OCS Study
BOEM 2022-011

Supporting National Environmental Policy Act Documentation for Offshore Wind Energy Development Related to Avian Species Research

U.S. Department of the Interior
Bureau of Ocean Energy Management
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ABOUT THE COVER

Front cover: Roseate Tern and Northern Gannett photos courtesy of David Pereksta (BOEM).

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List of Abbreviations and Acronyms

BOEM	Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
COP	Construction and Operation Plan
DOI	U.S. Department of the Interior
ESPIS	Environmental Studies Program Information System
FAA	Federal Aviation Administration
MW	Megawatt
NEPA	National Environmental Policy Act
NM	Nautical Mile
NOAA	National Oceanic and Atmospheric Administration
OCS	Outer Continental Shelf
OWF	Offshore Wind Facility
U.K.	United Kingdom
U.S.	United States
USFWS	U.S. Fish and Wildlife Service
VHF	Very High Frequency
WEA	Wind Energy Area

Executive Summary

A growing number of U.S. offshore wind leases are coming available in the Atlantic Outer Continental Shelf (OCS). With this, offshore wind projects are developing Construction and Operation Plans (COP) for the Bureau of Ocean Energy Management (BOEM), and National Environmental Policy Act (NEPA) analyses are being conducted. Project stakeholders, nonprofit organizations, and the public are also showing increasing interest in impacts to avian species from offshore wind. Impacts from offshore wind energy on avian species generally result from the following two aspects:

- Location—where the offshore wind facility (OWF) is located in relation to avian species. This includes proximity to shore and migration pathways—long distance seasonal migration (fall-spring) or movement between onshore and offshore habitat such as feeding areas.
- Turbine size—specifically, the distance from sea level to the span of the turbine blades. Avian species that fly below or above this area will have fewer collision-related impacts than those that fly within the same airspace as turbine blades.

To assist in understanding the aspects of avian research in the U.S. and Europe in relationship to OWFs, it is helpful to understand the progression of offshore wind energy in both places. Therefore, this paper provides a brief history of offshore wind in Europe and the U.S., specifically in the Atlantic OCS. The differences between the U.S. and Europe offshore wind development are described in Section 2. The differences in the development of offshore wind between Europe and the U.S. are important to understand when using the European experience to design avian research projects in the U.S. and conduct impact analyses of offshore wind on the OCS.

Offshore wind in Europe began in the 1990s when turbine technology was smaller and produced less energy compared to modern designs. These smaller turbines rotate faster than larger turbine technology planned for use in the United States (U.S.). European wind facilities were initially developed closer to shore (10-20 km) and with turbines spaced closer together (700 -1000 m) than modern wind facilities (Wind Europe, 2020). In comparison, offshore wind in the U.S. came online in 2016, when technology evolved to larger turbines and greater spacing. While there are only seven offshore turbines, they are larger than any used in the 20th Century. The design and location of existing and future U.S. offshore wind facilities differ in many ways. These differences make comparison of potential impacts to avian species from offshore wind between the U.S. and Europe unequal and often misleading.

A literature review and summary of avian research and potential impacts of offshore wind from Europe U.S. is provided in Section 3. Both the U.S. and Europe recognized the importance of baseline studies, especially when determining impacts from OWFs. Avian studies and research on the effects of offshore wind in Europe began during and following the first offshore wind facility in the 1990s. Over the decades, research has been conducted based on the smaller turbines with locations closer to shorelines. In comparison, the volume of avian research in the U.S. conducted years, even decades, prior to leasing and development of offshore wind has provided BOEM the ability to proactively determine where avian species may be affected and plan accordingly. The application of mitigation and other best practices, as discussed in Section 4, further helps to protect birds from direct and indirect effects of offshore wind energy.

Overall, the most important factors to consider for offshore wind and avian impacts include the following:

- Location of OWFs is critical in avoiding impacts to avian species.
- The ability to accurately determine species space use within and migration patterns through a proposed OWF site is key to ascertaining if the location of wind turbines may result in impacts to avian species.
- Use of the best available data, especially when determining avian density, habitat associations and feeding ecology within a proposed OWF, is the most important factor to consider in providing the greatest protection for avian species.

1 Introduction

Offshore wind is a relatively new and growing industry in the United States (U.S.). In Europe, offshore wind development began in the early 1990s, more than a decade earlier than in the U.S. Similarly, research, studies, and analysis of direct impacts to avian species from offshore wind in Europe have been conducted for a longer period of time. A growing number of U.S. offshore wind leases are coming available in the Atlantic Outer Continental Shelf (OCS). With this, offshore wind projects are developing Construction and Operation Plans (COP) for the Bureau of Ocean Energy Management (BOEM), and National Environmental Policy Act (NEPA) analyses are being conducted. Project stakeholders, nonprofit organizations, and the public are also showing increasing interest in impacts to avian species from offshore wind.

