Offshore Wind Energy Development and Birds in New York: Managing risk and identifying data gaps

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1. Introduction

Offshore wind energy development (OWED) is being pursued in the United States, including New York, as a component of a carbon reduction strategy. Offshore wind energy is framed as an energy alternative with lower life-cycle adverse effects to the environment than fossil fuels (Ram 2011). Yet, the new structures pose potential hazards to wildlife, including birds, which may cause adverse effects. While these adverse effects are required to be described and mitigated for in the permitting process, there are substantial gaps in knowledge on how birds will respond to these novel structures. Managing the risk of OWED to birds and identifying data gaps that need to be filled is a critical need in both New York, and the United States in general.

The Department of Energy (DOE) has established a goal of generating 54 gigawatts (GW) of offshore wind energy by 2030. If the goal were met, then up to 9,000 turbines would be installed in U.S. oceans and Great Lakes. The Atlantic Ocean off of New York has the potential to produce 38 GW,[1] and according to the New York Ocean Action Plan "the tremendous wind potential located offshore in the New York Bight has shown promise as a significant source of renewable energy development for New York."[2]

Currently, in New York marine waters, New York Power Authority (NYPA) and Consolidated Edison (ConEd) are considering proposing a project 13 miles from Rockaway Peninsula south of Long Island. The project would have the potential to produce 700 megawatts (MW) through the installation of up to 194 3.6-MW turbines. NYPA submitted an unsolicited request for a commercial lease to the Bureau of Ocean Energy Management (BOEM)—the federal agency overseeing OWED development in federal waters. While BOEM determined that NYPA was qualified to hold the lease, other entities expressed interest in the area, leading to a "Call for Information and Nomination" by BOEM on May 28, 2014 for commercial wind energy leases in the New York Call Area (Figure 1). In addition, BOEM has filed a notice of intent to prepare an Environmental Assessment for the Call Area.[3] According to a recent correspondence with BOEM by Biodiversity Research Institute, the agency is still working on finalizing a Wind Energy Area (WEA) in New York, and the Environmental Assessment will likely be available for public comment in late spring or summer of 2016.

The South Shore Audubon Society and New York City Audubon received funding from National Audubon through the 2014 Energy Siting Grant program to study possible effects on avian species of the proposed Long Island—New York City Offshore Wind Project. Grant funds were used, in part, to develop this report that summarizes the adverse effects of OWED on birds, reviews documents relevant to New York, and offers suggestions on future studies.

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[1] http://www.nyserda.ny.gov/offshorewind

[2] http://www.dec.ny.gov/docs/fish_marine_pdf/oceanactionplan.pdf

[3] http://www.boem.gov/New-York/

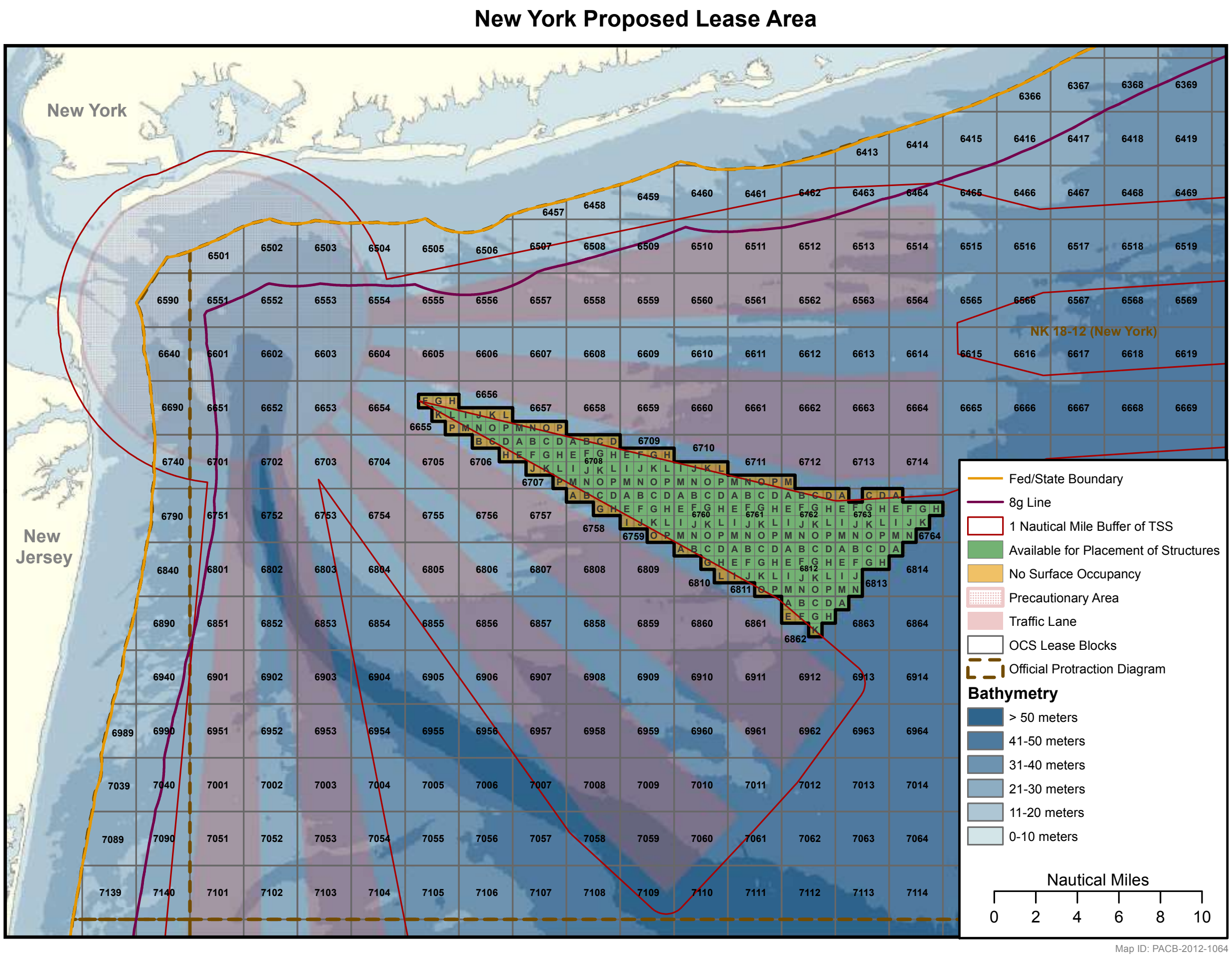


Figure 1. New York Call Area.[4]

[4]http://www.boem.gov/uploadedFiles/BOEM/Renewable_Energy_Program/State_Activities/NYPA%20Proposed%20Lease%20Area.pdf

2. Adverse effects of OWED on birds

The adverse effects of OWED on birds are direct, indirect, and cumulative.[5] Direct effects are mortality and injury caused by a bird colliding with the turbine structure; indirect effects are avoidance response leading to displacement and potential habitat loss (Fox et al. 2006). Cumulative adverse effects are the accumulation of adverse effects over time and space that lead to declines in population trends (Goodale and Milman 2014). For there to be a risk of adverse effects, *vulnerable* species must be *exposed* to OWED *hazards* (Crichton 1999, Goodale and Milman 2014) (Figure 2).

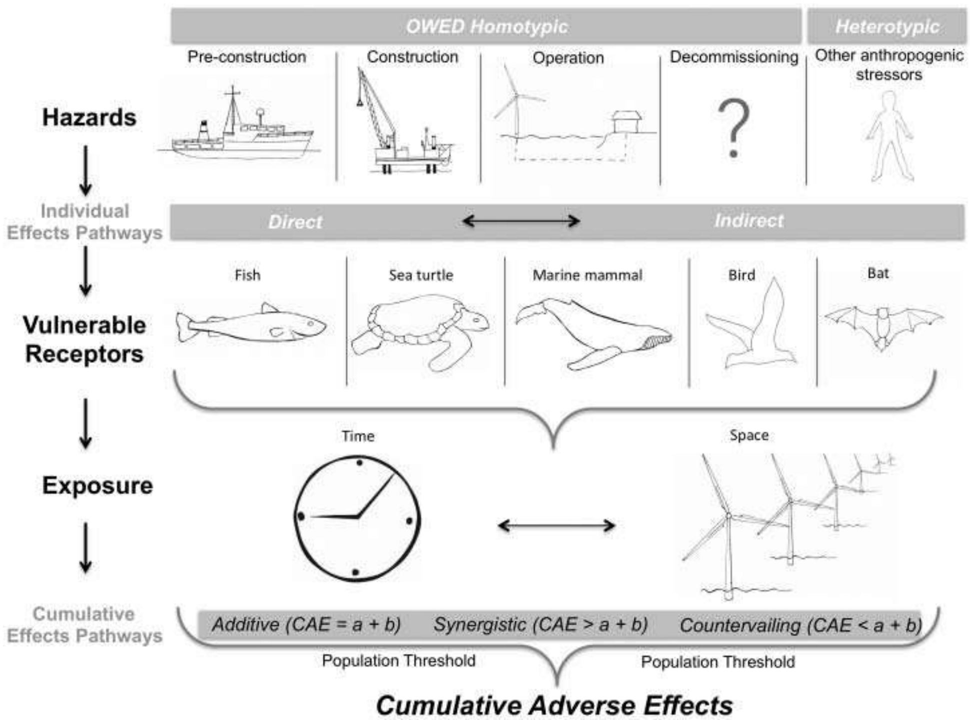


Figure 2. The direct, indirect, and cumulative effects of OWED on wildlife (Goodale and Milman 2014).

[5] *NOTE: Individual and population level effects:* Adverse effects occur to individuals (e.g., they are killed) and these individual adverse effects have the potential to accumulate to cause population level effects (i.e., cumulative effects). Most U.S. federal regulations specifically protect individuals (i.e., Migratory Bird Treaty Act and Endangered Species Act), but often agencies focus on managing populations. When seeking to understand risk of OWED to birds either quantitatively or qualitatively, it is important to specify if the risk is being considered on an individual or population level. Often in public discourse about the adverse effects of OWED on birds, there is a heuristic jump that individual effects will *de facto* have population level effects. In fact there is little to no evidence to date that OWED have caused population level effects. However, an important note is that with the exception of endangered species with small populations, there is substantial difficulty in relating any particular anthropogenic stressor to population level effects, and this task is often fraught with the necessity to make many assumptions. Given these challenges, understanding and mitigating adverse effects of OWED on birds is most realistic on the individual bird scale.

