al. 2006). Remote acoustic monitoring has also been used in marine environments to detect bird calls during migratory flight. This can provide information on the identity of birds moving over an area, and the frequency with which they are encountered in the area, even during darkness (Desholm et al. 2006). In 2010, Pandion Systems, Inc. (now Normandeau Associates, Inc.) designed a combination thermal imaging-acoustic detection monitoring system, which can be deployed in offshore areas (e.g., meteorological platforms) of the OCS zone to monitor the identity, density, and altitude of birds passing by (Pandion 2010). This information can be used to evaluate locations of future wind facilities in the OCS zone for interactions with birds. Successful pilot testing of the device in a coastal environment was completed in late 2010, and a project is currently underway to deploy the technology in the OCS zone.

• TAG TRACKING: Movement and distribution data of individual shorebirds can best be obtained with tag tracking technologies. Some of these technologies may also be used to determine the behavior of shorebirds that could expose them to wind turbines, such as flight altitudes and locations during migratory ascents and descents.

At 9.5 g, modern satellite tags are light enough to attach to large shorebirds such as whimbrels, oystercatchers, and godwits. Satellite tags transmit location data to an online server which can be downloaded and analyzed to understand movement pathways of individuals throughout the year.

Other technologies, such as geolocators, have been used to track shorebird species that are too small to be fitted with satellite tags. Geolocators record time-referenced light level data which can be analyzed to provide a near-continuous geographical record of an individual's location (Niles et al. 2010). Geolocators weigh only 1 g, allowing them to be attached to most shorebird species. Geolocator tracking has the drawback of requiring shorebird recapture to obtain data. This can be very difficult, unless birds are banded in areas of high inter-annual site fidelity, such as breeding grounds. Current geolocators are also unable to log altitude, an important metric for evaluating turbine collision risk. However, a new generation of geolocators is soon to be released with altitude-logging capability (L. Niles, Conserve Wildlife Foundation, pers. comm.).

Both satellite tags and geolocators are periodically subject to very large spatial errors (> 100km), which makes them less effectual tools for determining shorebird exposure risk at a site-based scale. One possible solution is a new, lightweight (~5 g) GPS tag (http://www.alanaecology.com/wildlife/MicroTraX_GPS_Tags.html) which has a high degree of precision. Like geolocators these tags would need to be recovered from birds to retrieve data, and their slightly higher weight makes them unusable on the smallest shorebirds.

Radio-telemetry has also been used to track offshore movements of birds (Green et al. 2002, Perrow et al. 2006). Radio transmitters are available in weights of < 0.5 g that could be used on the smallest shorebirds. Historically, birds had to be actively radiotracked by an observer. In offshore areas this required regular searches by aircraft or boat. More recently, however, automated radio telemetry receiving stations have been used to remotely log locations of transmitter-tagged birds in marine and coastal environments (e.g., Leyrer et al. 2006, Verkuil et al. 2010). Time-specific data obtained from arrays of automated radio telemetry receiving stations, strategically placed on offshore platforms, islands, and/or coastlines may be used to track flight paths of birds crossing large waterbodies or travelling offshore (e.g., Gulf of Maine passerine migration study, R. Holburton, University of Maine Orono, pers. comm.).

(4) Include shorebirds in offshore censuses.

Several published studies have recommended that focused aerial and boat-based bird surveys be conducted in the area where an offshore wind facility is being planned, as a component of a pre-construction assessment (Drewitt and Langston 2006, Kuvlesky et al. 2007, Allison et al. 2008). Surveys should be conducted throughout the year, and for a sufficient period of time to account for inter- and intra-annual variation in avian distribution patterns. Census data will identify locations where construction should be avoided due to high bird abundance and diversity, and/or the presence of sensitive species. It will also serve as a future reference dataset from which to evaluate changes in bird abundance and diversity in post-construction monitoring datasets. We recommend that shorebirds be included as part of any multi-taxa pre-construction survey effort.