Impacts from offshore wind energy on avian species generally result from the following two aspects:

- **Location**—where the offshore wind facility (OWF) is located in relation to avian species. This includes proximity to shore, breeding colonies, feeding areas, and migration pathways—long distance seasonal migration (fall-spring) or movement between onshore and offshore habitat such as feeding areas.
- **Turbine size**—specifically, the distance from sea level to the span of the turbine blades. Avian species that fly below or above this area will have fewer collision-related impacts than those that fly within the same airspace as turbine blades.

To assist in understanding the aspects of avian research in the U.S. and Europe in relationship to OWFs, it is helpful to understand the progression of offshore wind energy in both places. This paper provides a brief history of offshore wind in Europe and the U.S., specifically in the Atlantic OCS. As an early adopter of offshore wind, the progression of the offshore wind industry in Europe can be observed in the growth in size of wind facilities and turbine technology advances from the early 1990s to present day. Conversely, the first OWF in the U.S. began generating electricity in 2016.

The differences between the U.S. and Europe offshore wind development are described in Section 2. The differences in the development of offshore wind between Europe and the U.S. are important to understand when using the European experience to design avian research projects in the U.S. and conduct impact analyses of offshore wind on the OCS. A literature review and summary of avian research and impacts of offshore wind from Europe and potential impacts in the U.S. follows in Section 3. Both the U.S. and Europe recognized the importance of baseline studies, especially when determining impacts from OWFs. Avian migration patterns, flight height, habitat associations, and species seasonal density estimates are topics of growing interest and research development over the past 20 years. By understanding where avian species occur, which offshore locations are most important for life histories, and determining flight height and flight paths, impacts to avian species from offshore wind can be effectively reduced. As additional data is collected, future offshore wind projects can potentially be developed with fewer impacts to avian species.

2 Offshore Wind

Offshore wind in Europe and the U.S. has evolved quite differently, which has influenced avian research in the U.S. across the Atlantic. In order to bring context to the structures being studied in avian research and offshore wind, a brief history of offshore wind is provided in this section. In 1991, Ørsted constructed the first OWF off the coast of Vindeby, Denmark (Orsted, 2019). The Vindeby Offshore Wind Farm is comprised of 11 turbines generating a total of 5 megawatts (MW), or enough power to cover the annual consumption of 2,200 Danish households (Orsted, 2019). Deemed as a successful pilot project, OWFs have since spread throughout northern coastal Europe over the last three decades. Turbine technology advanced quickly from the 0.4MW turbine in 1991 to modern day 14MW turbines, making OWF energy financially feasible with an overall annual energy capture increase from 5MW to 564,000MW (International Renewable Energy Agency, N.D.).

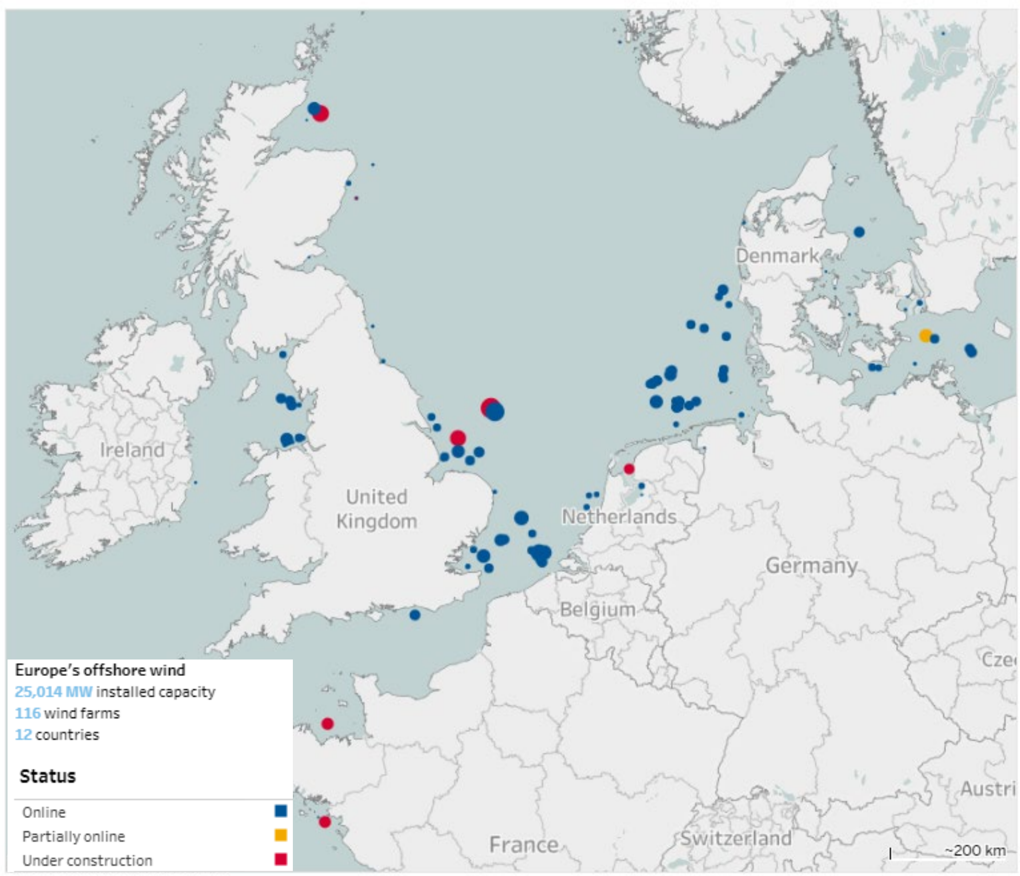

Figure 1. Map of Offshore Wind Development in Europe
(Wind Europe, 2021)