Many bird orders will be exposed to offshore wind energy developments (OWED), during breeding, migratory staging, migration, or non-breeding. However, life history differences between species will lead to variation in exposure; for example, perching birds (Passeriformes) will be exposed primarily during migration and loons (Gaviiformes) during wintering. While OWED pre-construction activities and construction may cause some collision mortality and displacement, population level impacts are likely low, and OWED's greatest effect on birds will likely be during operation.

2.1. Direct effects

The mortality from collisions is dependent on many different factors, including site, species, season, weather, and lighting. Collision risk for a particular species can vary depending on age, behavior, and timing within a breeding cycle (e.g., while feeding chicks) (Drewitt and Langston 2006). Collisions generally occur in three ways: birds can collide with (1) the superstructure, (2) the rotating turbine blades, or (3) are forced to the ground by the vortex created by the moving rotors (Drewitt and Langston 2006, Fox et al. 2006). For terrestrial wind farms in the U.S., there is estimated to be 234,000 (Loss et al. 2013) to 573,000 (Smallwood 2013) bird fatalities/year, and mortalities are often associated with specific turbines within a wind farm. Careful site selection, however, can significantly reduce potential adverse effects (Langston 2013).

Currently, avian fatalities from existing OWED are poorly understood. Low levels of direct mortality have been observed at most sites, though it is unclear whether these levels are representative of methodological challenges associated with detecting fatalities at OWED, or actually reflect low mortality rates. With the exception of a wind farm located directly adjacent to a tern colony in Zeebrugge, Belgium, where over 160 mortalities a year were calculated (Everaert and Stienen 2007), few direct mortalities have been observed at OWEDs. At Nysted, Denmark, 2,400 hours of monitoring with an infrared video camera detected the collision of one unidentified small bird (Petersen et al. 2006). One Common Eider (*Somateria mollissima*) mortality was observed at Yttre Stengrund, Sweden (Pettersson 2005). The number of seabirds estimated to be killed annually by the Bligh Bank wind farm (55 turbines) is as follows: Northern Gannet (*Morus bassanus*) 2, Common Gull (*Larus canus*) 2, Lesser Black-backed Gull (*Larus fuscus*) 42, Herring Gull (*Larus argentatus*) 7, Great Black-backed Gull (*Larus marinus*) 33, and Black-legged Kittiwake (*Rissa tridactyla*) 16. A model of collision risk with 10,000 hypothetical offshore wind turbines in North Sea estimated that 5,257 thrushes could be killed during one night when there was heavy migration. This same model predicted the 10,000 turbines would kill 1,046 seabirds annually—the majority of birds killed would be gulls (1,025) (Brabant et al. 2015).

2.2 Indirect effects

While direct collision mortality is the primary concern for terrestrial wind, behavioral response to OWED that leads to avoidance or attraction may have greater effects on birds in the offshore environment. Avoidance occurs through macro-avoidance (Langston 2013) and has been demonstrated by a 4.5-fold reduction in waterfowl flocks entering an OWED post-construction (Desholm and Kahlert 2005). The birds were more likely to enter the OWED at night but increased their altitude to avoid the turbines (Desholm 2006). This avoidance, however, only resulted in a small increase in energy expenditure (Masden et al. 2009). Avoidance behavior has also been documented for Black Scoter (*Melanitta nigra*), Northern Gannet, alcids (Lindeboom et al. 2011), Pink-footed Goose (*Anser brachyrhynchus*; Plonczkier and Simms 2012), Common Eider (Larsen and Guillemette 2007), loons (*Gavia* spp.; Lindeboom et al. 2011, Percival 2010), Tufted Duck (*Aythya fuligula*), Common Pochard (*Aythya ferina*), and Greater Scaup (*Aythya marila*; Dirksen and van der Winden 1998 *in* Langston 2013). In Belgium, seabirds have been shown to avoid wind farm areas and have the following decreases in abundance after a project was constructed: Northern Gannet 85%, Common Guillemot (*Uria aalge*) 71%, and Razorbill 64% (Vanermen et al. 2015). This avoidance may be a behavioral response to the visual stimulus (Fox et al. 2006). While macro-avoidance clearly reduces potential mortalities, OWED presents potential barriers to movement that could affect birds' flight paths during migration and daily movements (Drewitt and Langston 2006, Langston 2013). Avoidance behavior of wind projects particularly by loons and sea ducks can lead to permanent or semi-permanent displacement, resulting in *de facto* habitat loss (Langston 2013, Percival 2010, Petersen and Fox 2007); however, for some species this displacement may cease several years after construction as food resources, behavioral responses, or other factors change (Leonhard et al. 2013, Petersen and Fox 2007).

Habitat change caused by the hard substrate of the OWED can lead to indirect effects. The construction of OWED will have both a negative effect of direct loss of habitat and a positive effect with the gain of new habitat at turbine foundations and anti-scour protection. However, these direct habitat changes represent less than 5% of an OWED and are not considered to be significant (Fox et al. 2006). Cormorants (*Phalacrocorax* sp.) may be attracted to this habitat because of an increase in food resources, due to reduced fishing effort and newly available perching/loafing habitat, but research suggests gulls (Laridae) and terns (Sternidae) are not affected (Krijgsveld et al. 2011, Lindeboom et al. 2011). At Horns Rev, Denmark, gull and tern numbers increased at the OWED, and this may be due to being attracted to the increased boat traffic, new food resources, or new loafing habitat (i.e., perching areas) (Fox et al. 2006). In Belgium, numbers of Lesser Black-backed Gulls (*Larus fuscus*) increased by a factor of 5.3 and Herring Gulls by 9.5 (Vanermen et al. 2015). However, there can be inter- and intra-annual variation on the degree that birds interact with OWEDs. Lesser Black-backed Gulls are found to be present at differing levels per year, and the birds' use of the offshore environment was highest during chick-rearing and lowest before breeding and during incubation. In addition, the research found that males and females used the wind farm area differently, with males using the area more late in the breeding season (Thaxter et al. 2015). Overall, there appears to be a continuum of behavioral response to OWED, with some species completely avoiding installations, some being indifferent, and others being attracted.

In order for the risk of adverse effects to be understood for a particular species, guild (group of animals that utilize the same resource), or area, knowledge is needed on vulnerability, exposure, and hazard that are discussed in greater detail below.

3. OWED hazards to birds

The hazards are the changes to the environment caused by OWED during each development phase (i.e., pre-construction, construction, operation, and decommissioning). While pre-construction and construction activities have the potential to cause adverse effects to marine biota, the primary development phase that is a concern for birds is operation—at this time decommission activities are largely speculative. During operation there are two primary types of effects: direct effects from collision with the turbines, and indirect effects of displacement caused by macro-avoidance responses. Consequently, the hazard factors to consider for direct effects on birds are the turbines, support structures (i.e., meteorological towers and substations), and lighting which may attract birds; the hazard factor to consider for indirect effects is the overall physical footprint of a project.

3.1. Meteorological towers and buoys

In order to assess the wind resource and ocean conditions at a potential project site, a developer will need to install a meteorological tower or buoy. For the mid-Atlantic Wind Energy Areas (WEAs), a maximum of 12 towers and 25 buoys are predicted. The towers reach 90-100 m above mean sea level, and will have a mast that is a monopole or lattice structure (Figure 3). A tripod, steel jacket with three or four 0.92 m piles, or single 3 m monopole that is driven 7.5-30.5 m into the seafloor will support the deck. For example, the meteorological tower installed on Horseshoe Shoal for the Cape Wind project has three pilings, supporting a 60 m structure (BOEM 2012). The primary hazard posed by the towers would be the above-water lattice support structure.

Meteorological buoys are emerging as an alternative to towers to evaluate the wind, wave, and current resource at a proposed project site. Buoys may be used independently or in conjunction with towers, and BOEM predicts that two buoys would be used per lease. Buoy design would likely be similar to existing discus (10-12 m) and boat-shaped designs used by NOAA, and include a 16 m high spar (Figure 4). The largest buoy design expected would be 30 x 2 m. Installation will take approximately one day, and buoys will be moored using a combination of chain and 2,700-4,500 kg (~6.7 m x 6.7 m x 1 m in size) clump anchors. The total disturbed area, including boat and buoy anchors, will be approximately 73 m^2, with the greatest disturbance occurring during anchor deployment and removal (BOEM 2012). It should be noted, however, that to date there have been no buoys proposed to BOEM to assess the wind resource (BOEM 2014). Buoys are not likely to pose a hazard to birds.

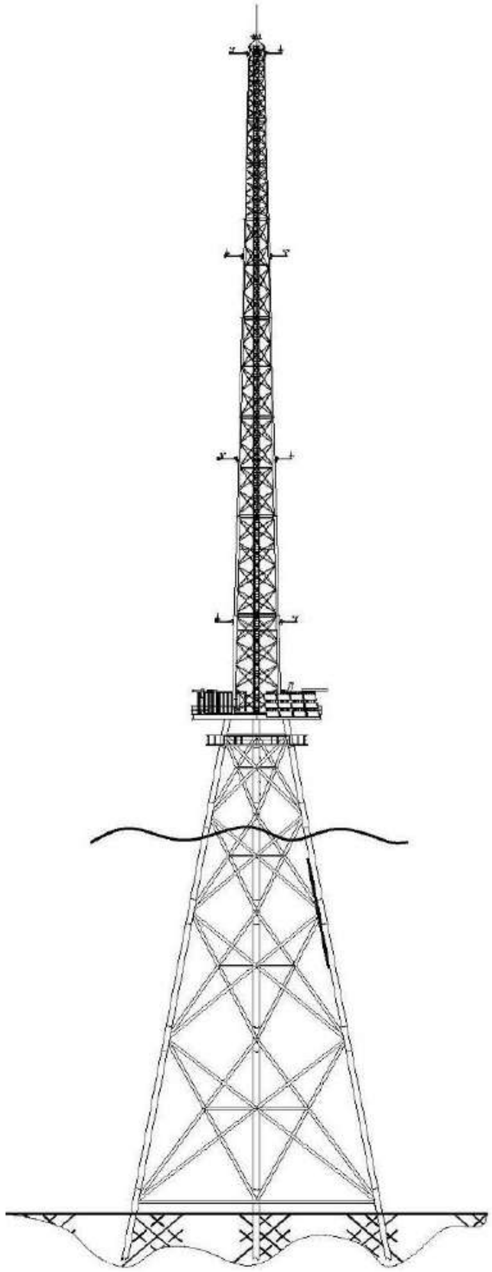


Figure 3.2(a) Example of a Lattice-type Mast Mounted on a Steel Jacket Foundation.
Source: Deepwater Wind, LLC.