To better understand shorebird distribution in the OCS zone, we also recommend that shorebird monitoring be included as a component of other marine surveys in the region (e.g., NOAA Fisheries Observer Program, Atlantic Marine Assessment Program for Protected Species), provided this effort does not detract from the primary objectives of those surveys. Observers could be informally trained to take abundance and GPS locations of all shorebird species encountered, following a simple standardized data collection protocol.

Data would be maintained in a centralized database (i.e., Offshore Atlantic Bird Compendium) and managed to insure long-term viability.

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Table 1. Population estimates (Morrison et al. 2006, B. Andres, USFWS, pers. comm.), conservation status (U.S. Shorebird Conservation Plan 2004), coastal and offshore U.S. Atlantic ranges by season (Poole 2010), rough estimates of coastal and offshore U.S. Atlantic abundance by season (Poole 2010, B. Andres, USFWS, pers. comm.), and common migratory paths (Poole 2010) of shorebird species and subspecies regularly occurring in the U.S. Atlantic region.

			U.S. Atlantic Range				U.S. Atlantic Abundance[b]				Migratory Path[c]	
Species / Subspecies	Pop.[a]	Status	Winter	Spring	Breeding	Fall	Winter	Spring	Breeding	Fall	Spring	Fall
Black-bellied Plover *Pluvialis squatarola cynosurae*	150↓	moderate concern	FL - MA	all states	*absent*	all states	large	very large	*absent*	very large	coastal (oversea)	coastal (oversea)
Amer. Golden Plover *Pluvialis dominica*	200↓	**high concern**	*absent*	all states	*absent*	NY - ME	*absent*	large	*absent*	very large	coastal (interior)	coastal (oversea)
Wilson's Plover *Charadrius wilsonia*	6	**high concern**	FL	FL - VA	FL - VA	FL - VA	very small	DD (mod?)	small	DD (mod?)	coastal (+Carib.)	coastal (+Carib.)
Semipalmated Plover *C. semipalmatus*	150	low concern	VA - NJ	all states	*absent*	all states	moderate	very large	*absent*	very large	coastal (oversea)	coastal & oversea
Piping Plover *C. melodus melodus*	2.9	**highly imperiled**	FL - NC	all states	NC - ME	all states	small	small	small	small	coastal (+Carib.)	coastal (+Carib.)
Amer. Oystercatcher *Haematopus palliatus palliatus*	11	**high concern**	FL - NJ	FL - MA	FL - MA	FL - MA	moderate	DD (mod?)	moderate	DD (mod?)	coastal	coastal
Black-necked Stilt[d] *Himantopus mexicanus mexicanus*	175	moderate concern	south FL	FL (small #s to DE)	FL - DE	FL - DE	moderate	large	moderate	large	coastal (+Carib.)	coastal (+Carib.)
American Avocet[d] *Recurvirostra americana*	450	moderate concern	FL - VA	*minimal*	NC - VA	FL - MA	moderate	small	small	moderate	coastal	coastal
Greater Yellowlegs[e] *Tringa melanoleuca*	100	moderate concern	FL - NY	FL - MA	*absent*	FL - MA	moderate	large	*absent*	large	coastal (+Carib.)	coastal (+Carib.)
Lesser Yellowlegs[e] *T. flavipes*	400↓	moderate concern	FL - NJ	all states	*absent*	all states	moderate	very large	*absent*	very large	coastal (+Carib.)	coastal (+Carib.)
Solitary Sandpiper *T. solitaria solitaria*	100↓	**high concern**	*absent*	all states	*absent*	all states	*absent*	large	*absent*	large	coastal & oversea	coastal & oversea
Willet[f] *Catoptrophorus semipalmatus*	250	moderate concern	FL - MA	all states	all states[d]	all states	moderate	very large	very large	very large	coastal & oversea	coastal & oversea
Spotted Sandpiper[g] *Actitis macularius*	150	low concern	FL - SC	all states	NY - ME	all states	small	very large	moderate	very large	interior (coastal)	coastal & oversea/TA
Whimbrel[h] *Numenius phaeopus*	66↓	**high concern**	FL - SC	SC - NJ	*absent*	FL - NJ	small	large	*absent*	large	coastal & oversea	oversea/TA (coastal)