2.1 Europe

Since OWF development began in Europe, offshore wind has spread throughout much of northern coastal Europe, with OWFs in the Celtic Sea, Irish Sea, English Channel, North Sea, Baltic Sea, and Gulf of Bothnia (4C Offshore, N.D.). From 1991 to 2001, OWF development spread to the United Kingdom (U.K.), Sweden, and the Netherlands. Figure 1 shows the number of European OWFs and the proximity to the shore of the various countries, which generally ranged from 10 to 20 km until 2013 (Wind Europe, 2020). European OWF distance to land due to geography, such as locations in the North Sea, is much closer when compared to most of the geography of the Atlantic coastline, where offshore development could extend out to 100 km or more. Individual European OWF leases tend to be small (continental average of approximately 39 km^2)[1], closer to shore (10-20 km), and the developed Wind Energy Areas (WEA) are split into smaller, more dispersed leases along a country's coastline. Between 2013 to 2020, average distance to shore was about 40 km with an average sea depth about 30 m (Wind Europe, 2017; Wind Europe, 2018; Wind Europe, 2020; Wind Europe, 2021; European Wind Energy Association, 2015; European Wind Energy Association, 2014).

Distance between turbines within an individual OWF is unique to the design of the facility. The spacing of turbines within wind facilities varies by size of turbines, location of the OWF, prevailing winds, and the "wake effect" of the turbines. Early development ranged from 500 to 1000 m, compared to the U.S. where distances are 1500 to 2000 m to accommodate the larger turbine size and vessel transit. Wake effect is the slowing down of wind energy after passing through a turbine, which reduces the wind speed and effectiveness of downwind turbines. The distance between turbines is measured by the span of the turbine blades and spacing varies from 5 to 15 turbine-diameter spaces. Generally, larger wind turbines will have greater distances between turbines due to the larger size and spacing between them due to wake effect. While the number of turbines will increase energy production, the wake effect can diminish the capacity of an OWF as the turbine density increases. (Deutsche Windguard, 2018; The Renewables Consulting Group, LLC, 2018)

Improvements in turbine technology increased power generation by almost six times the power generation at the Vindeby OWF from 0.4 MW to 2.3 MW (Orsted, 2019). Between 2002 and 2011, the size of OWF projects increased significantly and spread to countries such as Finland, Belgium, and Germany (Orsted, 2019a). In 2002, Horns Rev 1 was commissioned in the North Sea off the coast of Denmark with a 160 MW capacity (Orsted, 2019a). In 2003, the U.K. awarded leases to 15 projects totaling 7,200 MW (Orsted, 2019a). In 2008, the U.K. awarded additional leases with a cumulative capacity of 32,000 MW (Orsted, 2019a). During this time, turbine capacity grew from 2.3 MW to 3.6 MW (Orsted, 2019a). Between 2012 and 2017, turbine capacity grew exponentially from 3.6 MW to up to 8 MW (Orsted, 2019b). A single 8 MW turbine can cover the annual energy usage of more than 7,000 households (Orsted, 2019b). Figure 2 shows the difference in sizes of turbines used in current wind facilities and those expected for use in the future.

[1] Calculated using data from (4C Offshore, N.D.f; 4C Offshore, N.D.a; 4C Offshore, N.D.d; 4C Offshore, N.D.e; 4C Offshore, N.D.g; 4C Offshore, N.D.h; 4C Offshore, N.D.j; 4C Offshore, N.D.k; 4C Offshore, N.D.l)

