Frequently Asked Questions: Offshore Wind and Birds

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Version 1.0

Photo credit: White-winged Scoter © Daniel Poleschook

Developed by the Bird Communications Specialist Committee of the Environmental Technical Working Group, with support from the Biodiversity Research Institute

This document is intended to be a living document that is updated over time to address key emerging questions related to birds and offshore wind energy development. For the full FAQ version history visit https://www.nyetwg.com/specialist-committees/wildlife-faqs/bird-communications.

Introduction

The Environmental Technical Working Group (E-TWG) is an independent advisory body to the State of New York, formed in 2017, with a regional focus on offshore wind and wildlife issues from Maine to North Carolina. It is comprised of offshore wind developers, science-based environmental non-government organizations, and state and federal wildlife agencies. The E-TWG undertakes activities such as the development of best management practices and identification of research needs regarding wildlife and offshore wind development. With direction from the E-TWG and the New York State Energy Research and Development Authority (NYSERDA), topically focused Specialist Committees (SCs) bring together science-based subject matter expertise to develop specific products and recommendations that inform or advance environmentally responsible development of offshore wind energy. Specialist Committees include both E-TWG and non-E-TWG members from a range of backgrounds, as appropriate for each committee's charge.

The Bird Communications Specialist Committee was formed in December 2024 to develop communications materials to aid in the dissemination of current, accurate, and readily understandable science-based information around the potential effects and impacts to birds from offshore wind development. The Specialist Committee includes representatives from academic institutions, environmental nonprofit organizations, state agencies, offshore wind energy developers and environmental consultants, and receives technical support from the Biodiversity Research Institute. External reviewers of Committee products are scientific experts who may include federal and state agency representatives, academics, and other environmental professionals or other stakeholders with topical expertise.

The Specialist Committee developed this Frequently Asked Questions (FAQs) document, which groups topics into overarching themes and aims to provide two levels of information in response to each FAQ: (1) Brief bulleted summary and (2) Detailed Answer, an extended answer with associated scientific citations to provide readers with a better understanding of the scientific evidence base and information sources. Links to additional resources are provided when relevant. While focused on offshore wind development, FAQ responses may also include discussion of land-based wind energy development, other maritime industries, climate change, and/or other human activities, to provide detail and context. FAQ responses have been through multiple rounds of review by Specialist Committee members, E-TWG members, and external reviewers. More details about the general FAQ review process can be found at https://www.nyetwg.com/specialist-committees/wildlife-faqs. If readers with appropriate expertise would like to help review drafts of future FAQ topics, please reach out to Katrina Zarrella-Smith at katrina.zarrella-smith@briwildlife.org.

The FAQ document is intended primarily as a resource for stakeholders who are in direct communication with the public, and who regularly receive questions from the public on these topics. The intent of this document is to provide scientifically accurate answers in varying levels of detail to address common questions. End users should feel free to use or adapt the information in the FAQ as they see fit, along with attention to scientific integrity.

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Offshore Wind Development and Birds

Why should we care about birds and offshore wind development?

- Birds have substantial intrinsic, socioeconomic, and ecological value making their conservation a priority. Socioeconomically, bird-related activities such as birdwatching and hunting support emotional wellbeing and contribute millions of dollars to the economy each year. Ecologically, birds offer vital services such as insect control, seed dispersal, and nutrient transfer.
- The value of birds is reflected in state and federal laws, yet in North America, one third of bird species are at risk of extinction. **Climate change** is widely considered a leading cause of declining bird **populations**. To avoid the most catastrophic climate impacts, greenhouse gas emissions need to be greatly reduced. Renewable energy sources, including offshore wind, can help achieve this.
- Offshore wind energy offers economic, public health, and ecological benefits compared to other energy sources, including a pathway to meeting renewable energy goals, supporting energy independence, and reducing climate-driven threats to birds. Realizing these benefits responsibly, however, requires understanding how birds interact with offshore wind infrastructure and ensuring that projects avoid and **mitigate** potential harms so that the broader benefits of development outweigh its costs (see *How many birds are impacted by offshore wind development in the U.S. Atlantic?*).

Detailed Answer

Reasons to care about both birds and offshore wind development include (1) the intrinsic, socioeconomic, and ecological value of birds; (2) the imperative to pivot toward renewable energy to meet energy goals that limit the negative effects of **climate change** and support energy independence; and (3) the need to avoid and **mitigate** potential harm to birds from offshore wind development to ensure that broader benefits outweigh negative impacts.

The Multifaceted Value of Birds

Birds have high intrinsic, socioeconomic, and ecological value that result in multifaceted **ecosystem services**. The intrinsic value of birds stems from their inherent appeal and impact on human well-being. Studies have shown that birdwatching can increase human mental well-being by promoting a more peaceful and less stressed mindset (North American Bird Conservation Initiative 2025). Birds provide sociocultural value by representing beauty, inspiring art, and providing a sense of identity. For example, U.S. “state birds” serve as emblems of local heritage and pride, encouraging a deeper appreciation for regional wildlife and conservation. Additionally, many Indigenous cultures consider birds to be sentient entities representing kinship, guidance, and protection (Sault 2016).

Because many people enjoy watching birds, tourism and commercial industries provide goods and services to support this activity. According to a U.S. Fish and Wildlife Service report on the economic benefits of birding, approximately 37% of the U.S. population (~96 million people) participated in birdwatching in 2022, spending over $100 billion on trip and equipment related expenses (Figure 1; Carver 2024).

Birds similarly provide economic benefit to the hunting industry. The U.S. Fish and Wildlife Service reported that in 2022, approximately 2.8 million people in the U.S. partook in **migratory bird** hunting. This equated to nearly $100 million spent on hunting trip and gear related expenses. (USFWS 2022). Many hunting groups also support the conservation of bird populations. For example, Ducks Unlimited, a non-profit founded by duck hunters in 1937, has helped conserve over 19 million acres of **waterfowl habitat** in North America.[1]

Figure 1. Economic benefits of birding in the United States. Source: Carver 2024.

In addition to their socioeconomic benefit, birds also have immense ecological value. For example, many bird species eat insects, which can help naturally keep insect populations at bay.[2] Because birds can travel vast distances, they also play an important role in providing numerous ecological services such as pollination, seed dispersal, and nutrient transfer across landscapes (Whelan et al. 2008). **Seabirds** are particularly valuable contributors to nutrient transfer between ecosystems because they feed at sea and breed on land, depositing nutrient-rich guano (i.e., feces) in large quantities in these habitats (De La Peña-Lastra 2021). These nutrient deposits can substantially increase plant, algae, and/or **phytoplankton** growth both on land and in coastal waters (Bosman et

[1] Ducks Unlimited: Waterfowl, People, and Wildlife Need Wetlands
[2] Smithsonian's National Zoo and Conservation Biology Institute: How Birds Keep our World Sage from the Plague of Insects

al. 1986, Wait et al. 2005) and can affect other organisms via increased productivity at the base of food webs (Wootton 1991, Hentati-Sundberg et al. 2020, Espíndola & Carlo 2024).