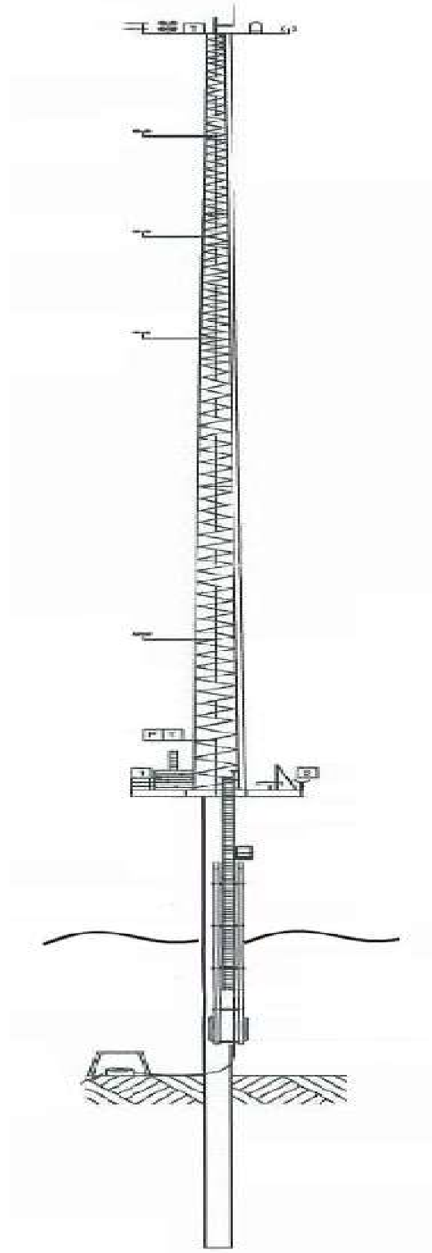
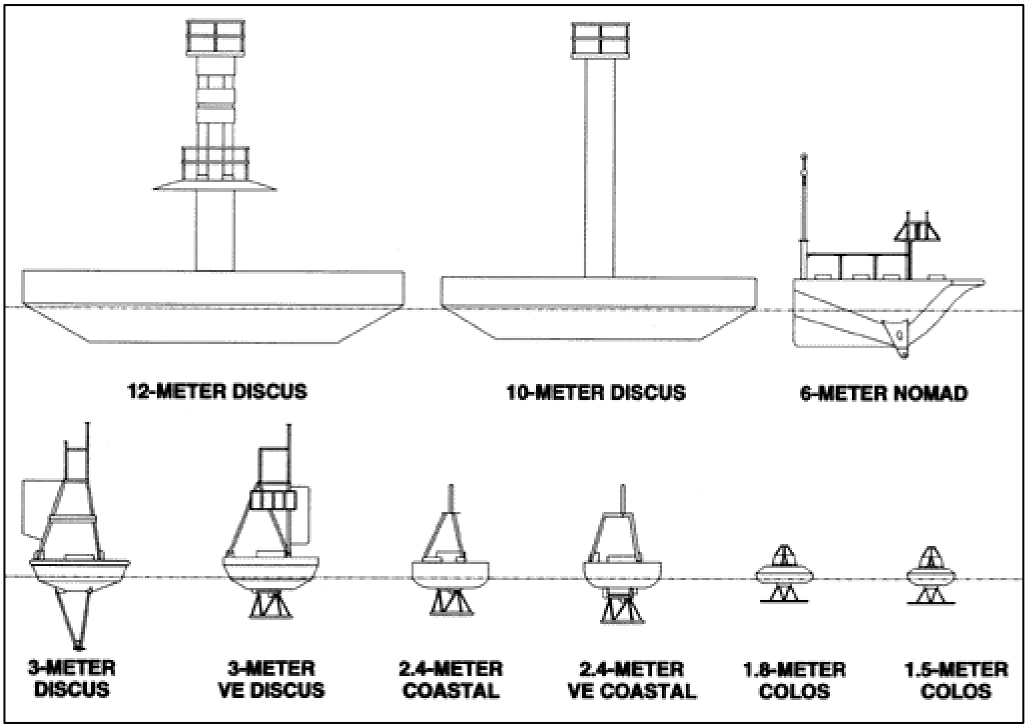


Figure 3.2(b) Example of a Lattice-type Mast Mounted on a Monopile Foundation.
Source: Fishermen's Energy of New Jersey, LLC.

Figure 3. Schematic of meteorological tower (BOEM 2012)



Source: National Data Buoy Center, 2008

Figure 4. Schematic of buoy (BOEM 2012)

3.2. Wind farms hazards

The hazards contributing to OWED posing the risk of direct and indirect adverse effects to birds are primarily the rotating blades and the monopole support, and the total area occupied by the wind farm. Existing wind farms in Europe are comprised of turbines ranging in capacity from 2-6 MW (4COffshore 2015, Breton and Moe 2009). Turbine capacity in the UK on projects under construction and pre-construction, or authorized and proposed is 6-8 MW (4COffshore 2015). In the U.S., projects under construction or proposed have turbines ranging in capacity from 3.3-6 MW. The proposed project by NYPA in New York would have a turbine capacity of 3.6-5 MW (4COffshore 2015). Given the continued advancement in turbine technology, a reasonable assumption is that a project built in New York marine waters would have a 5-6 MW capacity. A 5 MW offshore turbine is likely to have a rotor diameter of 126 m; a sweep area of 12,470 m^2; a hub height of 90 m; a cut-in wind speed of 3 m/s, rated speed of 11.4 m/s, and cut-out speed of 25 m/s; and a rated tip speed of 80 m/s (178 mph) (Jonkman et al. 2009). Siemens' direct drive 6 MW turbine (Figure 5) has a 154 m rotor diameter and a rotor sweep area of 18,600 m^2 (Siemens 2014); Alstrom's 6 MW turbine has a rotor diameter of 151 m, a swept area of 17,860 m^2, a hub height of 100 m, and a rated tip speed of 90.8 m/s (203 mph) (Alstrom 2014).

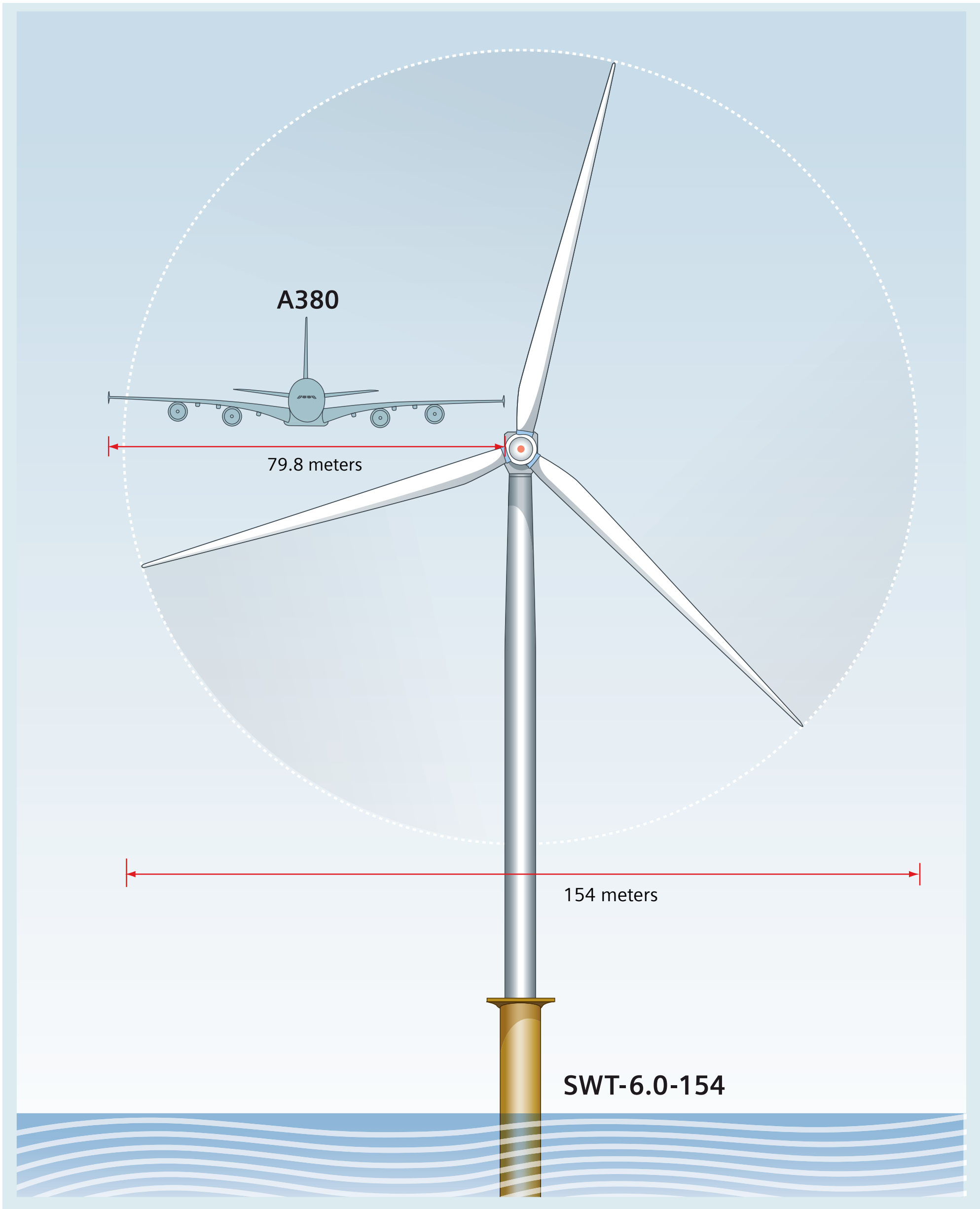


Figure 5. Example of a 6 MW monopile turbine (Siemens 2014)

Wind farm layouts require that wind turbines are spaced a sufficient distance from each other to reduce the wake effect (turbulence). While dependent upon the specific wind speed and direction at a project site, optimum spacing will be 6-10 rotor diameters apart, with 6-7 possible if wind speeds are greater than the rated speed of the turbine (Elkinton et al. 2008). The London Array—the world's largest wind farm—is comprised of 175 3.6-MW turbines, occupies 100 km^2,[6] and has 5.4-8.3 rotor diameter spacing (Nygaard 2014). The New York Call Area is ~330 km^2. A wind farm of 50 5-MW turbines spaced 9.5 rotor diameters apart (1.2 km) would occupy ~52 km^2, and 100 turbines would occupy ~117 km^2. Figure 6 shows the

[6] http://www.lorc.dk/offshore-wind-farms-map/london-array-1

potential area that could be developed in New York waters with the assumption that projects would not be built closer than 10 km to land because of visual impacts, and not further than 50 km because of additional costs in developing, maintaining, and delivering the power at greater distances. The shipping lanes have also been removed from the potential build out area. Each full block in the grid represents the approximate area that would be occupied by a 500 MW wind farm. Generally projects built at depths of 0-20 m will use monopiles; 20-45 m, jacket and gravity foundations; and deeper than 45 m, floating support structures (Figure 7).