Table 1. Continued. Population estimates (Morrison et al. 2006, B. Andres, USFWS, pers. comm.), conservation status (U.S. Shorebird Conservation Plan 2004), coastal and offshore U.S. Atlantic ranges by season (Poole 2010), rough estimates of coastal and offshore U.S. Atlantic abundance by season (Poole 2010, B. Andres, USFWS, pers. comm.), and common migratory paths (Poole 2010) of shorebird species and subspecies regularly occurring in the U.S. Atlantic region.

Species / Subspecies	Pop.[a]	Status	U.S. Atlantic Range				U.S. Atlantic Abundance[b]				Migratory Path[c]	
			Winter	Spring	Breeding	Fall	Winter	Spring	Breeding	Fall	Spring	Fall
Long-billed Curlew *N. americanus*	90↓	**highly imperiled**	FL - SC	*absent*	*absent*	*absent*	moderate	*absent*	*absent*	*absent*	*absent*	*absent*
Hudsonian Godwit[g] *Limosa haemastica*	70	**high concern**	*absent*	*minimal*	*absent*	NJ - MA	*absent*	*minimal*	*absent*	large	interior (oversea)	oversea
Marbled Godwit[g] *L. fedoa fedoa*	170↓	**high concern**	FL - NJ (small #s to MA)	FL (small #s to NJ)	*absent*	FL - MA	very large	DD (small?)	*absent*	DD (small?)	coastal	coastal (oversea/TA)
Ruddy Turnstone *Arenaria interpres morinella*	180↓	**high concern**	FL - MA	all states	*absent*	all states	moderate	very large	*absent*	very large	coastal (oversea)	coastal & oversea
Red Knot[i] *Calidris canutus rufa* *C. canutus roselaari*	20↓ 20↓	**highly imperiled**	FL (small #s to MA)	NC - MA	*absent*	NJ - ME	moderate	large	*absent*	large	oversea	oversea/TA
Sanderling *C. alba*	300↓	**high concern**	FL - NY (small #s to ME)	all states	*absent*	all states	large	very large	*absent*	very large	coastal (oversea)	coastal (oversea)
Semipalmated Sandpiper *C. pusilla*	2000↓	moderate concern	*absent*	all states	*absent*	*minimal*	*absent*	very large	*absent*	*minimal*	coastal	oversea/TA
Western Sandpiper[g] *C. mauri*	3500↓?	**high concern**	FL - NJ	*absent*	*absent*	FL - MA	large	*absent*	*absent*	very large	*absent*	coastal
Least Sandpiper *C. minutilla*	700↓	moderate concern	FL - NJ	all states	*absent*	MA - ME	large	very large	*absent*	very large	coastal	oversea/TA
White-rumped[g] **Sandpiper** *C. fuscicollis*	1120↓	low concern	*absent*	all states	*absent*	*minimal*	*absent*	large	*absent*	*minimal*	interior (coastal)	oversea/TA
Baird's Sandpiper[g] *C. bairdii*	300	low concern	*absent*	*minimal*	*absent*	FL - MA (mostly juveniles)	*absent*	*minimal*	*absent*	moderate	interior	coastal
Pectoral Sandpiper[g] *C. melanotos*	500↓?	low concern	*absent*	*minimal*	*absent*	FL - MA	*absent*	*minimal*	*absent*	very large	interior (coastal)	coastal (+Carib.)
Purple Sandpiper *C. maritima maritima* *C. m. belcheri*	25	moderate concern	SC - ME	SC - ME	*absent*	SC - ME	large	DD	*absent*	DD	interior (coastal)	interior (coastal)
Dunlin *C. alpina hudsonia*	225↓	moderate concern	FL - NJ	all states	*absent*	all states	very large	DD (mod?)	*absent*	very large	interior (coastal)	coastal

Table 1. Continued. Population estimates (Morrison et al. 2006, B. Andres, USFWS, pers. comm.), conservation status (U.S. Shorebird Conservation Plan 2004), coastal and offshore U.S. Atlantic ranges by season (Poole 2010), rough estimates of coastal and offshore U.S. Atlantic abundance by season (Poole 2010, B. Andres, USFWS, pers. comm.), and common migratory paths (Poole 2010) of shorebird species and subspecies regularly occurring in the U.S. Atlantic region.