The collective value birds provide is formally recognized in state and federal laws, such as the Endangered Species Protection Act and the Migratory Bird Treaty Act (see *What federal environmental laws and international agreements protect birds?*). Violating these laws can result in substantial fines and penalties.

The Importance of Offshore Wind

Rapid and substantial reductions in greenhouse gas emissions are critical to avoiding the most severe impacts of climate change caused by emissions. Renewable energy sources, such as wind, play a vital role in this reduction (Allison et al. 2019). Consequently, decreasing fossil fuel reliance while expanding renewable energy capacity supports achieving both national emissions targets and international climate change **mitigation** goals (USGCRP et al., 2023). In addition, substantial climate, economic, and human health benefits from planned or proposed offshore wind development along the U.S. Atlantic and Gulf coasts across is projected (Shawhan et al. 2024). The offshore environment is optimal for wind energy development as there is space offshore for new infrastructure, it can support coastal urban power needs, and it has higher and more consistent wind speeds than on land, thus offering more efficient and predictable energy.[3]

Birds and Offshore Wind

In North America, one third of bird species are at heightened risk of extinction from multiple human threats, including the environmental impacts of climate change (Figure 2; North American Bird Conservation Initiative 2025). Climate change from greenhouse gas emissions is a leading cause of declining bird populations (Wilsey et al. 2019). Many bird species, including **songbirds**, **raptors**, and seabirds, have shown changes in their migration and movement patterns, diets, **reproductive success**, and survival rates in response to climate-induced environmental changes, which can contribute to population declines (Crick 2004, Oro 2014). Offshore wind can benefit birds by helping to mitigate long-term environmental impacts from climate change.

While offshore wind energy plays a critical role in achieving climate goals, the potential risks to birds must be considered, given their ecological and socioeconomic value and current declining population trends. Some birds may be affected by offshore wind development (see *What are the types of potential effects to birds from offshore wind energy development?*); however, the extent of this impact has not been fully determined (see *How many birds are impacted by offshore wind development in the U.S. Atlantic?*). As offshore wind expands in the U.S., it is necessary to understand how possible effects on birds relate to existing sources of bird mortality and habitat loss (see *How does offshore wind development compare to other sources of bird mortality?*). This will allow us to place offshore wind effects into context and improve our understanding of the potential effects on birds.

[3] BOEM: Renewable Energy on the Outer Continental Shelf

Responsible siting, design, and operation of offshore wind facilities are needed to advance renewable energy growth while balancing potential risks to birds. The large and growing body of scientific research can inform environmentally responsible offshore wind development; in addition, regulatory frameworks support the implementation of key processes and measures to assess, monitor, and mitigate potential negative effects and impacts to birds from offshore wind (Seavy et al., 2025; see *What federal environmental laws and international agreements protect birds?*).

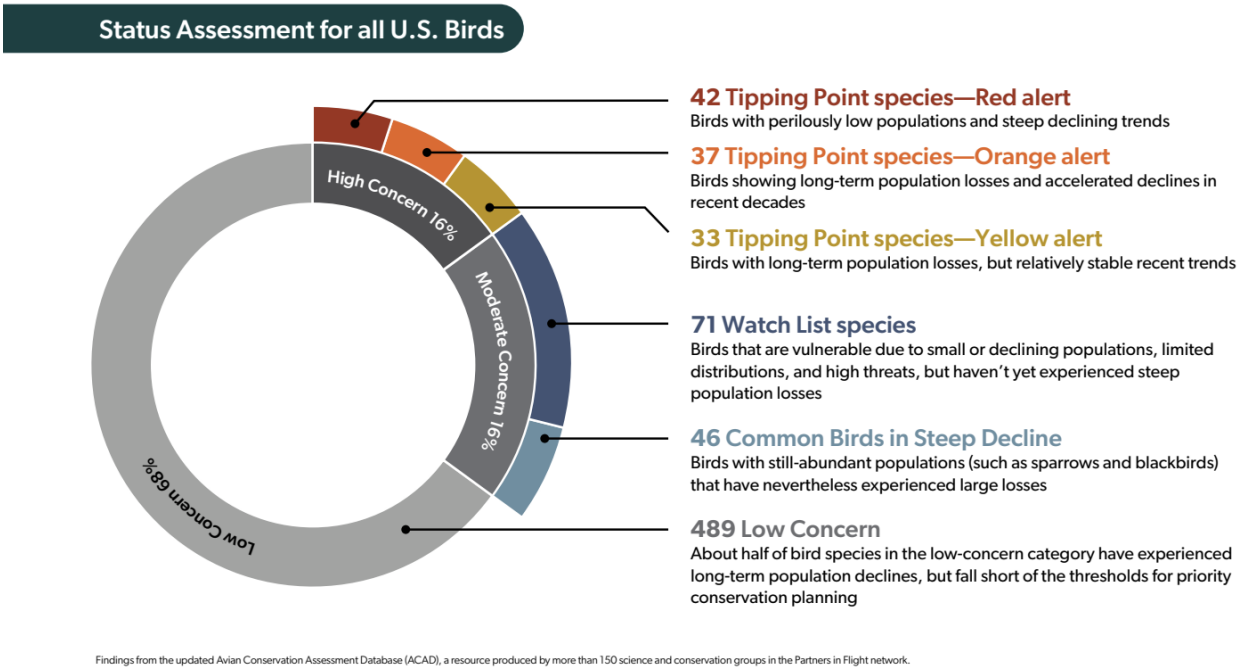

Figure 2. Population status of bird species with high, moderate, and low conservation concern in the United States. Source: North American Bird Conservation Initiative 2025.

For More Information

- Bring Birds Back (A campaign by the American Bird Conservancy, Audubon, and others): Why Care About Birds?
- National Audubon Society, 2025: Birds and Offshore Wind Report

What are the major components of an offshore wind facility?

- Offshore wind facilities are typically comprised of turbines, whose rotors convert mechanical energy from wind into electrical energy, and offshore substations, which collect and modify energy from turbines for transmission. Energy is transported between substations and the shore via subsea power cables (which are typically buried in the seafloor) so it can be integrated into the electrical grid on land.
- Turbines can have either fixed foundations installed on the seafloor, or floating foundations, which are anchored to the seafloor with specialized mooring lines. Floating turbine designs are newer and are generally deployed in deeper waters (50–300 m, or 164–984 ft).