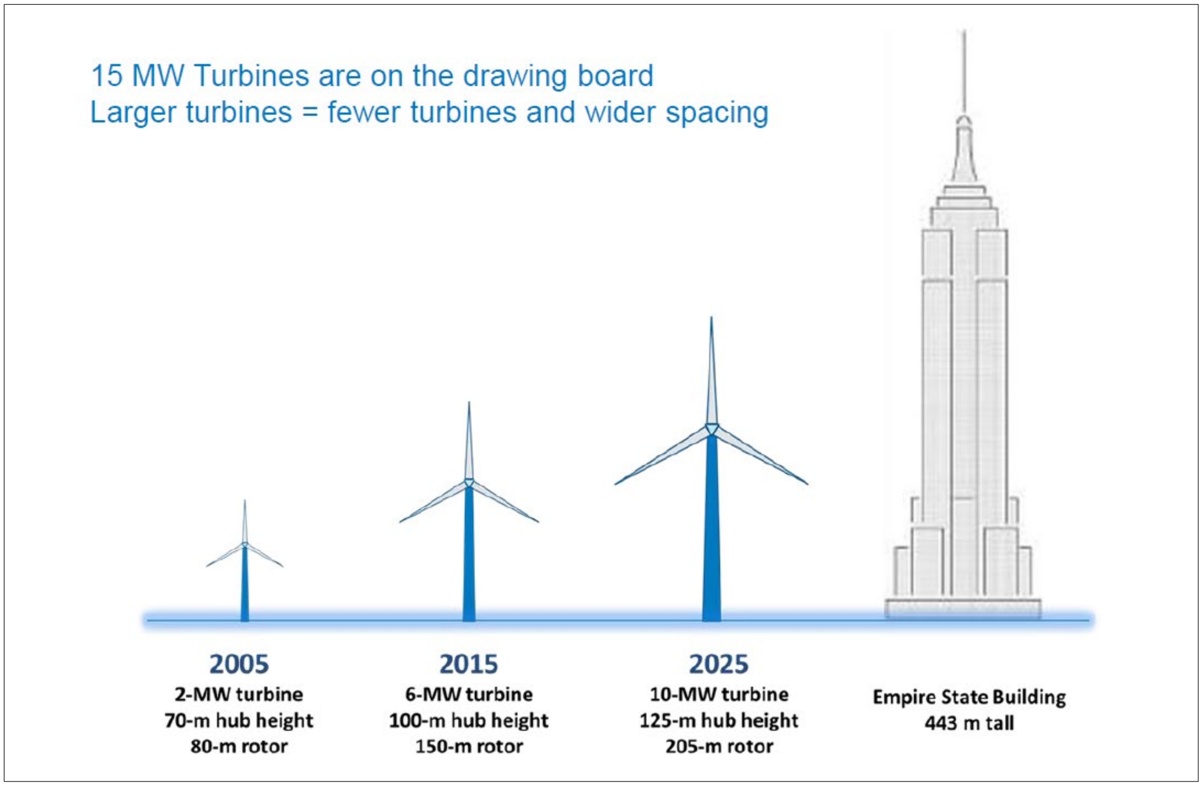

Figure 2. Offshore Wind Turbines—Past and Future Size
(Musial, 2018)

At the time of construction, European OWFs used the most effective modern turbines that fit their energy demands and regulatory, financial, and environmental constraints. Since many OWFs were built in the late 1990s and early 2000s, the turbines selected (and still in use) are often significantly smaller and generate less energy than the turbines available today. This means that when compared to modern capabilities, these OWFs have more turbines than a European OWF constructed today.

Due to the nature of WEA leases and OWFs, different size turbines were constructed within different size areas. For example, Germany has 26 fully operational OWFs encompassing approximately 851km^2 with 12 different size turbines in use (4C Offshore, N.D.a). Table 1, below, depicts data about European offshore wind energy production. Distance to shore in the table is an average from 2013 to 2020, and is relatively comparable to the U.S. which is from more recent OWF data. Of the early European OWFs, the Horns Rev 1 is located about 18 km from shore, the London Array Phase 1 is about 20 km from shore, and the Greater Gabbard is about 36 km from shore (Das, 2013).

Table 1. Comparison of Offshore Wind Facilities in Europe and the U.S.

	OWFs	Total Area (km^2)*	Total Turbines	Types of Turbines	Avg. Distance from Shore (km)
Europe	116[a]	4,138[a-f]	5,402	16[g]	40[a, i-k]
U.S. -Total leases	17/2**	7,051[m]	7[n-p] (operational)	2[n-p] (operational)	47[q]

*Data has been rounded to the nearest whole number

**Currently leased/ operational (as of December, 2021)

[a] (Wind Europe, 2021)

[b] (4C Offshore, N.D.d)

[c] (4C Offshore, N.D.a)

[d] (4C Offshore, N.D.e)

[e] (4C Offshore, N.D.f)

[f] (4C Offshore, N.D.g)

[g] (4C Offshore, N.D.h)

[h] (The Wind Power, N.D.)

[i] (Wind Europe, 2020)

[j] (Wind Europe, 2019)

[k] (Wind Europe, 2018)

[l] (Wind Europe, 2017)

[m] (BOEM, N.D.b)

[n] (U.S. Energy Information Administration, 2015)

[o] (4C Offshore, N.D.b)

[p] (Dominion Energy, 2020)

[q] (National Renewable Energy Laboratory, 2020)

2.2 United States

In 2015, the U.S. began construction of their first OWFs off Block Island, Rhode Island comprised of five 6 MW turbines generating a total of 30 MW (U.S. Energy Information Administration, 2015) (4C Offshore, N.D.b). Due to its timing into offshore wind energy production, the Block Island Wind Farm was outfitted with some of the most modern turbine technology at the time, which significantly increased energy output in comparison to similarly sized European OWFs built in earlier years. Whether the offshore wind structures could withstand the frequent storms, hurricanes, and turbulent waters of the Atlantic Ocean was a prevalent stakeholder concern. Due to this concern, the Block Island Wind Farm was constructed strategically between Long Island Sound and Rhode Island Sound to offer some level of protection from the elements. In 2020, Dominion Energy completed phase one of the Coastal Virginia Offshore Wind project located on the OCS, which included two 6 MW turbines (Dominion Energy, 2020). The Coastal Virginia Offshore Wind project, which has been subjected to the harsh conditions of the Atlantic Ocean, has been successful thus far, providing further evidence that offshore wind power generation in the Atlantic Ocean is feasible.