			U.S. Atlantic Range				U.S. Atlantic Abundance[b]				Migratory Path[c]	
Species / Subspecies	Pop.[a]	Status	Winter	Spring	Breeding	Fall	Winter	Spring	Breeding	Fall	Spring	Fall
Stilt Sandpiper *C. himantopus*	820	moderate concern	*minimal*	FL - VA	*absent*	FL - NY	*minimal*	large	*absent*	very large	interior (coastal)	interior (coastal)
Buff-breasted[g] Sandpiper *Tryngites subruficollis*	30↓	**highly imperiled**	*absent*	*absent*	*absent*	NY - ME	*absent*	*absent*	*absent*	small	*absent*	coastal & oversea
Short-billed Dowitcher[j] *Limnodromus griseus hendersoni; L.g.griseus*	78↓ both subsp	**high concern**	FL - VA	FL - MA	*absent*	all states	small	large	*absent*	large	coastal & oversea/TA	coastal
Long-billed Dowitcher[g] *L. scolopaceus*	400	low concern	FL - NC	FL - NC	*absent*	FL - MA	large	moderate	*absent*	large	interior (coastal)	interior (coastal)
Wilson's Phalarope[g, k] *Phalaropus tricolor*	1500↓	**high concern**	*absent*	*absent*	*absent*	*minimal*	*absent*	*absent*	*absent*	*minimal*	*absent*	interior (coastal)
Red-necked Phalarope[l] *P. lobatus*	2500↓?	moderate concern	*minimal*	SC - ME	*absent*	NY - ME	*minimal*	very large	*absent*	very large	oversea	oversea
Red Phalarope[l] *P. fulicarius*	1250↓	moderate concern	*absent*	all states (far offshore)	*absent*	all states (far offshore)	*absent*	very large	*absent*	very large	oversea	oversea

[a] Population estimates **in thousands** of birds. Downward arrows indicate declining populations, and arrows with "?" indicate possibly declining populations.

[b] A rough estimate of coastal/offshore Atlantic abundance: very small (< 500 birds), small (500 - 2,500 birds), moderate (2,501 - 10,000 birds), large (10,001 - 50,000 birds), very large (> 50,000 birds), and data deficient "DD" (no information provided in BNA). Abundances in parentheses are a best guess, based on anecdotal information.

[c] Interior - primarily inland of Atlantic; Coastal - primarily along the Atlantic coast and nearshore; "+ Carib." - some migrate over Atlantic to the Caribbean; Offshore - primarily Atlantic offshore; Offshore/TA - high elevation transatlantic flights which skip U.S. Atlantic coast have been noted; parentheses indicate a less-common migration pathway.

[d] Mostly found in salt marshes, not nearshore or offshore.

[e] Low elevation migrants observed 80 - 130 km offshore.

[f] Population estimate includes western subspecies *C. s. inornatus* which uses U.S. Atlantic coast during migration.

[g] Most of the population of species occurs in areas other than the U.S. Atlantic coast and offshore waters.

[h] Two subspecies *N. p. hudsonicus* and *H. p. rufiventris* may use U.S. Atlantic region during migrations, based on recent satellite tracking data (B. Watts, unpublished data).

[i] *C. c. rufa* primarily found in U.S. Atlantic region during migration, and *C. c. roselaari* primarily found in U.S. Atlantic region during winter.