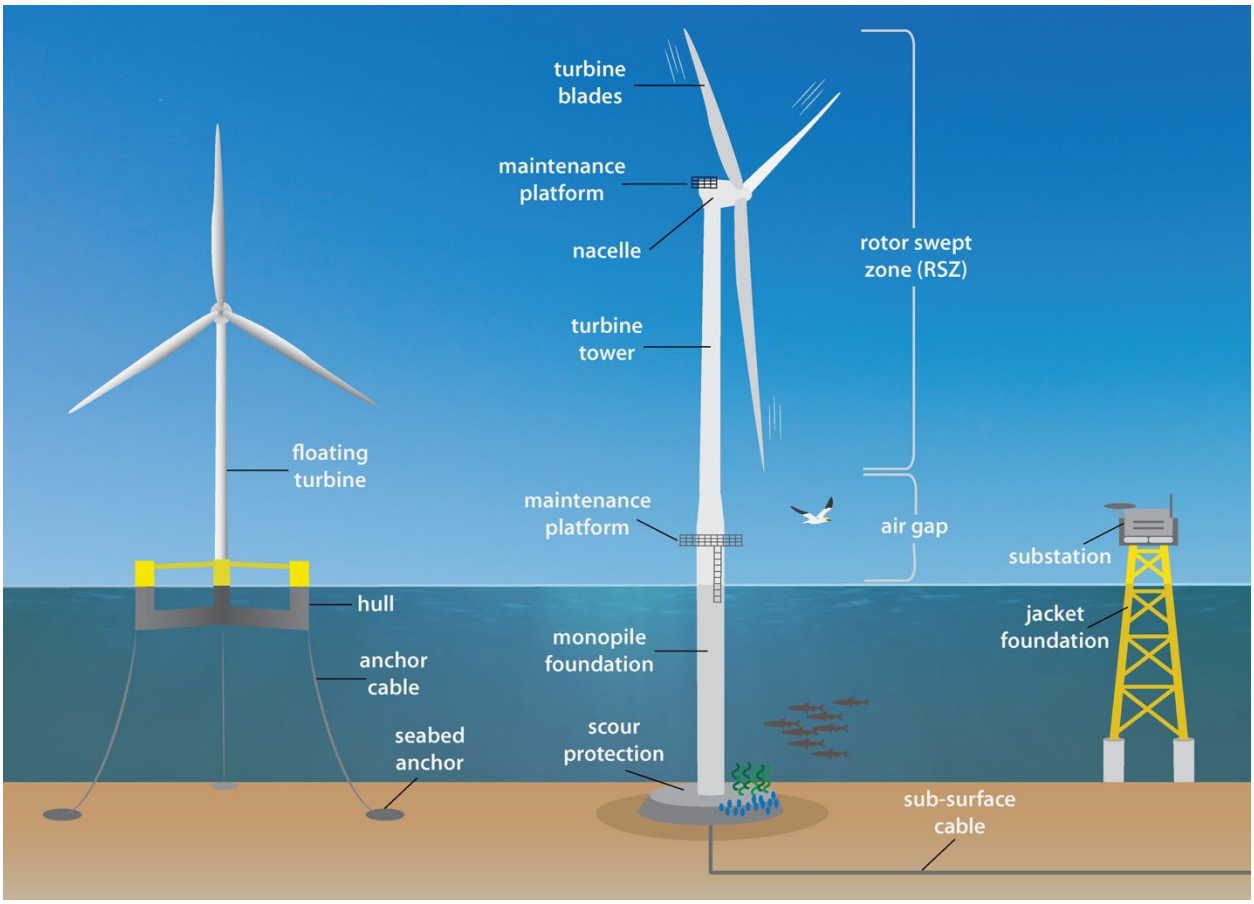

Figure 3. Floating and fixed foundation (monopile and jacket examples) components of offshore wind facilities. "Rotor-swept zone" (RSZ) describes the area in which the turbine blades spin, and "air gap" describes the air space between the bottom of the RSZ and the sea surface. Source: Biodiversity Research Institute.

Detailed Answer

Offshore wind facilities comprise several offshore and onshore structures that are physically connected by a network of subsea cables (typically buried in the seafloor). Mechanical wind energy is harnessed and converted to electrical energy via blade rotation at multiple linked offshore turbines (Figure 3).[4] Electricity is collected and prepared for transmission at offshore substations, then transported via subsea export cables to an onshore substation, where the energy is integrated into the electrical grid (Figure 4). The configuration and design of each wind facility is site-specific, depending on physical characteristics of the site, available technologies and components, and other factors.

Fixed-foundation turbine designs have several important components (Figure 3), including the turbine foundation, which is directly installed on the seafloor. When needed, scour protection, such as rocks or concrete mattresses, prevents erosion of the seabed around the foundation. The foundation is connected to a tower, which extends skyward from the sea surface and supports the

[4] NYSERDA: Offshore Wind 101

rotating pieces of the structure.[5] There may also be a work platform that sits between 0–30 m (0–98 ft) above sea level on the tower, and includes a landing area for boats, ladders, handrails, and other equipment required for maintenance. The nacelle is on top of the tower; it houses a maintenance platform and the components that transfer mechanical power from the rotating hub and blades into electrical energy. The blades extend from and rotate around the hub, which houses the system that controls blade pitch and rotation speed.

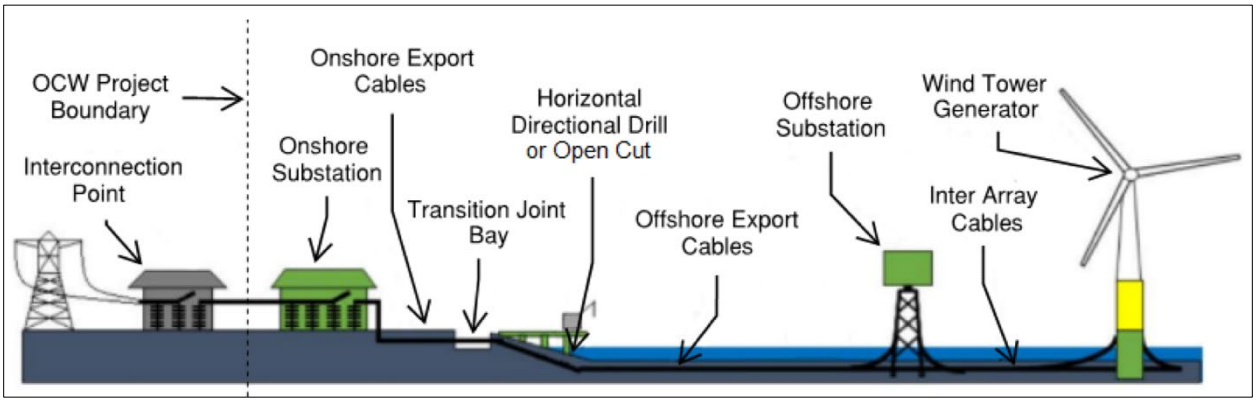

Figure 4. Diagram of main offshore wind project components. Source: HDR (https://media.fisheries.noaa.gov/2022-03/OceanWind1OWF_2022_508APP_OPR1.pdf).