In the U.S., BOEM administers federal wind energy projects, with jurisdiction of offshore energy leasing on the OCS encompassing the area within 3 nautical miles (NM) (5.56 km) to about 200 NM (370 km) from the Atlantic shoreline (BOEM Environmental Studies Program, 2020). In 2019, the average distance of U.S. OWFs was about 25 NM (47 km) at depths of approximately 31 m (National Renewable Energy Laboratory, 2020). According to the National Renewable Energy Lab, the U.S. has an estimated 4.2 million MW of developable offshore wind potential; the U.S. Energy Information Administration calculates that 66 percent of potential U.S. WEAs are graded as the highest or second highest classification for wind power production (National Renewable Energy Laboratory, 2012; U.S. Energy Information Administration, 2015). As energy demands grow and climate concerns accelerate, the U.S. has increased research and investment into OWFs and turbine technology. This is reflected in the construction plans for recently approved commercial scale projects on the Atlantic OCS: Vineyard Wind 1 and South Fork Wind Farm.

Turbines contracted for the Block Island OWF are 6 MW with a diameter of 150m and a 17,860m^2 sweep area (General Electric, 2015). Turbines contracted for the Coastal Virginia OWF are 6 MW with a 154m diameter and an 18,600m^2 sweep area (Siemens Gamesa, N.D.). The other six planned OWFs providing turbine data plan to use 8 MW to 12 MW turbines with diameters ranging from 164 m to 220 m and sweep areas of 21,124 m^2 to 38,000 m^2 (Vestas, 2011; General Electric, 2019). Current data supports that the U.S. is trending towards using physically larger turbines capable of generating more energy. Spacing between turbines is likely to be larger as well, providing lower density of turbines within an OWF. Considering the average area of U.S. OWFs is 282 km^2, the U.S. is poised to harness offshore wind energy on an unprecedented scale.

2.3 Similarities and Differences

Early European OWFs used older turbine technology, which was smaller, spaced closer together, rotate at a faster velocity, and OWFs were located closer to shore. As advancements in the effectiveness of updated turbine technology, wind facility and turbine size have increased, along with turbine spacing and distance from shore. In 1991, turbines started generating approximately 0.5 MW, then 2.3 MW by the end of the next decade, and 3.6 MW by the end of the following decade (Orsted, 2019; Orsted, 2019a). The first turbines in the U.S., installed in 2015, generated 6 MW and planned OWFs will use turbines generating between 8 MW and 12 MW (4C Offshore, N.D.b; Power Technology, N.D.; General Electric, 2019). A similarity can be drawn between both regions' propensity to use the best available technology, although this is a standard industry practice. It would be financially irresponsible and inefficient for the U.S. to use, for example, 24 of the smaller 0.5 MW turbines when one modern 12 MW turbine would suffice. Turbine specification data shows that as turbines increase in energy producing capabilities, turbine diameter, sweep area, and total height increase.[2] Furthermore, 64 percent of fully commissioned European OWFs operate with turbines smaller than the smallest turbine in use or planned for use in the

[2] Calculated using data from references listed in Table 1.

U.S.[3] Based on current conceptual designs and construction plans, the U.S. will continue trending towards larger, more efficient modern turbines.

For example, each OWF in the Netherlands, which has the highest turbine density per OWF in Europe, has an average of 74 turbines per lease with the largest turbines having a 164 m diameter and 21,124 m^2 sweep area (4C Offshore, N.D.g; Vestas, 2011).[4] Whereas the Ocean Wind OWF located off the coast of New Jersey will be using 90 12 MW turbines with 220 m diameters and 38,000 m^2 sweep areas (General Electric, 2019). It is difficult to compare European OWFs with their greater turbine density and smaller turbines to a conceptual U.S. OWF with fewer but physically larger turbines.

Since the U.S. is in the early phase of OWF development, there is limited data available for these future development plans. Only eight U.S. OWFs provide details on the turbines to be used on their leases compared to the 116 existing European OWFs with available data. Thousands of square kilometers of available OWF ocean in the U.S. Atlantic are still considered Development Zones or Call Areas, meaning they are sanctioned for development and have not been leased or BOEM has identified the area with sufficient potential to construct an OWF. Many U.S. leased plots are still in the conceptual/early planning stage or awaiting consent to build and respective energy companies offer no insight into turbine specifications or other pertinent data.