[j] Only *L. g. hendersoni* winters along U.S. Atlantic coast. During spring, *L. g. hendersoni* found from FL - NJ, and *L. g. griseus* from NJ - MA, with some transatlantic migrations noted . Historical records of large numbers of low-flying spring migrants "six miles out at sea".

[k] Mostly an interior species, associated with fresh water.

[l] Nearly entirely marine species. Large numbers congregate in Atlantic waters of south Canada and New England during migration.

Table 2. Quantitative and descriptive estimates of avian collision with turbines located in European waters, > 5.6 km off the coastline.

Bird type	Location	Collision estimate	Source[a]
Common Eider	Denmark[b]	no collisions observed[c]	Exo et al. 2003 (LR)
Common Eider	Sweden[d]	11 - 14 collisions/turbine/yr	Kuvlesky et al. 2007 (LR)
Migratory waterfowl	Sweden[e]	1 collision/~ 1.5M migrating birds	Drewitt and Langston 2006 (LR)
Waterfowl at sea	Denmark[f]	collision risk 0.9%/night, 0.6%/day	Desholm and Kahlert 2005 (P)
Gulls	U.K.[g]	collision risk = 0.18%/night[h]	Chamberlain et al. 2006 (LR)
All bird species	Denmark[f]	collision risk = 0.02%/study period	Snyder and Kaiser 2009 (LR)
Scoter	Denmark[d]	"little impact" from turbines	Kuvlesky et al. 2007 (LR)
Migratory eiders	Denmark[b]	collision unlikely,"turbines avoided"	Noer et al. 2000 (LR)

[a] LR - source is a literature review reporting on several field studies, P - primary source detailing study conducted
[b] Tunø Knob
[c] Unspecified timeframe
[d] Unspecified location
[e] Kalmar Sound
[f] Nysted
[g] Kentish Flats
[h] Modeled rate calculated from surrogate estimate of passerine avoidance rate