Though turbines and offshore substations have typically been secured to large poles (monopiles) driven into the seafloor through **pile driving**, developers have explored a range of other foundation types, such as suction bucket, piled jacket, and gravity-based foundations, whose use typically depends on the seabed type (e.g., rocky vs. sandy), water depth, supply chain availability, and other factors. As of March 2026, offshore wind projects deployed in the U.S. have only used monopile and jacket foundation types, though a proposed research array in the Gulf of Maine could potentially deploy up to 12 floating offshore wind turbines.[6] Floating offshore wind turbines are newer, with several designs in use at pilot projects around the world; as of March 2026, the largest floating offshore wind facility consists of 11 turbines in Norway.[7] Floating turbines include varied in-water structures that support the tower and are connected to large cabling systems anchored to the seafloor (Figure 3). Traditional turbine designs can be only installed in depths of less than 50 m (164 ft), and are typically installed in <30 m (98 ft) of water; floating wind turbines can be deployed in depths up to about 300 m (984 ft) (Lin et al. 2021) that would otherwise be inaccessible (e.g., most of the Gulf of Maine, the U.S. West Coast, and some areas of the U.S. Atlantic Continental Shelf).[8]

Offshore wind turbine size and facility footprints can vary greatly. As turbines increase in size, the energy capacity per unit of footprint is increasing (Wiser et al. 2023). Turbine capacity, blade diameter, and height of the structures have all increased steadily in the last 20 years, both on land and in marine environments (Figure 5), which increases efficiency of energy generation and influences the potential effects on wildlife and the marine environment. In addition, the cost per

[5] More information: Offshore support structures
[6] BOEM: State of Maine Research Lease
[7] Equinor: Hywind Tampen
[8] NYSERDA: Offshore Wind Powers New York

unit of energy has typically decreased as the offshore wind facility size increases, driving the expansion of both turbine size and facility size (Shields et al. 2021).

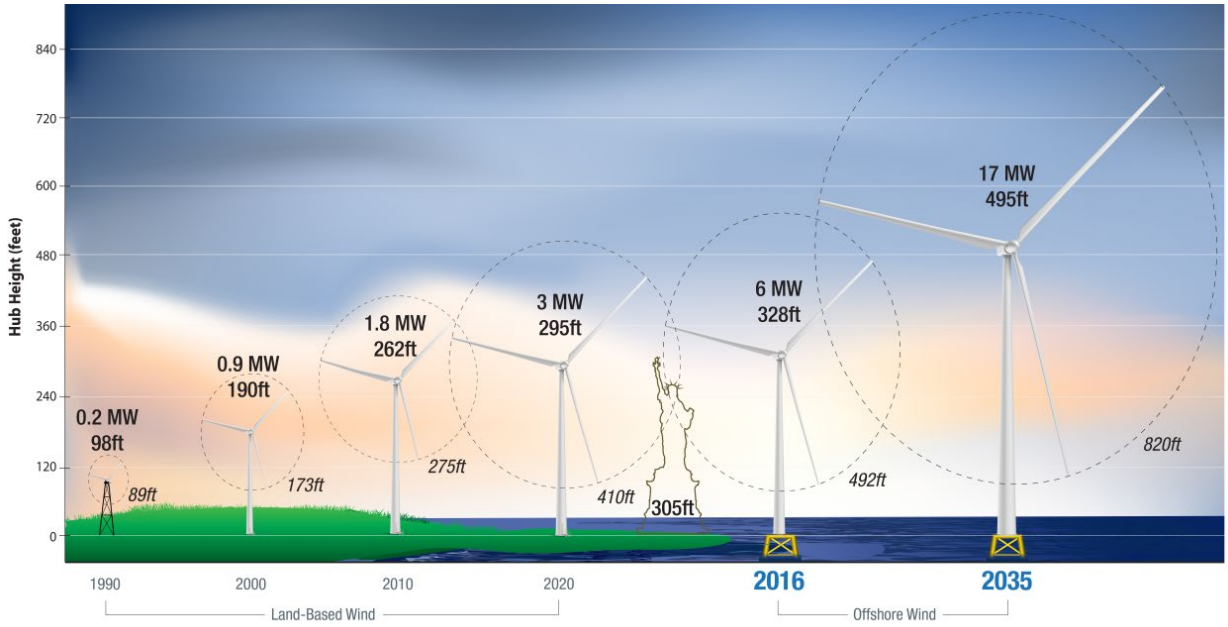

Figure 5. Illustration of increasing turbine heights and blade lengths over time. Source: U.S. Department of Energy (https://www.energy.gov/eere/articles/wind-turbines-bigger-better).

For More Information

- NYSERDA: Offshore Wind 101
- Ørsted: Constructing an offshore wind farm (video)
- BVG Associates: Guide to an Offshore Wind facility
- U.S. Department of Energy: Wind Turbines: the Bigger, the Better

Where and when are birds found in U.S. Atlantic offshore environments?

- Birds use offshore environments for various activities such as **foraging**, resting, overwintering, and migrating. **Seabirds** can be found in offshore environments year-round, but the types, numbers, and density of species vary seasonally and geographically.
- **Songbirds** and other primarily terrestrial species can occur in large numbers over the ocean, especially during **migration**. When, where, and at what altitudes these birds fly offshore varies by species.
- When birds are offshore, their locations are behavior-specific and depend on multiple factors. Seabird **distributions** are driven in part by their nesting locations (in breeding season) as well as by prey availability and distribution. Migrating **shorebirds** and songbirds are more influenced by weather and **staging** (migratory stopover), breeding, and overwintering locations.
- Seasonal distribution models are available for 49 **marine bird** species, providing information about when and where birds are found in the U.S. Atlantic region. The

distribution models indicate that the relative density of marine birds is highest nearshore and decreases beyond approximately 10 km from land.

Detailed Answer

Worldwide, many bird species depend on offshore environments during one or more stages of their life. Offshore environments are used by **seabirds** year-round, but are also used by **shorebirds**, **songbirds**, **wading birds**, and **raptors** for **migration** and/or **foraging** (Robinson Willmot et al. 2013, Kelsey et al. 2025). The timing of when birds use offshore environments can vary greatly. For example, some birds migrate and forage offshore during the day, while other species may do so at night (Kelsey et al. 2025). Additionally, some species may use offshore environments during certain parts of their migration (e.g., northward versus southward migration).

Eighty-three **marine bird** species are known to occur along the U.S. Atlantic coast either seasonally or year-round. These species include gulls, sea ducks, phalaropes, auks, jaegers, terns, loons, shearwaters, petrels, storm-petrels, gannets, and cormorants (Nisbet et al. 2013). The composition of species found offshore changes considerably throughout the year, largely driven by **life history** stage (i.e., whether birds are breeding, migrating, or overwintering) and the **distribution** of resources. For example, Great Black-backed Gulls breed on coastal islands, have residential **populations** in the northeast U.S. and Canada, and therefore use offshore waters in the U.S. Atlantic year-round (Figure 6). In contrast, Northern Gannets breed exclusively in Atlantic Canada and migrate through the U.S. Atlantic in the fall and spring, using offshore areas predominantly during the winter (Figure 7).