Given an average turbine height of approximately 200 m [lowest blade tip above water[7] 27.4 m + 61.5 (NREL blade length) + 90 m (NREL hub height)=179 m], a 100-turbine wind farm would occupy an airspace of 23.328 km^3. The spherical volume occupied by the rotor swept zone of the 100 turbines would be 0.01 km^3. Thus, the percentage of airspace occupied by the rotor swept zone, assuming the rotors were spinning in all directions simultaneously, would be 0.4%, or 1/250th of the total project area.

In sum, for a 100-turbine wind farm, the hazard of the rotating blades would occupy 0.01 km^3 of airspace where birds may be at risk of direct effects caused by collision mortality or injury; and the hazard of the project on a whole would occupy ~120 km^2 where birds may be at risk of indirect effects caused by displacement.

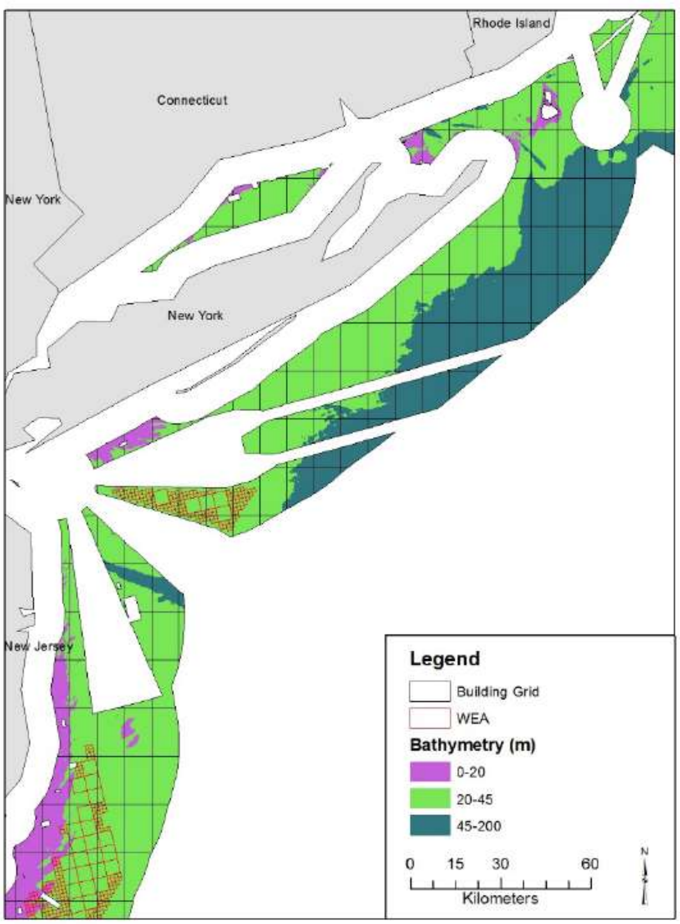


Figure 6. Potential areas for OWED build out in New York. Each full block represents the approximate area occupied by a 500 MW wind farm. The red/brown shading areas are Wind Energy Areas (WEA) identified by BOEM

[7] http://www.rwe.com/web/cms/en/413712/rwe-innogy/sites/wind-offshore/developing-sites/triton-knoll/the-offshore-array/

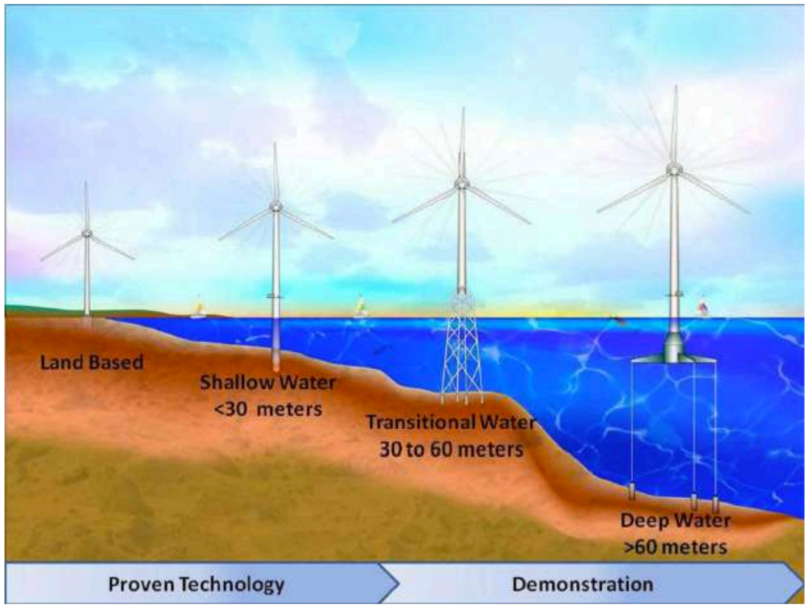


Figure 7. Types of OWED foundations by water depth.[8]

3.2.1. Lighting

While the structure of the turbine is a hazard to birds, that hazard can increase for birds if they are attracted to an OWED. Lighting can be one of the leading causes for attraction of migratory songbirds to wind farms (Langston 2013). Lighting at an OWED will be required both for aircraft and watercraft safety by the FAA and USCG respectively. The FAA regulations 14 CFW 77.17 require that any structure above 61 m (200 ft), which would include all OWED turbines, will require a study to determine the appropriate lighting scheme. The FAA guidelines for wind facilities (Chapter 13, Advisory Circular 70/7460-1K) state that the primary goal of lighting is for the wind farms to be visible to pilots, and that the nacelles of outer turbines be lighted at night with a recommended light of L864 flashing red lights with a median intensity of 2000 candela. The guidelines call for the lighting of each corner of a turbine array, and no lighting gaps greater than 0.8 km for perimeter turbines. While the guidelines do not specify that interior turbines have to be lit, they do recommend that if the distance across the OWED is greater than 1.6 km, then some of the interior turbines should be lit. All flashing lights must be synchronized (Orr et al. 2013).

The U.S. Coast Guard under 33 CFR 66 will categorize the meteorological towers, buoys, and turbines as Private Aids to Navigation and they will be required to have lights for navigation (BOEM 2012). 33 CFR 67 regulates marine navigation, and "all structures" will require red or white lighting at night. While each OWED will be evaluated individually and aspects of the regulations can be waived by the District Commander, the regulations suggest that OWED will require two white lights visible

[8] http://www.boem.gov/uploadedImages/BOEM/Renewable_Energy_Program/Renewable_Energy_Guide/Foundations.jpg

up to 5.5 km mounted on either side of a turbine at least 6 m above the water (Orr et al. 2013).

4. Avian vulnerability to OWED

In order for OWED to pose a risk to birds, the birds must be vulnerable to the hazards of the project described above. Vulnerability is species specific and is comprised of biological and sociological parameters. Biologically, species vulnerability includes both demographic and population sensitivity, as well as ethological factors (Figure 8). Birds have higher demographic sensitivity if they are long-lived, have high adult survival, and low reproductive success; for these species the sustained loss of adults has the potential to cause a decline in population growth rates. Birds have higher population vulnerability if their population is already declining and/or a large portion of the population is exposed to the OWED hazards (Goodale and Stenhouse *in press*).

Birds have higher ethological sensitivity if intrinsic behaviors increase exposure (e.g., flying within the rotor sweep area), or response behaviors lead to displacement and possible habitat loss. The most important factor determining a bird's collision risk is generally thought to be flight altitude (Furness et al. 2013). Research in the Netherlands indicates that 1.6 million birds pass through the Egmond aan Zee wind farm annually at the rotor swept zone between altitudes of 25-115 m (Fijn et al. 2015). Once the birds are within the rotor sweep area, micro-avoidance of the turbines is the primary factor determining collision rates. Changes in these predicted avoidance rates have a large influence on the output of collision risk models, and these rates change according to weather conditions, time of day, lighting, species, and life stage. Our current understanding of avoidance rates is so poor, however, that collision risk models cannot accurately predict collision mortality (Chamberlain et al. 2006).

Sociological factors include legal status, economic importance, and stakeholder interest. Each of these factors can independently elevate a species' vulnerability, and multiple factors can exist for some species that make them particularly vulnerable (e.g., flight at rotor height, long-lived, population in decline, listed as a species of concern) (Goodale and Stenhouse 2016). While existing vulnerability indices focus strictly on biological factors (Desholm 2009, Furness et al. 2013, Garthe and Huppop 2004, Willmott et al. 2013), sociological factors do become an important factor in how the risk of OWED is perceived to certain species. For example, gulls are considered by some as being nuisance species and are rarely considered a conservation priority, while other species, such as Northern Gannet or Red-throated Loon (*Gavia stellata*), receive much greater focus even though they all rank highly in vulnerability indices and are afforded the same level of legal protection under the Migratory Bird Treaty Act. In sum, birds will be considered to be at risk of adverse effects *only* if they are considered vulnerable.