3 Avian Studies

European OWFs have operated several decades longer than in the U.S., and subsequently, research and studies on potential impacts to avian species have been undertaken longer in Europe than in the U.S. During this time, avian survey techniques range from visual observations on boats and GPS tracking of individual bird species to data simulations, thermal imagery, acoustic and ultrasound sensors, very high frequency (VHF) sensors, and aerial photography or telemetry from aircraft (Band, 2012; Lapena, et al., 2010; Plonczkier & Simms, 2012; Peschko, et al., 2020; Viet, et al., 2015; Normandeau Associates, Inc., 2014; Paton, et al., 2021; White & Veit, 2020). While earlier studies provide valuable information regarding the effects of OWFs on birds in the offshore environment (Section 3.1), current study methodologies consider new factors that were previously difficult to measure. Factors such as flight height above sea level introduce a means to study whether a species travels within blade height of turbines during travel to feeding areas, movement from breeding or nesting habitat offshore, or during migration flights (Willmott, et al., 2015; Winship, et al., 2018; Johnston, et al., 2014; White & Veit, 2020).

As described in Section 2, the features of OWFs, from the dimensions of the turbines to the size and physical location of the wind facilities, all impart dynamic components for consideration of offshore wind locations in the U.S. and Europe. The following sections describe avian research in Europe and the U.S. and discuss similarities and differences, best practices, and conclusions.

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[3] Calculated using data from references in Table 1.
[4] Calculated using data from references in Table 1.

3.1 Europe

Studies in Europe can be grouped into two categories: 1) baseline studies of avian species and 2) effects on avian species from wind development, which generally focus on displacement (including attraction or avoidance) and mortality due to collision. Because Europe has numerous existing OWFs to conduct research on direct impacts to avian species, there are more studies from Europe on this subject.

3.1.1 Avian Baseline Studies and Data Collection

Early avian studies conducted for OWFs, such as the Horns Rev in 2002, specifically denoted existing information regarding avian species and offshore wind was poorly known (Christensen, et al., 2003). The Horns Rev study used aerial visual surveys to determine bird densities prior to and during construction of the OWF (Christensen, et al., 2003). Within the next 15 years, research and studies on avian density, development of survey methodology, and avian use of OWFs have evolved, enriching literature reviews, and providing solid foundations for environmental impact assessments (Willmott, et al., 2015; Thaxter, et al., 2018; Buckland, et al., 2012). Robust datasets of offshore use by avian species were collected in U.K waters, supplying information sources for maps and building models of species sensitivity to OWFs, likelihood of collision with turbines, and probability for displacement for all or part of their life history (Bradbury, et al., 2017; European Commission, 2020; LIFE EuroBirdPortal, 2021; Wright, et al., 2012; Cleasby, et al., 2020).

3.1.2 Avian Displacement and Mortality

The geography of much of Europe consists of islands and landforms separated by small expanses of open sea or channels. This geography influences avian habitat use, movement, and breeding that is considered in the models developed in Europe. Displacement of avian species within OWFs has been studied across Europe for a range of species (Langston, 2013; Thaxter, et al., 2018; Fox & Petersen, 2019; Rexstad & Buckland, n.d.). In some studies, changes to the offshore environment, such as new reef habitat from turbine bases leading to an increase of food sources, showed no decrease of some avian species or an increase of certain avian species, such as Gulls (Thaxter, et al., 2018; Vanermen, et al., 2013). Habituation to the presence of OWFs has been hypothesized at smaller offshore developments for species such as Terns, Ducks, Cormorants, and Gulls (Vanermen, et al., 2013; Rexstad & Buckland, n.d.). For other species, such as Red-throated Divers and Common Scoters, some amount of avoidance of offshore wind development has been observed and/or modelled (Peschko, et al., 2020; Vanermen, et al., 2013; Plonczkier & Simms, 2012; Fox & Petersen, 2019, Sckov et al., 2018). Aspects such as day- and night-time flight patterns, flight height, season, and differences in habitat use are evaluated in displacement studies (Peschko, et al., 2020). In many studies, the need for additional data is noted to strengthen the study/modeling results (Furness, et al., 2013; Vanermen, et al., 2013; BirdLife International, 2013).

Structural differences, such as the variation in size of OWFs and turbine height and size, are more pronounced in Europe. Studies considering flight height and collision risk have led to 3-dimensional models and recommendations for clearance of turbine blades for selected avian species and locations in the U.K. (Thaxter, et al., 2018; Cleasby, et al., 2015). Direct mortality caused by wind structures is difficult to measure offshore, unless observed at the moment of collision due to the movement of ocean water, predators or scavengers, or submersion of deceased birds (Willmott, et al., 2015; Vanermen, et al., 2013). Numerous inputs of species-specific data, such as migration routes, flight height during differing activities offshore (e.g., migration, hunting, foraging, or nesting/breeding), flight speed, and avoidance or use of OWF areas, are used to predict possible collisions and mortality (Thaxter, et al., 2018; Green, et al., 2020; Johnston, et al., 2014; Cleasby, et al., 2015; Lapena, et al., 2010).