In general, migrant and wintering marine birds are more abundant along the U.S. Atlantic coast than breeding birds (Nisbet et al. 2013). This is because the U.S. Atlantic shelf does not serve as a primary breeding ground for most marine species; instead, many breed in Atlantic Canada, the Arctic, or the Antarctic during the austral winter, and only occupy U.S. Atlantic offshore waters outside of the breeding season. Shorebirds, songbirds, raptors, and wading birds are most likely to be found offshore in the U.S. Atlantic during fall and spring migration, when some species make long migratory flights over the ocean. Even primarily terrestrial/coastal species will fly offshore when weather conditions are favorable, leading to hundreds of millions of migrants passing over the U.S. Atlantic throughout migration seasons (Dokter et al. 2018).

Several species of shorebirds listed under the Endangered Species Act, including Piping Plovers and Red Knots, migrate through offshore environments in the U.S. Atlantic in the fall and spring (see *What federal environmental laws and international agreements protect birds?*). The Atlantic Flyway population of Piping Plovers primarily breeds on beaches along the Canadian and U.S. Atlantic coast (Loring et al. 2019), whereas Red Knots breed in the Arctic but use coastal **staging** areas along the U.S. Atlantic in the spring and fall (Loring et al. 2018). In addition to geographic variation in species presence offshore, vertical airspace is used differently across species based on flight height and behavior. For example, Red-necked Phalaropes may rest in large numbers on the water's surface throughout the winter, while migratory songbirds can fly at altitudes up to several thousand meters over the ocean (Bulte et al. 2014, Curley et al. 2025).

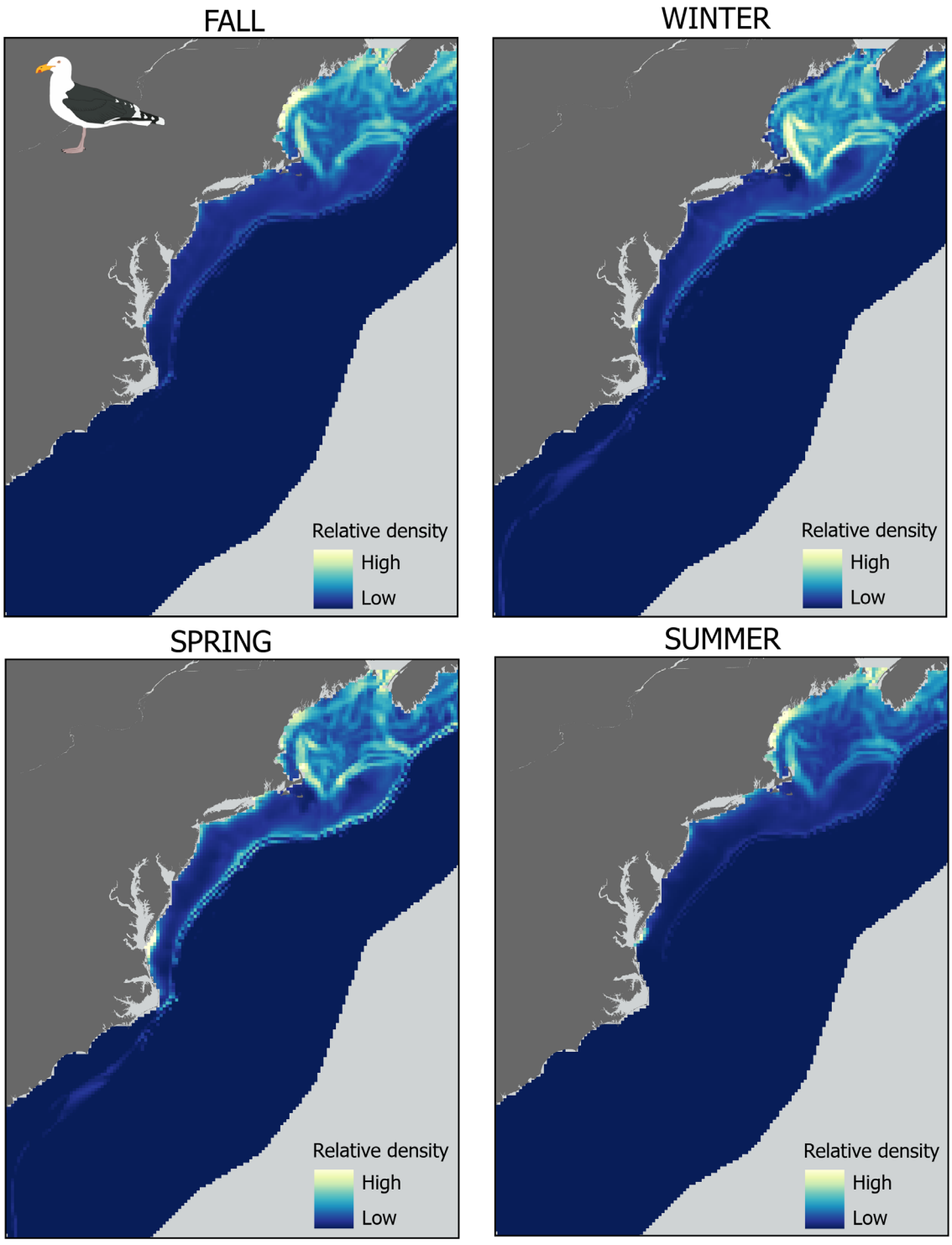

Figure 6. Predicted relative density of Great Black-backed Gulls by season (relative density represents hotspots for comparison between areas and does not represent total counts per unit area). Relative density is generated from model-based estimates of relative abundance fit separately for each species, accounting for differences in survey platforms, interannual variation, and environmental conditions. Data source: Winship et al. 2023. Art credit: Aliya Caldwell.