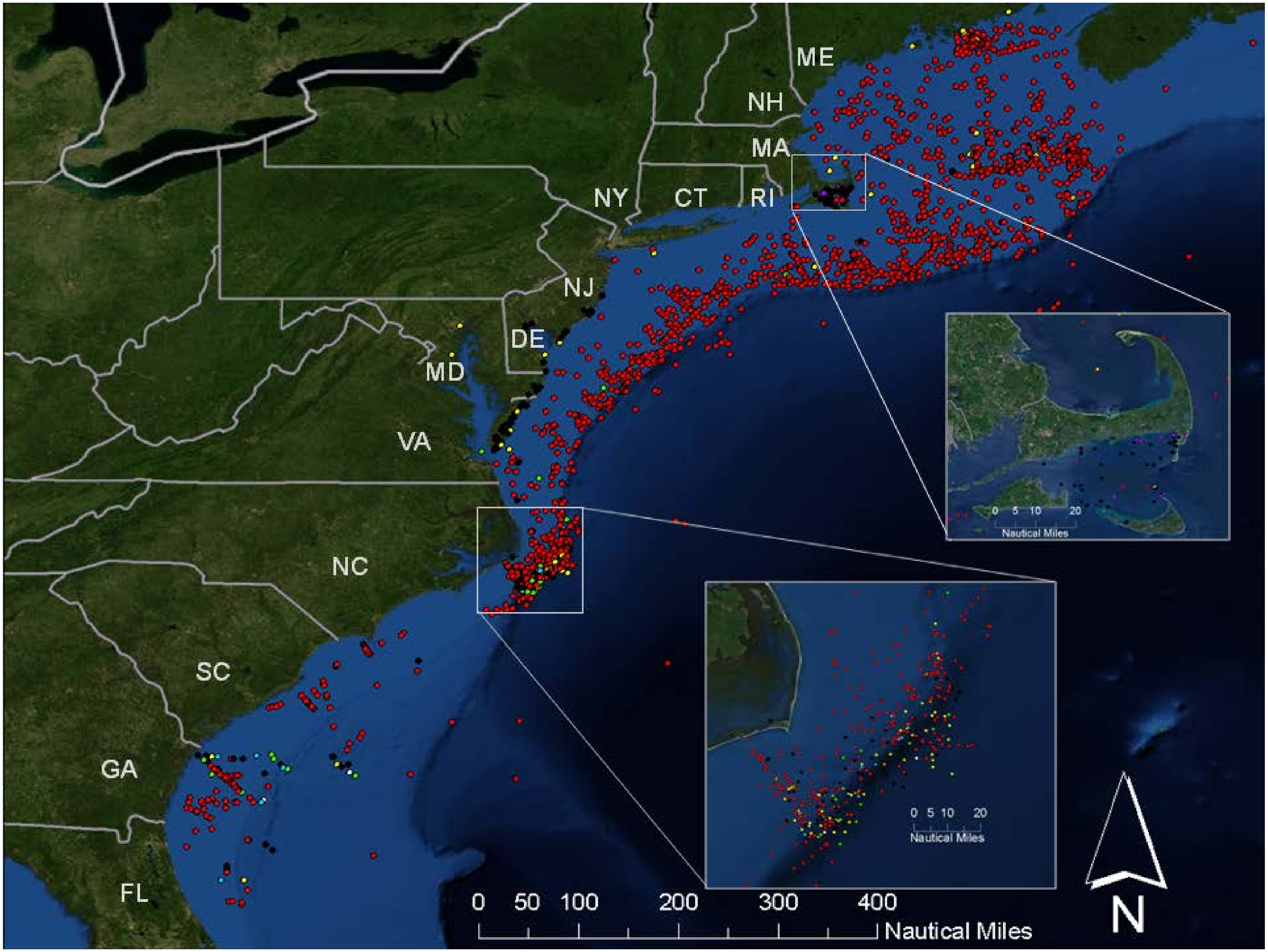

Figure 1. All shorebird locations from the Offshore Atlantic Bird Compendium (O'Connell et al. 2009). **Color key:** White = plovers (Black-bellied Plover, American Golden Plover, Wilson's Plover, Semipalmated Plover, Piping Plover); Purple = American Oystercatcher, Black-necked Stilt, American Avocet; Blue = Tringa sandpipers (Greater & Lesser Yellowlegs, Solitary Sandpiper, Willet); Orange = Whimbrel, Long-billed Curlew, Hudsonian & Marbled Godwits; Yellow = Calidrid sandpipers (Red Knot, Sanderling, Semipalmated Sandpiper, Western Sandpiper, Least Sandpiper, White-rumped Sandpiper, Baird's Sandpiper, Pectoral Sandpiper, Purple Sandpiper, Stilt Sandpiper); Green = Other sandpipers (Spotted Sandpiper, Ruddy Turnstone, Buff-breasted Sandpiper, Short-billed & Long-billed Dowitcher); Red = Wilson's Phalarope, Red-necked Phalarope, Red Phalarope; Black = unidentified shorebird species