3.2 United States

The first onshore federal wind energy development in Riverside County, California in 1982 prompted the first avian research and NEPA documentation for a wind facility (Bureau of Land Management, N.D.; State of California, 2021). The Energy Policy Act was passed in 2005 and BOEM established the Renewable Energy Program for the Outer Continental Shelf (OCS), which began in 2009 (BOEM, N.D. c). With this policy in place, offshore wind along the OCS was on the path for leasing and future development. The first offshore wind project, the Block Island Wind Farm, off the coast of Rhode Island, began operation in late 2016 (BOEM, N.D.a; Paton, et al., 2021). Given that the U.S. only has two OWFs to conduct research on direct impacts to avian species, the majority of avian studies have focused on baseline studies and data collection. Researchers have looked to Europe for lessons learned, and studies to collect additional detailed information, such as flight height to consider with turbine placement, in addition to developing models to predict flight height for avian species that may occur within OWFs.

3.2.1 Avian Baseline Studies and Data Collection

At least a decade before the first U.S. OWF began operation, a diverse working group of federal, Canadian, state, academic, and nonprofit professionals developed a *Waterbird Conservation Plan for the Mid-Atlantic/New England/Maritimes Region: 2006-2010* which contains a species list, details of each species, and conservation priorities (MANEM Waterbird Working Group, 2006). In 2009, avian data gathering and research on seabirds was conducted in anticipation of future offshore wind energy development (Allison, et al., 2009; O'Connell, et al., 2009). These early studies built on existing aerial surveys and datasets, and used technology, such as satellite transmitters and data processing programs, to collect and compile results for the studies (Allison, et al., 2009; O'Connell, et al., 2009).

Over the last decade, research on avian species and offshore wind along the Atlantic OCS has grown. Studies on habitat use for specific avian species, such as Black Scoters, Red-throated Loons, Surf Scoters, and Northern Gannets, to groups of pelagic species have been conducted. The studies contribute to the baseline understanding of density, offshore use, and movement patterns of avian species that may use the same areas where future OWFs may be located (Loring, et al., 2014; Viet, et al., 2015; Spiegel, et al., 2017; Stenhouse, et al., 2020; White & Veit, 2020). Many of these species migrate between the U.S. and Europe; it is assumed these species will have similar habits and avoidance behavior to OWF development in the U.S as has been studied in Europe (Stenhouse, et al., 2020). Additionally, large-scale data collection efforts continue for Atlantic seabirds by the U.S. Fish and Wildlife Service, U.S. Geological Survey, National Oceanic and Atmospheric Administration (NOAA), and BOEM (O'Connell, et al., 2011; Jones & Leirness, 2015; Winship, et al., 2018; NOAA, 2020). These research efforts have been used to build datasets available to the public on sites such as the Northeast Ocean Data Portal (Northeast Ocean Data, 2021).

3.2.2 Avian Displacement and Mortality

Studies about displacement and mortality of avian species caused by offshore wind are not as prevalent due to the small number of constructed U.S. OWFs. Numerous technologies previously used for identifying avian collisions from onshore wind structures are planned for testing or are currently being tested for offshore wind study use. These technologies include the Thermal Animal Detection System and Multi-Sensor Bird Detection System and the Visual Automatic Recording System, both of which are currently being tested offshore in the U.S. (New York State Energy and Research Develpment Authority, 2020). Information about flight altitudes to aid in determining collision risk is being collected for three avian species, Common and Roseate Terns, and Piping Plovers (Loring, et al., 2019). A new study by Loring, et. al., on 12 migratory bird species that use stopover sites along the Atlantic coast is collecting data to estimate collision risk with offshore wind turbines in the U.S. (Loring, et al., 2020). The flight height data can be used to determine if any species use the space within the sweep area of turbines planned for future OWFs, and plans could be changed accordingly.

Turbine lighting is an area of concern for avian safety. The color of lights, flashing frequency, or steady beam have been studied due to instances of avian mortality, especially Neotropical songbirds during their nighttime migration (Gehring, et al., 2009). Towers, including wind turbines, must have lighting to ensure aircraft safety, even offshore, which is required up to 12 NM (22km) by the Federal Aviation Administration (FAA) (Orr, et al., 2016). Reviews of literature for Europe generally denote international and country-specific requirements and refer to research in the U.S. as more informative on this subject (NatureScot, 2020). Based on research, the generally accepted and safest lighting for avian species is a red flashing light, which is also the preferred lighting for the FAA (Orr, et al., 2016; NatureScot, 2020; U.S. Fish and Wildlife Service (USFWS), 2020; Gehring, et al., 2009). Studies have shown that use of no lighting may be the most preferable option to avian safety, and some future technologies may lead the way to dimming or shutting off lights when no aircraft are within range (Orr, et al., 2016; NatureScot, 2020). Other studies have shown that green or blue lights, especially for overall illumination of offshore structures, are the least disruptive to migrating birds (Poot, et al., 2008).