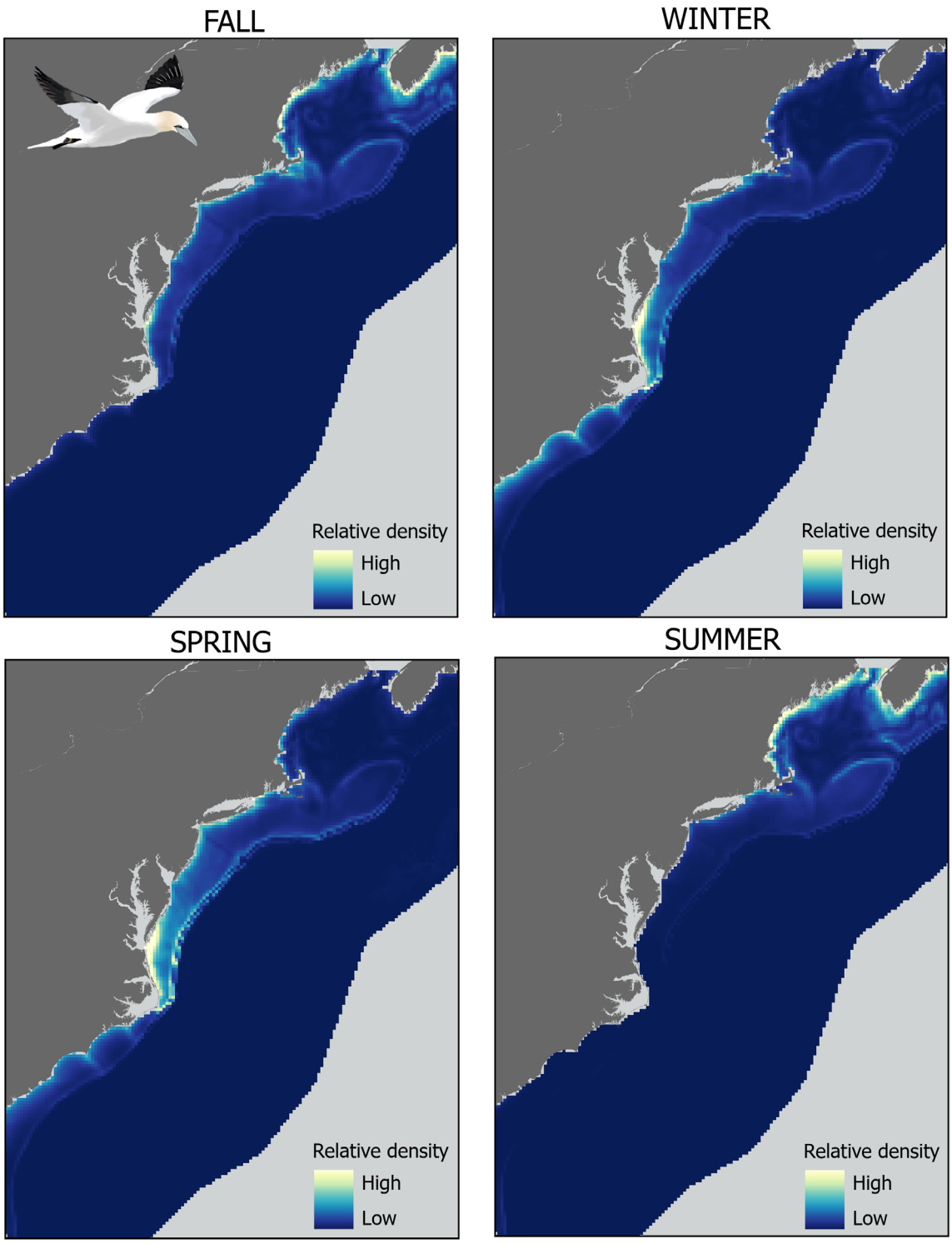

Figure 7. Predicted relative density of Northern Gannets by season (relative density represents hotspots for comparison between areas and does not represent total counts per unit area). Relative density is generated from model-based estimates of relative abundance fit separately for each species, accounting for differences in survey platforms, interannual variation, and environmental conditions. Data source: Winship et al. 2023.

Much of what is known about seabird distributions in the U.S. Atlantic comes from **visual observations** and photo/video surveys conducted from vessels and planes (see *How is bird monitoring conducted at offshore wind facilities?*). These datasets have been used collectively to create spatial models showing seasonal patterns of relative density for 49 marine bird species across the Atlantic Outer Continental Shelf (OCS; Winship et al. 2018, 2023). The models show steep declines in relative density after approximately 10 km from land (Figure 8). Additional studies have assessed marine bird distributions and abundance in specific subregions of the U.S. Atlantic offshore environment, and more recent tracking studies have further advanced understanding of **habitat** use and movement patterns across the Atlantic OCS (Williams et al. 2024). Unlike seabirds, coastal and terrestrial species are generally present offshore during spring and fall migration only, making them much harder to detect with visual surveys. For this reason, tracking (i.e., tag-based) data, along with complementary technologies like radar, are especially valuable for understanding when, where, and how many migratory birds occur offshore during these critical periods of the year (Curley et al. 2025).