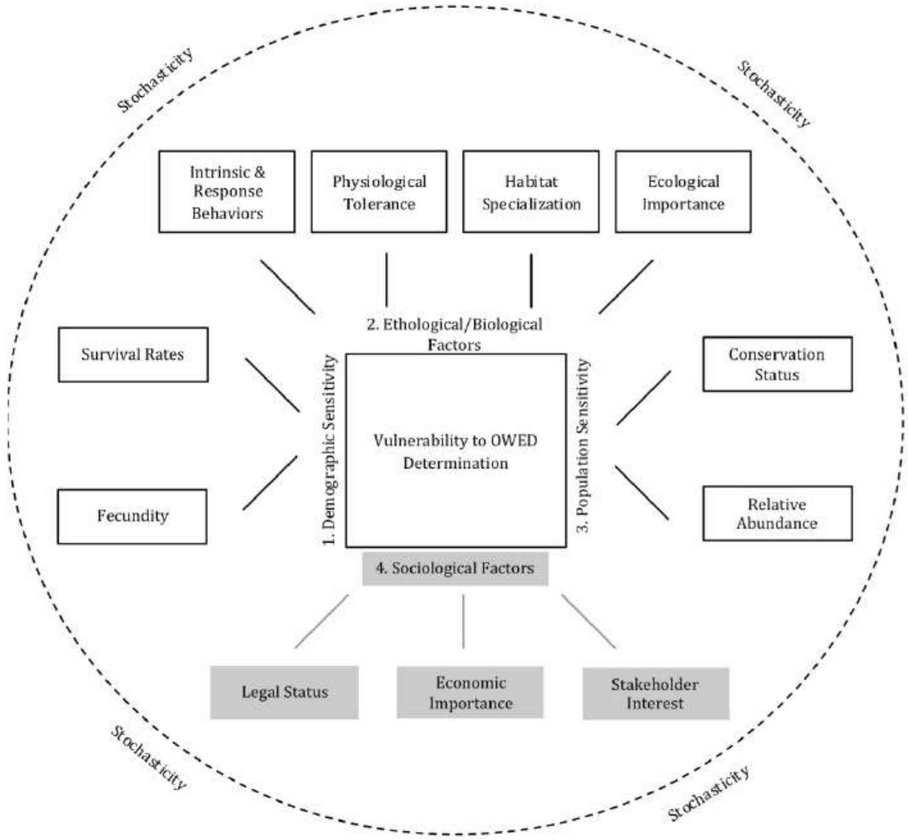


Figure 8. Factors influencing wildlife vulnerability to wildlife population (Goodale and Stenhouse, *in press*)

5. Exposure of birds to OWED

For vulnerable species to be at risk they must be exposed to the hazard. Exposure has both temporal and spatial components. Temporal exposure is measured by the duration that an individual bird is exposed to the project, with the life stage of the bird being particularly important (e.g., exposure during breeding, fall migration, or wintering). Temporal exposure includes the duration of sustained adverse effect as measured over the lifetime of the project (e.g., 30 years).

Spatial exposure includes the spatial scale of the population being affected, how the population is using the affected space, and the actual area where the effect will occur (Goodale and Milman 2014). The spatial component has a three-dimensional quality because some birds may be present at a project site but are flying below or above the rotor sweep zone and, thus, would not be exposed or vulnerable during fair weather conditions.

The exposure will be dramatically different depending upon the species, season, and environmental conditions. A project near a seabird colony might cause the birds to have to interact with the turbines multiple times a day while provisioning their chicks; in contrast, migratory songbirds may only be exposed to a project for a short time during one night. Exposure also has the potential to increase for migratory birds under high headwinds where they are forced down to lower altitudes, or during rain and fog. Lighting of the turbines can attract the birds and increase their collision risk. At an offshore wind research station in Germany, 50% of all mortalities occurred during two nights that had poor visibility due to mist and drizzle (Huppop et al. 2006).

6. New York birds and OWED

There are many different species of birds that could potentially interact with an OWED. The New York Bight is located along the Atlantic Flyway for migratory waterfowl, shorebirds, raptors, songbirds, and seabirds. Seabirds and waterbirds that use the New York Bight waters include sea ducks,[9] loons,[10] grebes,[11] cormorants,[12] shearwaters and petrels,[13] and Northern Gannet (NYSERDA 2010).

6.1. Seabirds and waterbirds

Adverse effects: OWED has the potential to cause both direct and indirect effects as described above. How birds in New York will interact with an OWED is unknown. However, based upon European research, terns and gulls may collide with turbines, and the wind farms may displace sea ducks and loons.

Exposure

Seabirds that utilize the New York Bight in federal waters [>3 miles (4.8 km)] include shearwaters, cormorants, petrels, fulmars, gannets, phalaropes, skuas, kittiwakes, gulls, jaegers, and auks. However, there is limited data on seabirds within the area being considered for OWED. During the summer, the relative density and abundance is lower when many of the birds are breeding in other locations. There are concentrations of birds around the Hudson Shelf Valley/Hudson Canyon as well as south and east of Montauk Point. Shearwaters and petrels are most abundant during the summer, and terns and gulls nest locally. There are higher densities of birds during spring and fall migration; these birds concentrate in the

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[9] Common Eider (*Somateria mollissima*), Surf Scoter (*Melanitta perspicillata*), White-winged scoter (*Melanitta deglandi*), Black Scoter (*Melanitta americana*), Long-tailed Duck (*Clangula hyemalis*)

[10] Common (*Gavia immer*), Red-throated (*Gavia stellata*)

[11] Red-necked (*Podiceps grisegena*), Horned (*Podiceps auritus*)

[12] Double-crested (*Phalacrocorax auritus*), Great (*Phalacrocorax carbo*)

[13] Northern Fulmar (*Fulmarus glacialis*), Cory's Shearwater (*Calonectris borealis*), Greater Shearwater (*Puffinus gravis*), Sooty Shearwater (*Puffinus griseus*), Manx Shearwater (*Puffinus puffinus*), Audubon's Shearwater (*Puffinus lherminieri*), Wilson's Storm Petrel (*Oceanites oceanicus*), and Leach's Storm Petrel (*Oceanodroma leucorhoa*)

shelf break near Block Canyon. In the winter, birds are observed through the entire continental shelf with concentration areas similar to those observed in the fall (NYSERDA 2010).

Substantial data was collected on seabirds in the New York Bight from 1980-1988, and then used to develop hotspot maps for individual species, and species groups. Table 1 shows the results from the surveys by season, showing that the most common birds were Herring Gull, Northern Gannet, and Great Black-backed Gull (*Larus marinus*). Figures 9-11 show a sum of species abundance, richness, and Shannon diversity index. Abundance is the sum of total individuals of all species, richness is the total number of species, and the Shannon index combines abundance and richness figures to show areas that have the highest overall species diversity (for more information on this index please follow link in footnote[14]). Abundance estimates show that close to shore there are more individuals, greatest richness appears in a band 50-150 km offshore where there is the intersection of the coastal and pelagic species, and the diversity index has the highest values off of Martha's Vineyard (Kinlan et al. 2012). *NOTE*: The New York Department of State Offshore Atlantic Ocean Study utilized these same models in their report.

Table 1. Species and species groups recorded by season in the 1980-1988 surveys (Kinlan et al. 2012)

SPECIES OR GROUP NAME	TOTAL N	N SPRING	N SUMMER	N FALL	N WINTER
Individually mapped species					
Black-legged Kittiwake	1,391	260	2	469	660
Common Loon	217	112	4	60	41
Common Tern	171	57	80	33	1
Cory's Shearwater	458	3	301	153	1
Dovekie	161	37	0	27	97
Great Black-backed Gull	2,172	788	176	587	621
Great Shearwater	951	33	502	407	9
Herring Gull	4,252	1,671	282	1,565	734
Laughing Gull	404	47	115	236	6
Northern Fulmar	392	228	43	45	76
Northern Gannet	2,302	1,142	9	537	614
Pomarine Jaeger	130	14	7	108	1
Sooty Shearwater	205	88	114	3	0
Wilson's Storm-Petrel	1,680	300	1172	207	1
Species groups					
Alcids, less common	147	80	0	5	62
Coastal Waterfowl	300	120	0	67	113
Jaegers	79	13	8	58	0
Phalaropes	294	247	7	36	4
Shearwaters, less common	196	16	93	87	0
Small Gulls, less common	210	53	3	110	44
Storm-Petrels, less common	225	46	126	53	0
Terns, less common	127	57	49	21	0
Unidentified gulls	291	55	19	163	54
Cormorants	66	13	9	21	23
Rare Visitors	42	18	1	11	12
Skuas, less common	36	12	2	11	11
Special category					
No birds sighted	2,299	511	847	812	129
Number of unique locations	***9,148***	***2,549***	***2,674***	***2,777***	***1,148***

[14] http://www.tiem.utk.edu/~gross/bioed/bealsmodules/shannonDI.html

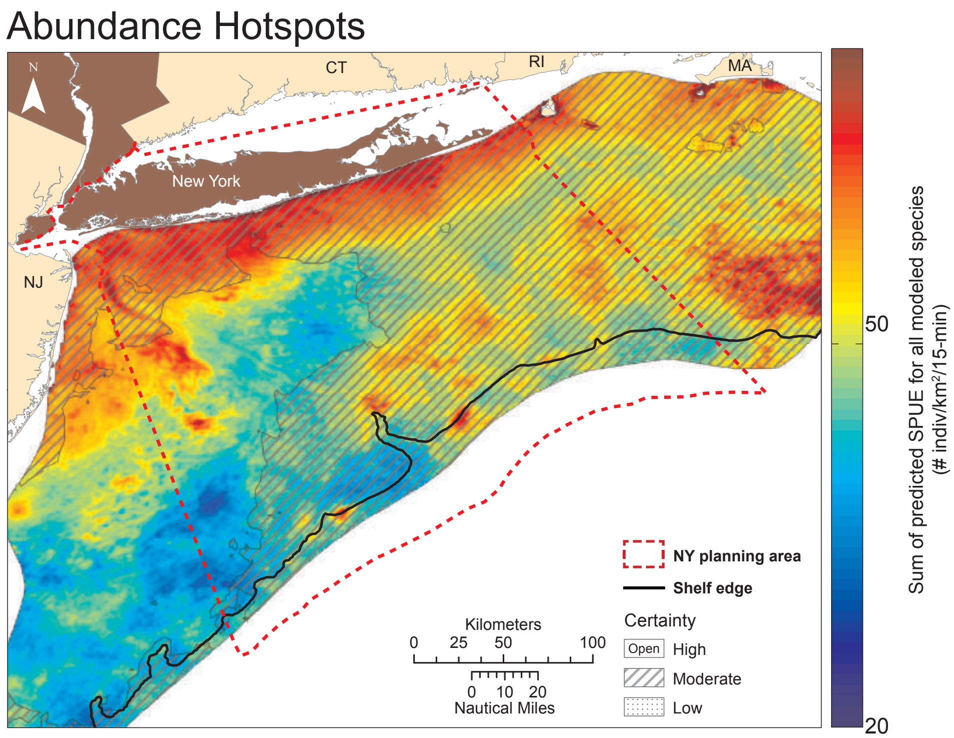


Figure 9. Predicted seabird abundance hotspot map (Kinlan et al. 2012). The certainty level refers to how certain the model output is based upon the underlying survey data.