3.3 Similarities and Differences

3.3.1 Similarities—Future Offshore Wind

Because of the increasing push for low-emission energy development such as offshore wind and anticipation of reduced impacts from avian habitat loss from climate change, well placed and researched offshore wind is receiving support from government entities and nonprofit organizations in the U.S. and Europe (National Audubon Society, 2020; The White House, 2021; The Crown Estate, 2019). Through the decades of research conducted to date, specific offshore locations have been removed or precluded from wind development due to the prevalence of avian species (The Crown Estate, 2019; BOEM, 2013). In addition, marine protected areas have been designated offshore in Europe and the U.S. with varying levels of protection (National Marine Protected Areas Center, N.D.; European Environment Agency, 2018). As more research is conducted for avian and marine species, it is likely that additional restrictions will be added to existing protected areas, or new protected areas will be established in the U.S. and Europe.

3.3.2 Differences—Past Avian Research

When Europe began offshore wind development, baseline data and studies were not very robust and often non-existent. A great deal of catching up on baseline data was needed as wind development progressed. Because of the lack of initial data on avian species, it is likely that avian mortality may have been higher in early OWFs. With offshore wind well-established across Europe, more studies on displacement and mortality of avian species are now available in Europe.

The U.S. began data collection for avian species proactively, well before the first OWF was constructed, providing strong baseline information for planning and locating OWFs, in addition to preparing avian studies for COPs and NEPA documents. Although there are few studies about direct displacement or mortality of avian species in the U.S. due to the low number of OWFs, data and modeling research are providing additional information to assist with locating and planning future OWFs. Avian studies conducted in Europe, while consisting of slightly longer-term data and similar species for comparison, may not always directly apply to the offshore wind energy development in the U.S. due to the distance from shore and larger turbines planned for use in the U.S.

4 Best Practices and Mitigation

In 2020, BOEM updated their *Guidelines for Providing Avian Survey Information for Renewable Energy Development on the Outer Continental Shelf Pursuant to 30 Code of Federal Regulations (CFR) Part 585* which requires offshore energy lessees to submit results of a site characterization surveys for avian species (BOEM, Office of Renewable Energy Programs, 2020). Species lists and surveys to identify "key species" in the project area should also include species density and flight heights for each species (BOEM, Office of Renewable Energy Programs, 2020). This requirement provides critical information of avian species that may be present in the offshore lease areas and can be used as a baseline for monitoring following construction (BOEM, Office of Renewable Energy Programs, 2020). The guidelines also include references for surveys and methodology, and recommendations for different types of survey methodologies (e.g., digital aerial, boat, and traditional aerial) (BOEM, Office of Renewable Energy Programs, 2020).

Baseline information for U.S. Atlantic avian species can be found at the following websites:

- U.S. Fish and Wildlife Service (USFWS) IPaC -Information for Planning and Consultation (USFWS, 2021);
- BOEM and NOAA MarineCadastre.gov (BOEM and NOAA, 2021);
- Avian Knowledge Network (Avian Knowledge Network, 2021);
- Northeast Ocean Data Portal (Northeast Regional Ocean Council, 2009); and
- Mid-Atlantic Data Portal (MARCO) (MARCO, 2021).

In 2013, the Bern Convention Bureau Meeting presented *Wind Farms and Birds: An Updated Analysis of the Effects of Wind Farms on Birds, and Best Practice Guidance on Integrated Planning and Impact Assessment*, which included case studies and integrated planning and assessments for both onshore and offshore wind development (BirdLife International, 2013). Mitigation measures for OWFs are included in this document, which lists locating OWFs away from avian populations, especially those that are most vulnerable (BirdLife International, 2013). Other options include the following modifications to:

- Site design and layout;
- Turbine design and operation; and
- Bird activity (lighting or deterrence).

There are many documents and sources listed on the BirdLife International website to support low-impact wind energy locations and minimal effects to avian and other wildlife species (BirdLife International, 2021).

5 Conclusion

To date, OWF development in Europe has evolved over time with size and technological advances in turbine size. This evolution means that there is little consistency among European OWFs. Early European wind facilities are closer to shore with smaller, faster rotating turbines, spaced close together. Facilities that are located farther offshore are often between large land masses, such as those located within the North Sea, which may be within flyways between land masses.

Moving forward, technology will likely become more similar between the U.S. and Europe as construction of OWFs expands along the Atlantic OCS. Presently, OWF size in the U.S. is planned to be much larger than those currently existing in Europe. Turbine size and subsequent turbine height and sweep areas are also much larger due to recent advances in technology. The scale of U.S. OWFs in planning phases will be larger and of more consistent scale than the existing OWFs in Europe.

Overall, the most important factors to consider for offshore wind and avian impacts include the following:

- Location of OWFs is critical in avoiding impacts to avian species.
- The ability to accurately determine species habitat associations, feeding ecology, space use and migration patterns within and through a proposed OWF site is key to ascertaining if the location may result in impacts to avian species.
- Use of the best available data, especially when determining avian density and distribution, habitat associations, and feeding ecology within a proposed OWF, is the most important factor to consider in providing the greatest protection for avian species.

For additional resources on avian studies, including many referenced in this document, please see BOEM’s Renewable Energy Research, Completed Studies Website. In addition to avian research, other important subjects such as marine mammals and economics are also found on this website.

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