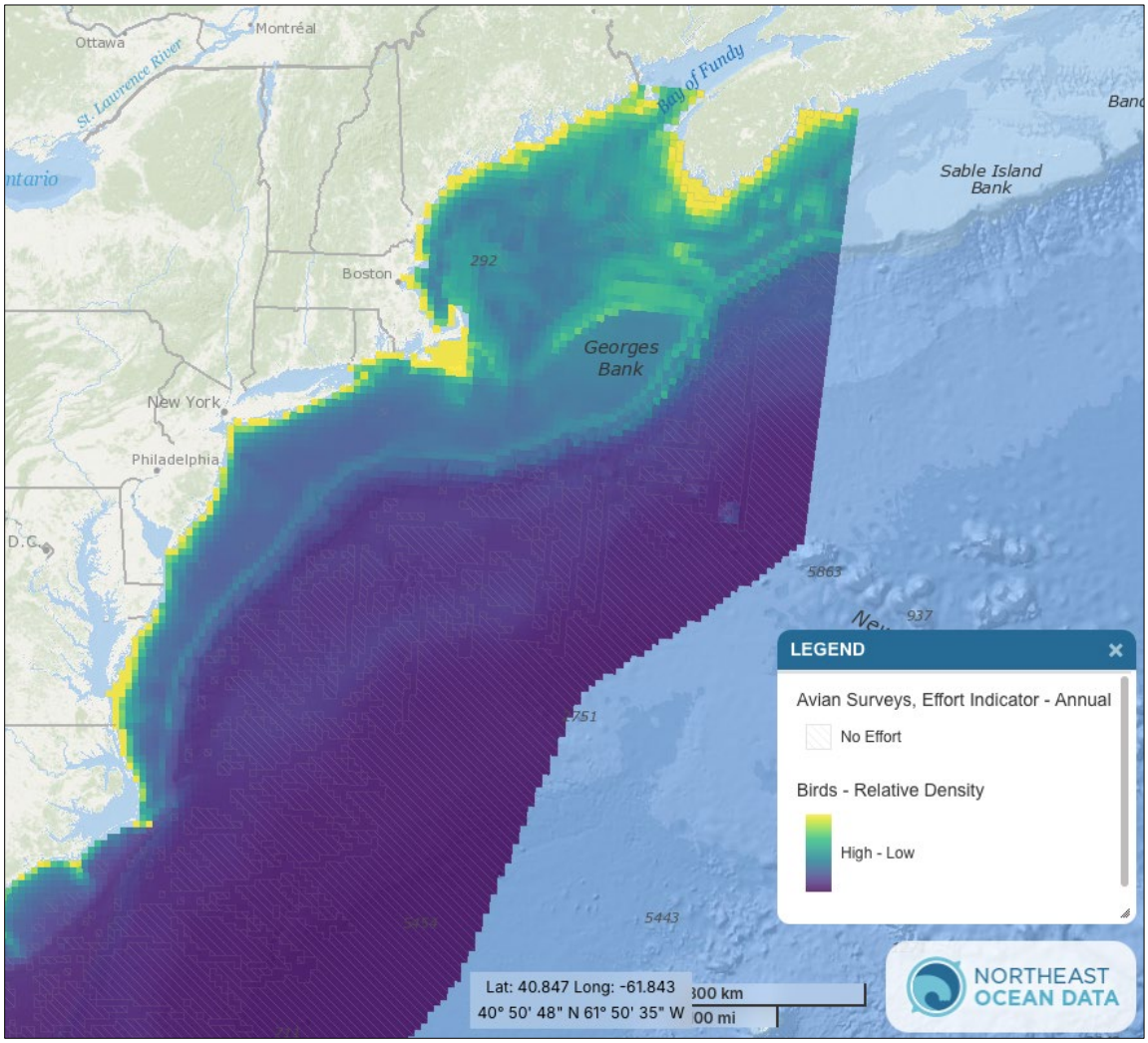

Figure 8. Relative density of 49 bird species in the U.S. Atlantic (relative density represents hotspots for comparison between areas and does not represent total counts per unit area). Source: Northeast Ocean Data Portal (https://www.northeastoceandata.org).

The Northwest Atlantic Seabird Catalog[9, 10] was established in 2005 to inform coastal and offshore planning. It serves as a comprehensive database of hundreds of marine bird species and species groups, centralizing aerial and boat-based survey data from government agencies, scientists, and the wind energy industry. Other publicly available repositories of large datasets of bird distributions or related data products include the Ocean Biodiversity Information System,[11] the Northeast Ocean Data Portal,[12] and the Northeast Marine Mapping Tool.[13] Tracking data repositories such as Motus[14] and Movebank[15] are widely used to explore animal movement data from tagged individuals.

While existing surveys and tracking data provide valuable insights into species distributions, abundance, and movements, substantial knowledge gaps remain. It is challenging to estimate bird abundance offshore as their distributions are highly variable over time and can appear more aggregated or unevenly distributed compared to on land, especially when assessed via boat-based surveys (Goyert et al. 2015). Furthermore, gathering information on birds offshore requires extensive effort both logistically and financially. Current datasets often lack the spatial and temporal resolution needed to fully identify the environmental drivers of bird distributions offshore and how these patterns are changing over time and space, especially in response to **climate change** (Williams et al. 2024) and offshore wind development. Despite these limitations, avian biologists have successfully used available data to estimate the relative vulnerability of birds to offshore energy development for both the U.S. Atlantic and Pacific coasts (Robinson Willmot et al. 2013, Kelsey et al. 2025).

What factors determine risk to birds from offshore wind development?

- Potential effects on birds from offshore wind are evaluated based on a combination of exposure (e.g., overlap in space/time between birds and wind facilities), **effectors** (the threat[s] posed by the wind facility), and vulnerability (e.g., how susceptible an individual bird or the bird species is to the threat). All three factors contribute to overall risk.
- Attributes of individual offshore wind facilities (including the physical presence of structures, associated lighting, and vessel traffic) can change **habitat**, resources, and **foraging** conditions. These shifts may exert positive, neutral, or negative effects on the surrounding ecosystem, and effects may change over the construction and operational periods of an offshore wind facility.
- Various bird **life history** characteristics such as flight height, body size, flexibility of habitat use, and migration strategy factor into the potential level of risk posed by offshore wind development across individuals, **populations**, and species.

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[9] U.S. Fish and Wildlife Service: Northwest Atlantic Seabird Catalog
[10] BOEM Environmental Studies Program: Maintenance of the Northwest Atlantic Seabird Catalog
[11] Ocean Biodiversity Information System: Mapper
[12] Northeast Ocean Data: Maps, data, and information for ocean planning in the northeastern United States
[13] The Nature Conservancy: Northeast Marine Mapping Tool
[14] Motus: All species
[15] Movebank: For animal tracking data

Detailed Answer

Potential risks to birds from offshore wind facilities are evaluated based on a combination of exposure, **effectors**, and vulnerability (Figure 9; Crichton 1999, Goodale & Milman 2016, Williams et al. 2024). Exposure describes whether animals overlap with the effector in space and time. This may include overlap in the **distribution** and/or flight altitudes of a species with the **rotor-swept zones** of wind turbines. Animals exposed to offshore wind facilities may be impacted by specific components of a wind facility and its surroundings (Southall et al. 2021) which results in the component becoming an effector; effectors are also commonly called "stressors," "hazards," "conditions and stimuli," and "impact-producing factors"). Potential effectors are attributes of the offshore wind facility, such as the physical presence of structures, associated lighting and vessel traffic, that have consequences for **habitat**, resources, or **foraging** conditions of benthic and pelagic ecosystems that may cause a response by individuals. Effectors may influence animals in either a positive or negative way, including changing behavior, movement patterns, and resource use. The ways that animals respond to effectors may also change over the construction and operational periods of an offshore wind facility as conditions change.

The third component of risk that determines potential effects is the vulnerability of exposed animals to specific effectors. Vulnerability encompasses (1) individual sensitivity to effects, which is driven by factors such as individual behavior (e.g., flight height, time spent conducting various activities), **morphology** (e.g., size, maneuverability), response to disturbance, and habitat flexibility, among other factors; and (2) **population** sensitivity, defined by the population characteristics, such as conservation status and **demographic parameters**. How effects from offshore wind on individuals may translate into population-level impacts helps determine vulnerability. Threatened and endangered species or species that are slow-growing, long-lived, and produce few offspring can be more vulnerable to some types of **anthropogenic** effectors. Not all individual risks become population risks—to affect the population/species, enough individual birds must be affected so that the structure of the population changes (e.g., through reduced survival or **reproductive success**).

There are three primary effects of interest on birds from offshore wind facilities (see *What are the types of potential effects to birds from offshore wind energy development?*):

(1) collision mortality;
(2) behavioral response; and
(3) effects mediated by changes in habitat and prey.

Each of these effects can lead, individually or collectively, to a range of ecological effects, physiological and **energetic costs**, and the potential for changes in fitness (e.g., changes in survival or reproductive success). Collisions can lead to direct mortality of individuals, but most other effects from offshore wind development are non-lethal, such as potential energetic costs due to changes in prey availability or foraging success that may have downstream impacts on birds. By understanding energetic and physiological costs and fitness effects for individuals and groups, potential population-level consequences that include changes in population size and structure can begin to be understood. Environmental drivers including **oceanographic**, meteorological, and climatological processes interact with baseline distributions of prey and other resources, which can influence the types and degree of risk posed by offshore wind energy development.