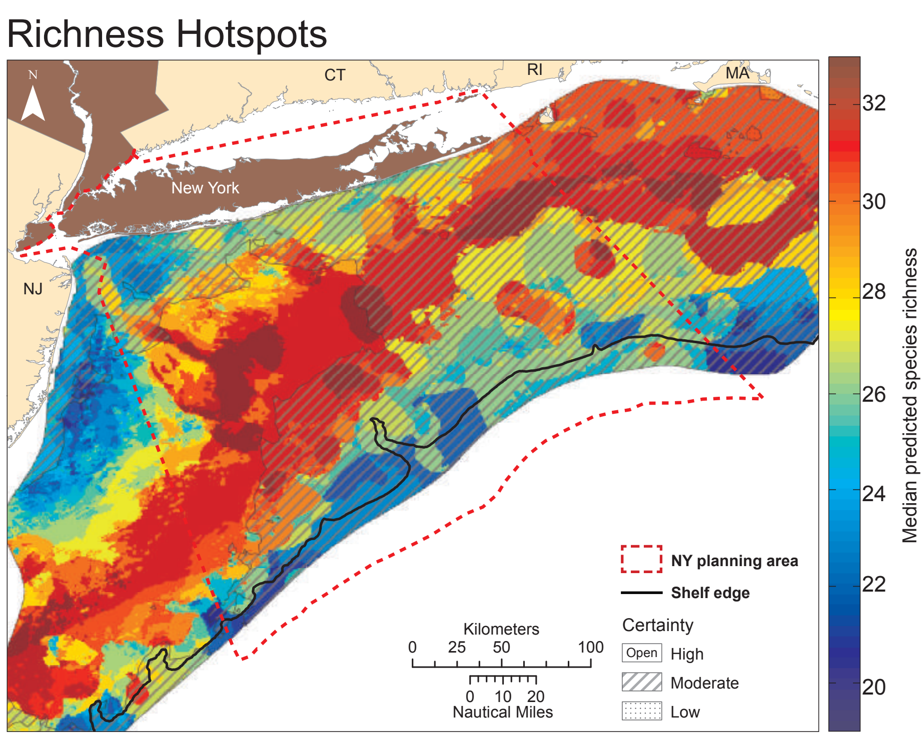


Figure 10. Predicted species richness hotspot map (Kinlan et al. 2012). The certainty level refers to how certain the model output is based upon the underlying survey data.

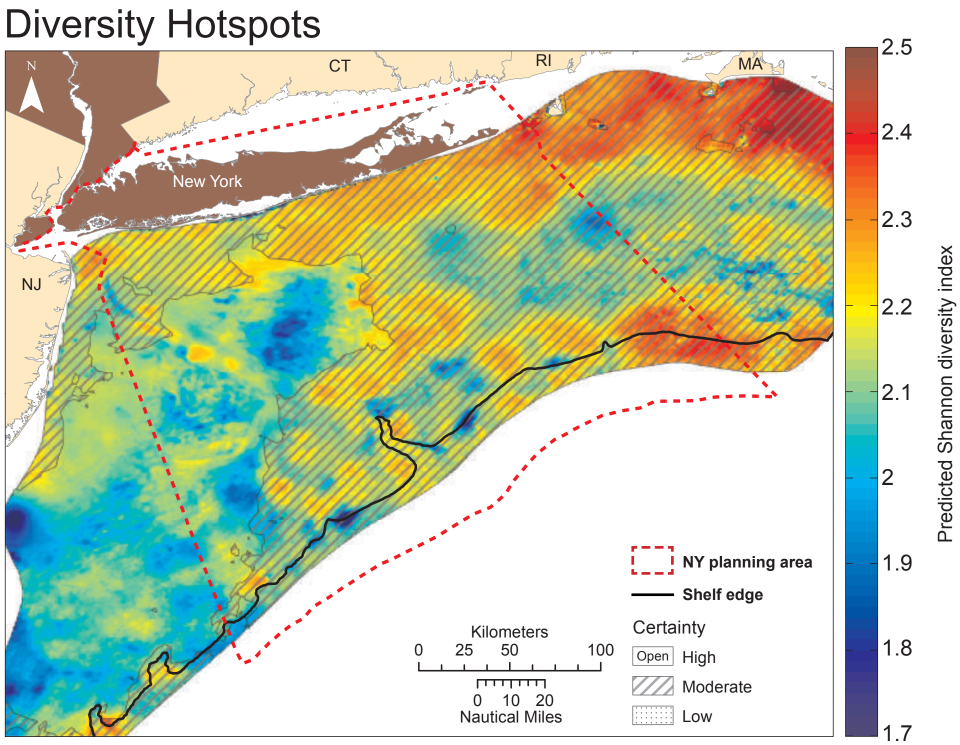


Figure 11. Predicted Shannon diversity index (Kinlan 2012)

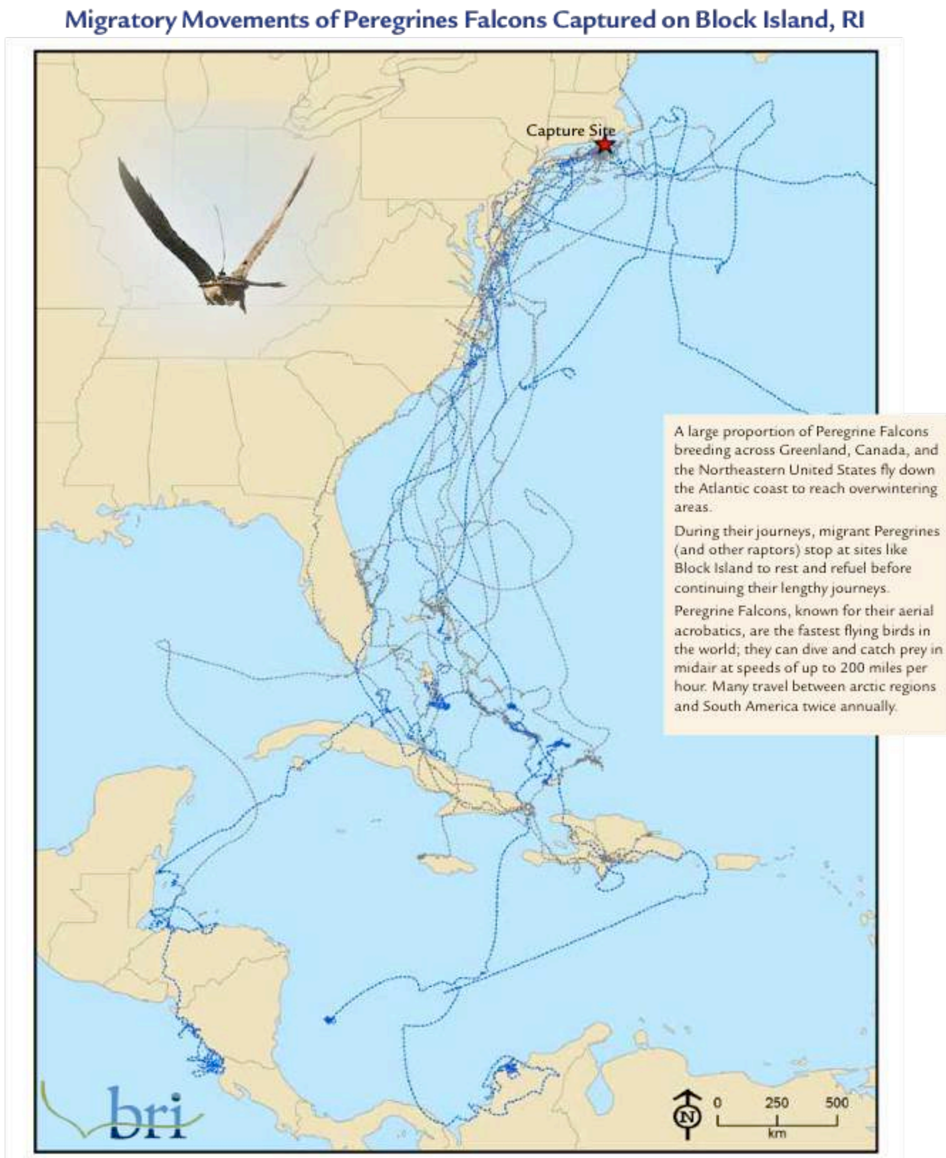
<u>Vulnerability</u>
For the Atlantic Outer Continental Shelf, gulls, phalaropes, cormorants, and jaegers are of high concern for collision risk. For displacement, sea ducks, loons, and some alcid species are considered most vulnerable (Willmott et al. 2013). In the Great Lakes, wintering and migratory waterbirds considered high priority were Canvasbacks (*Aythya valisineria*), scaup spp. (*A. marila/A. affinis*), Redheads (*A. americana*), Long-tailed Ducks (*Clangula hyemalis*), loons (*Gavia spp.*), and Red-breasted Mergansers (*Mergus serrator*), which ranked relatively high in three vulnerability categories and may overall have a higher vulnerability (Goodale, Morgan et al. 2014). Of the birds observed in the 1980-88 surveys in New York Bight (Kinlan et al. 2012), Furness et al. (2013) ranked Herring Gull, Great Black-backed Gull, Northern Gannet, and Black-legged Kittiwake (*Rissa tridactyla*) of highest collision risk, and Red-throated Loon, Common Loon, and sea ducks at highest risk of displacement.

6.2. Raptors

<u>Adverse effects</u>: While there is little data on how raptors will respond to OWED, they have been found in certain circumstances to collide with terrestrial wind turbines. How they will respond to OWED in the U.S. is unknown.