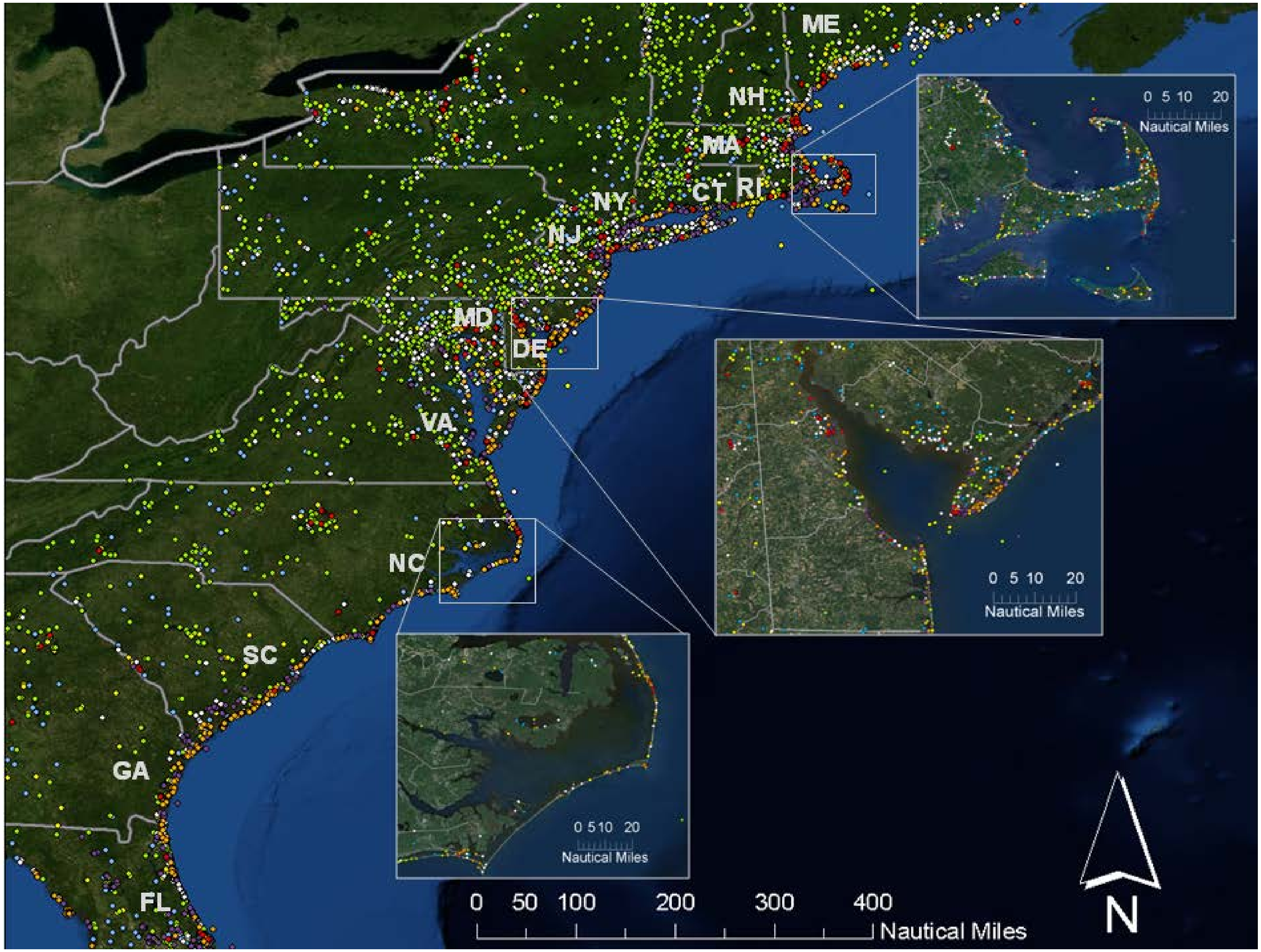

Figure 2. Locations of shorebirds in the U.S. Atlantic Region from the Avian Knowledge Network, 1990 - 2010. **Color key:** White = plovers (Black-bellied Plover, American Golden Plover, Wilson's Plover, Semipalmated Plover, Piping Plover); Purple = American Oystercatcher, Black-necked Stilt, American Avocet; Blue = Tringa sandpipers (Greater & Lesser Yellowlegs, Solitary Sandpiper, Willet); Orange = Whimbrel, Long-billed Curlew, Hudsonian & Marbled Godwits; Yellow = Calidrid sandpipers (Red Knot, Sanderling, Semipalmated Sandpiper, Western Sandpiper, Least Sandpiper, White-rumped Sandpiper, Baird's Sandpiper, Pectoral Sandpiper, Purple Sandpiper, Stilt Sandpiper); Green = Other sandpipers (Spotted Sandpiper, Ruddy Turnstone, Buff-breasted Sandpiper, Short-billed & Long-billed Dowitcher); Red = Wilson's Phalarope, Red-necked Phalarope, Red Phalarope