<u>Exposure</u>
Raptors routinely migrate along the coast of New York during the day. Falcons, Osprey (*Pandion haliaetus*), and Northern Harrier (*Circus cyaneus*) fly over water

and have been shown to fly from Fire Island Inlet to the New Jersey coast. Peregrine Falcons (*Falco peregrinus*), Merlins (*Falco columbarius*), and American Kestrels (*Falco sparverius*) have been observed flying over open water (NYSERDA 2010). Peregrine Falcons in particular have been shown to migrate over the New York Bight and to fly substantial distances offshore.[15]



Fall migration paths used by migrant Peregrine Falcons fitted with satellite transmitters on Block Island. Males (n = 4) are represented in blue and females (n = 8) are shown in gray. Peregrines used both inshore and offshore habitats along the mid-Atlantic U.S. states. After reaching North Carolina, many flew over open water to reach wintering areas in the Caribbean and Central and South America. Male peregrines tended to migrate further south compared to females, but sample sizes are limited (particularly for males). Photo by Ken Wright, Map by Jeff Tash.

Figure 12. Peregrine falcon migration. Results of satellite telemetry studies by Biodiversity Research Institute[16]

[15] http://www.briloon.org/uploads/BRI_Documents/Raptors/Raptors_Block_Island_Map_Insert_053014.pdf
[16] Ibid

Vulnerability
Flight height of migratory raptors can often be within the rotor swept zone (NYSERDA 2010). Peregrine Falcons, Merlins, and American Kestrel have a medium collision risk, and a lower displacement risk (Willmott et al. 2013).

6.3. Shorebirds and wading birds

Adverse effects: How shorebirds and wading birds will interact with an OWED is largely unknown, although they could potentially collide with the turbines during migration.

Exposure
Migratory shorebirds utilize the marine estuary, freshwater habitats, and adjacent uplands of the south shore of Long Island during breeding, migratory staging, and wintering. While phalaropes do forage offshore, most shorebirds are concentrated in beaches, tidal flats, and wetlands. In the spring and fall, Red-necked Phalaropes (*Phalaropus lobatus*) migrate through the New York Bight. At sea, the birds are associated with continental shelf-breaks, fronts, and upwellings. Red Phalaropes (*Phalaropus fulicarius*) spend eleven months in the marine habitats, and during migration are completely pelagic. There are nine species of egrets, herons, and ibis that nest on Long Island but they are only expected offshore during migration (NYSERDA 2010).

Vulnerability
Both Red-necked Phalaropes and Red Phalaropes are considered to have a high collision risk, and medium displacement risk (Willmott et al. 2013). During favorable conditions wading birds will fly above 150 m, but if they are flying into a headwind often fly below 150 m (NYSERDA 2010). Wading birds are considered to have a medium collision risk, and a lower displacement risk (Willmott et al. 2013).

6.4. Passerines

Adverse effects: Passerines have the potential to collide with offshore wind turbines during migration, particularly during periods of precipitation and poor visibility.

Exposure
Passerines will be potentially exposed to OWED during spring and fall nocturnal migration. Millions of passerines migrate through Long Island (NYSERDA 2010).

Vulnerability
Passerines typically migrate between 90-600 m (NYSERDA 2010), but can fly lower during inclement weather or with headwinds. Vulnerability can increase if there is substantial lighting of turbines or associated structures.

6.5. Endangered Species

Adverse effects: For the species described below (Table 2), collision mortality and injury would be the greatest risk.

Exposure
Table 2 lists the species of greatest conservation concern that are in the Mid-Atlantic/New England coast areas. Birds that are protected under the Endangered Species Act, which include Roseate Tern (*Sterna dougallii*), Piping Plover (*Charadrius melodus*), and Red Knot (*Calidris canutus*), will receive more focus during OWED permitting. Piping Plovers are expected to follow the coast during migration. Roseate Terns forage up to 30 km from breeding colonies, but on average forage closer to the colonies in water depths less than 5 m. Terns migrate primarily offshore (NYSERDA 2010). Until site-specific surveys or baseline data is collected, exposure of these species to a potential wind farm at any given location is largely unknown.

Vulnerability
Studies conducted for the Cape Wind project found that 90% of the terns flew 23-134 m above the water (NYSERDA 2010). The Roseate Tern is considered to have a higher collision and displacement risk; Red Knot and Piping Plover are considered to have a medium collision risk, and a lower displacement risk (Willmott et al. 2013).

Table 2. Birds of conservation concern that could be exposed to offshore wind in New York (Kinlan et al. 2012). NOTE: In addition to the table, Piping Plovers, which are listed as endangered by New York and threatened by US Fish and Wildlife Service, have the potential to be exposed.

Table 6.1. Birds of conservation concern identified by the U.S. Fish and Wildlife Service for the New England/Mid-Atlantic Coast (Bird Conservation Region 30 [BCR30]) and birds listed under the Endangered Species Act (ESA). Species shaded in grey are commonly observed greater than 10 km from shore.

Roseate Tern (*)	Buff-breasted Sandpiper (nb)
Red-throated Loon (nb)	Short-billed Dowitcher (nb)
Least Tern (c)	Pied-billed Grebe
Gull-billed Tern	Horned Grebe (nb)
Great Shearwater (nb)	Black Skimmer
Audubon's Shearwater (nb)	Short-eared Owl (nb)
American Bittern	Whip-poor-will
Least Bittern	Red-headed Woodpecker
Snowy Egret	Loggerhead Shrike
Bald Eagle (b)	Brown-headed Nuthatch
Peregrine Falcon (b)	Sedge Wren
Black Rail	Wood Thrush
Wilson's Plover	Blue-winged Warbler
American Oystercatcher	Golden-winged Warbler
Solitary Sandpiper (nb)	Prairie Warbler
Lesser Yellowlegs (nb)	Cerulean Warbler
Upland Sandpiper	Worm-eating Warbler
Whimbrel (nb)	Kentucky Warbler
Hudsonian Godwit (nb)	Henslow's Sparrow
Marbled Godwit (nb)	Nelson's Sharp-tailed Sparrow
Red Knot (rufa ssp.) (a) (nb)	Saltmarsh Sharp-tailed Sparrow
Semipalmated Sandpiper (Eastern) (nb)	Seaside Sparrow (c)
Purple Sandpiper (nb)	Rusty Blackbird (nb)
(*) ESA listed, (a) ESA candidate, (b) ESA delisted, (c) non-listed subspecies or population of Threatened or Endangered species, (nb) non-breeding in this BCR	

7. Mitigating adverse effects

The primary way to manage the risk of OWED on birds is through mitigation. The National Environmental Policy Act regulations' section 1508.20[17] defines mitigation as having the following components:

- Avoiding the impact altogether by not taking a certain action or parts of an action.
- Minimizing impacts by limiting the degree or magnitude of the action and its implementation.
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
- Compensating for the impact by replacing or providing substitute resources or environments.

In the context of OWED and birds, this report will focus on avoiding, minimizing, and compensating as these generally are the focus of mitigation efforts in environmental assessments. To manage the risk of OWED to birds, projects should first seek to avoid the hazard. If the hazard cannot be avoided, then every effort should be made to minimize the frequency, duration, and magnitude of the hazard. Finally, if the hazard cannot be avoided or minimized to a satisfactory degree, then adverse effects should be compensated for.

7.1. Avoid

Avoiding the exposure to hazard of OWED will be focused on macro-, meso-, and micro-siting decisions. Avoiding exposure will have both a spatial and temporal component, and will be focused on siting projects away from biological 'hotspots.' Hotspots are defined as an area that has a high relative abundance for one or more species, and/or an area that has high overall species diversity. Areas that are closer to the coast, upwelling areas, shoals, estuaries, river mouths, or highly productive embayments will generally have higher overall diversity and relative abundance. However, other areas may play particularly important roles for vulnerable species, such as migratory staging areas. Siting on a macro-scale will likely be most effective, while meso-scale may be difficult to assess. For birds, micro-siting will be most important if projects are being built in close proximity to the shore or nesting colonies. Offshore wind projects that have been built close to seabird colonies have had high rates of collision mortality (Everaert and Stienen 2007). However, an important note is that OWED will involve putting novel structures into the air and water that will directly change the environment—these structures are expected to have a lifespan of approximately 30 years. Birds will respond to this new element

[17] https://ceq.doe.gov/nepa/regs/ceq/1508.htm#1508.20

within the ecosystem and may be attracted to or avoid the projects. In addition, the marine system is a highly dynamic system that is constantly changing because of other natural and anthropogenic actions (e.g., climate change, fishing). Consequently, there is uncertainty on whether biological hotspots (and corresponding predicted cold spots) that are identified today will remain consistent through time, and that avoiding them would in fact reduce the exposure of birds to OWED hazards.

7.2. Minimize

Minimizing the risks of the OWED hazard will focus on reducing collision mortality. Potential measures include temporarily shutting down the turbines, reducing the motion smear (larger turbines will have less motion smear), increasing visibility, reducing lighting, and using deterrents (Cook et al. 2011). The most effective minimization options are altering turbine speed, temporary shutdown, reflectors, visual deterrence, lasers, and audible deterrence. The measures are species specific and should be tailored to species most vulnerable to collision. Deterrents that cause birds to move away from the wind project site have the potential to push the birds into suboptimal habitat, which may have an overall greater adverse effect than the loss of birds through collision. Given that sound attenuates with the square of distance, audible deterrents will be most effective close to the turbines (May et al. 2015). The Cape Wind project was directed to use perching deterrents, conduct oil spill planning, and have only the perimeter turbines lit at night (USFWS 2008).

7.3. Compensate

If the adverse effects at a project's site cannot be avoided or minimized, then compensation measures will be considered. Compensation should focus on increasing the survival rate of adults (primarily) and juveniles (secondarily) and/or increasing reproductive success. When adverse effects are experienced by migratory species, compensatory measures may be required to occur at a different geographic location from the OWED (e.g., at a breeding colony; Goodale and Milman 2014). Compensatory mitigation can be in-kind, direct replacement of lost resource, or out-of-kind replacement of biologically different resources than those that were lost. The level of compensation required will depend upon the efficacy of avoidance and minimization measures (USFWS 2012). Examples of compensatory mitigation for terrestrial wind is power pole retrofitting to reduce eagle electrocution mortality and lead abatement.[18] While there is little precedent in the U.S. for OWED mitigation, Cape Wind is being required by the state of Massachusetts to establish a $10 million fund to conduct predatory management to protect beach nesting birds, conduct population management of plovers and terns, identify plover and tern post-breeding staging and migration areas, and support a full-time coastal waterbird conservation assistant. In addition, USFWS requires that Cape Wind contribute $780,000 to a Roseate Tern habitat restoration project on Bird Island (USFWS 2008).

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[18] https://nationalwind.org/wp-content/uploads/assets/research_meetings/Research_Meeting_IX_Abstracts_By_Session6.pdf

8. Data gaps and recommendations

In the U.S. there are currently no operating offshore wind facilities, and an operating wind farm in New York waters is likely many years in the future. Consequently, new research cannot be conducted on birds responding to actual wind farms. Rather, research needs to be focused on understanding which species may be at risk to OWED, and methods to manage this risk. Research in Europe on OWED and birds has provided substantial information on how birds will respond to OWED. This knowledge can be used to focus research in New York. Overall, there are data gaps on which New York birds will be most vulnerable to OWED, the potential exposure of these vulnerable species to OWED, and the most effective methods to reduce the hazards of OWED—the recommendations below focus on these three factors.

8.1. Increase knowledge on vulnerability

Conducting research on birds over the ocean is exceedingly expensive and it will be nearly impossible to increase the knowledge base on how all species of birds in New York will be potentially exposed to OWED. From a practical perspective, focusing research on species suspected of being vulnerable to OWED will focus limited financial resources.

Therefore, I recommend that the following actions be taken to increase the understanding of species vulnerability in New York:

1. <u>Conduct a New York specific vulnerability assessment</u>: Determining vulnerability, like most aspects of OWED/bird risk assessments, is challenging because of the complexity of vulnerability and the uncertainty of how different species will respond to the wind farms. Yet, there is great value in developing a consensus list of species that professional biologists and stakeholders perceive to be most vulnerable. Developing a priority species list for New York should use a combination of qualitative and quantitative methods. See Goodale and Stenhouse (*in press*) for suggested methods.
2. <u>Assess existing knowledge on priority species and identify data gaps</u>: Once a vulnerable species group has been developed, a review of the literature could be conducted on these vulnerable species to refine the vulnerability assessment. The literature review will also help identify species-specific data gaps (e.g., flight heights, avoidance rates).
3. <u>Conduct field studies to fill data gaps</u>: Based upon the data gaps identified above, conduct field studies to increase knowledge of species-specific vulnerability factors.

8.2. Increase knowledge on exposure

In New York, there is a wealth of general knowledge on which seabird species are present in New York waters, and how abundance/richness/diversity changes by season—these data provide a resource on which species will likely be exposed to

OWED. However, the bulk of these data were collected during the 1980s and are now close to 30 years old. Data on the offshore movement of shorebirds, raptors, wading birds, and passerines is limited.

Currently, BOEM is finalizing the New York Wind Call area and will be conducting and Environmental Assessment of this area. This will be a significant step in formally identifying areas to be developed for offshore wind, and will be the primary driver of where development is considered. (*NOTE*: OWED can be proposed in any federal waters at any time and are not limited to areas established by BOEM). BOEM's establishment of the Wind Call area could be considered a macro-siting decision. Within the context of mitigation, questions should be asked during this macro-siting if there are areas under consideration that are avian 'hotspots' that could potentially be avoided. In order to model the location of 'hotspots,' baseline avian data is needed for not only the area being considered for development, but also reference areas within the New York Bight. Once a project is proposed, developers will likely be required by BOEM and USFWS to conduct two-to-three years of boat and potentially aerial surveys in the immediate development area, while it is unlikely they will be required to conduct broader contextual surveys.

Therefore, I recommend that baseline information should be collected on vulnerable species to aid in macro-siting decisions, and data to be used to put project site-specific surveys within a context. There are three basic methods to use to collect baseline data on birds:

1. <u>Conduct boat-based surveys</u>: Boat-based surveys are a customary approach to collecting avian data in the marine environment. Ideally, they should be conducted monthly, with a minimum of eight surveys per year (two per season). Surveys should be conducted for three years. Ten km spacing is a standard approach, although the area being surveyed and the level of funding available will dictate exact spacing. The advantage of boat surveys is that birds can generally be identified to species level, bird behavior can be recorded, and environmental covariate data (e.g., biomass, temperature, conductivity) can be simultaneously collected. Disadvantages include bird attraction/displacement, weather constraints, and reliance on individual observers.

2. <u>Conduct high-definition video aerial surveys</u>: High-definition video aerial surveys use two to four cameras to record video of strips of the ocean. Birds and other targets are then identified in the video. Advantages include being able to cover a larger area rapidly, not disturbing wildlife, and having a record of all the data, which can have a third-party audit. Disadvantages include lower species level identification rates, and less information to determine behavior. We do not recommend traditional visual aerial surveys because of the danger of flying low over open ocean.

3. Conduct individual tracking studies: Boat and aerial surveys provide a snap-shot of species diversity and relative abundance for a particular area, but the data cannot provide information on what the birds were doing before or after the survey. Satellite tracking of individual birds allows for highly detailed movements of individuals over multiple years. These data can be used *inter alia* to show how long individuals remain in particular areas, how they respond to weather, levels of site fidelity, and identify breeding, migrating, and wintering areas.

4. Analyze eBird data: An available data set that can be used to understand the presence of species by season is the eBird[19] database. These data could be analyzed to provide insight into the species that may be exposed to an OWED.

5. NEXRAD radar: Weather radar, Next Generation Radar (NEXRAD), is designed to detect precipitation but also can detect bioscatter (i.e., wildlife). NEXRAD is now used in biological studies and in particular can be used to study the timing and intensity of bird migration. An analysis of these data would provide information into when migratory birds (and bats) would be most likely to be exposed to an OWED.

8.3. Increase knowledge on reducing hazards

While research on the exposure of vulnerable species will aid in macro-siting decisions, there will also be a need to reduce the potential for adverse effects by increasing knowledge on effective mitigation practices.

Therefore, I recommend that research be conducted on methods to avoid and minimize the OWED hazards to the greatest degree possible as well as effective compensatory actions for unavoidable adverse effects. The following, while not a comprehensive list, are potential focal areas for research:

1. Avoid: identify biological hotspots
    a. *Model species habitat relationships*: Some birds will concentrate in particular areas because of specific habitat requirements. Spatially modeling the relationships between species and habitat requirements will allow the identification of particular habitats where species may consistently concentrate, and, thus, an area that development could avoid. Both survey and satellite telemetry data can be used.

    b. *Model relative abundance by species and season*: Exposure of species is going to vary substantially during different seasons. Modeling how species numbers fluctuate during different seasons will be critical in understanding individual species risk. These data could then be used to determine if certain areas have concentration of birds during

[19] www.ebird.org

critical life stages, such as breeding or migratory staging. Development could avoid these areas.

c. *Model biological diversity*: Some areas of the ocean may be important for some individual species, and other areas may be important to multiple species. Using new survey data (aerial and/or boat), methods used in Kinlan et al. (2012) could be implemented to determine areas of high species richness and diversity. Development could avoid these areas.

d. *Model persistence*: While modeling persistence requires multiple years of data, models of relative abundance, species richness, and diversity can be conducted with time series data to determine if particular areas have consistently high levels of avian activity. Development could avoid these areas.

2. Minimize: reduce the hazard
    a. *Reduce lighting*: One of the most important minimization efforts will be to reduce lighting during all phases of OWED, particularly during operation. Overall lighting should be reduced as much as is practicable. Direct communication with the FAA and USCG on lighting requirements, perhaps via a workshop, may be helpful in developing guidelines on lighting that would minimize the OWED risk to birds.

    b. *Research efficacy of curtailment*: Curtailment, ceasing of operation during bird migration, is commonly discussed as an important minimization method. However, more research is needed on the likelihood and efficacy of this method.

    c. *Research increasing visibility*: Methods have been suggested to increase the visibility of the rotating blades by coloring them with UV paint, by coloring one blade, or by using patterns and colors (Marques et al. 2014). How effective these methods are in increasing bird avoidance rates is unclear.

    d. *Research visual and audio deterrents*: Methods have been discussed to use visual (e.g., lasers) and audio (e.g., horn blast) deterrents to scare birds away from wind turbines. This technology can be passive (i.e., constantly working), or active (i.e., responding to targets detected on radar or cameras). More research is needed on developing new methods as well as testing the efficacy of existing technology.

    e. *Research methods for monitoring*: While not specifically focused on minimizing adverse effects, monitoring will be critical to understand if minimization efforts are effective, and to measure potential adverse effects. Monitoring bird mortalities over the ocean is very difficult;

consequently, research needs to be conducted on methods to detect and quantify mortality, particularly in poor weather conditions.

3. Compensate: compensate for mortality or reduced productivity
    a. *Increase knowledge on how to increase adult and juvenile survival*: While there will be challenges in determining actual mortality rates of vulnerable species, compensatory measures could be taken to reduce existing stressors on adults and juveniles. Compensatory actions may be separated both temporally and spatially from the OWED and will be species specific. An example would be to reduce the mortality from fisheries by-catch. New York specific research that identifies, ranks, and explores the efficacy of options for increasing adult and juvenile survival of vulnerable species would be critical to an overall mitigation strategy.

    b. *Increase knowledge on how to increase reproductive success*: Another method to compensate for lost individuals is to increase the reproductive success. Again, these efforts will be species specific but would be focused around breeding. Examples include predator control or increasing available nesting habitat. New York specific research that identifies, ranks, and explores the efficacy of options for increasing reproductive success of vulnerable species would be critical to an overall mitigation strategy.

9. Conclusions

The risk of adverse effects from OWED on birds is the combination of vulnerable species being exposed to OWED hazards. Research conducted in Europe provides information on cause/effect relationships, but how avian species that breed, migrate, and winter in the New York Bight will be adversely affected remains largely unknown. While accurately predicting adverse effects of OWED on birds will be challenging because of complexity and uncertainty, measures can be taken to reduce the risk through mitigation measures. Mitigation will focus on first avoiding bird concentration areas, second on minimizing the OWED hazard, and third compensating for potential direct and indirect effects. Effective mitigation is contingent upon robust information on which vulnerable species will be exposed to the development, the efficacy of minimization efforts, and compensatory actions that are proven to reduce mortality and increase reproductive success.

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