Understanding the influence of these drivers can help to disentangle potential impacts of offshore wind from the effects of other larger scale human impacts, such as **climate change**/severe weather, fisheries, and **invasive species** (Dias et al. 2019).

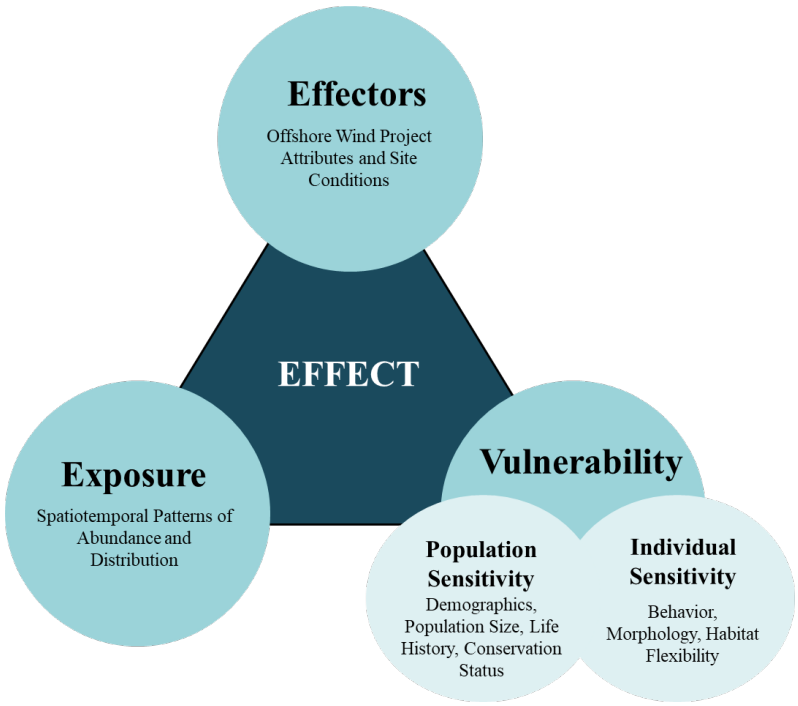

Figure 9. Main factors that determine the effects to birds from offshore wind energy development. Impacts are determined based on a combination of exposure, effectors, and vulnerability (modified from Crichton 1999, Goodale & Milman 2016). Figure adapted from Williams et al. 2024.

How does offshore wind development compare to other sources of bird mortality?

- There are many human-related sources of bird mortality that are broad in scope and challenging to measure, including **climate change** and **habitat** loss. Other sources of direct mortality include collisions, fisheries **bycatch**, and **invasive species**, which, in some cases, can be measured more easily.
- The scale of bird mortalities in the U.S. varies by source. On land, the leading direct cause of bird mortality is domestic cat predation (billions of annual mortalities). Collisions with buildings, automobiles, and power lines, along with interactions with oil pits, each additionally cause millions of annual bird mortalities. **Seabirds** also face many threats, with fisheries bycatch, invasive species, and climate change as top sources of mortality.
- Much less is known about potential bird mortality from U.S. offshore wind development, given the nascency of the industry and the difficulty of counting birds that collide with offshore infrastructure and fall into the ocean. European models for the heavily developed

North Sea estimate bird collisions in the tens of thousands per year for planned 2030 buildout of this region. However, there is a great deal of uncertainty in these modeled estimates and offshore wind turbine collisions are thought to be much rarer than at land-based wind facilities. Bird mortality from offshore wind development needs to be balanced with the benefits of renewable energy in reducing climate change, as climate change is a leading cause of bird **population** declines globally.

Detailed Answer

There is a global **biodiversity** crisis in which animals are being driven to extinction by **habitat** loss, **climate change**, and other human activities (IPBES 2019). As part of this global pattern, North American bird **populations** were estimated in 2019 to have declined by 29% since the 1970s (Rosenberg et al. 2019). Since the 2019 study, many populations have continued to decline at varying levels by taxonomic group (North American Bird Conservation Initiative 2025). There are many **anthropogenic** sources of bird mortality that affect different groups of birds to varying degrees. It is important to accurately estimate bird mortality associated with offshore wind development and other anthropogenic threats (but see Limitations in Estimates section below), and the efforts being made to keep bird mortality at offshore wind facilities low. The scale of bird mortality from offshore wind should also be considered in the context of other sources of bird mortality and the need for renewable energy to combat climate change impacts to birds (see *Why should we care about birds and offshore wind development?*).

Indirect effects, such as habitat loss and climate change, can be more challenging to quantify compared with direct sources of mortality like collisions and fisheries **bycatch**, where it may be possible to calculate the raw number of mortalities. However, the number of mortalities alone is not enough to understand the potential impact of these mortalities on populations and species. Species that have smaller populations, particularly those that are threatened or endangered, may be more sensitive to small changes in mortality rates compared with more abundant species. In addition, species have different reproductive strategies—some species, like many **songbirds**, are shorter-lived and produce many offspring each year, while others, like **seabirds**, are longer-lived and slow-breeding, producing only one or a small number of offspring per year. As such, even small increases in mortality of seabirds may have a larger impact on the population size of species.

Climate Change and Habitat Loss

The effects of climate change and the destruction of natural habitats via human activities are two of the greatest threats to biodiversity broadly (Jetz et al. 2007). Climate change and habitat loss are also leading causes of bird population declines (Wilsey et al. 2019), affecting both landbirds and seabirds. Many groups of landbirds have shown population declines attributed to changing environmental conditions (e.g., wildfires, droughts) that are exacerbated with climate change (North American Bird Conservation Initiative 2025) and habitat loss (e.g., agricultural conversion, industrial timber management). Seabirds are one of the most threatened groups of birds (Croxall et al. 2012), with populations facing many threats related to climate change. These threats can include marine heatwaves, sea level rise, and ocean acidification, and can negatively affect both seabirds and their prey (Seavy et al. 2025). Directly quantifying the effects of climate change and habitat loss on bird mortality is challenging. In the absence of direct measures (e.g., carcasses, tracking long-term survival) to quantify effects, researchers have modeled a range of climate scenarios to examine how climate change and habitat loss affect the size of species ranges as an

indicator of risk. Jetz et al. (2007) found that across bird species globally, expected range contraction by the year 2050 varies between 21–26%, and in more extreme climate and habitat loss scenarios, ~400–900 bird species are projected to have over 50% of their current range transformed to a different habitat by 2050. Another similar study focused on climate change alone predicted that 15–37% of species would be headed to extinction by 2050 based on moderate climate warming scenarios (Thomas et al. 2004).

Collisions

While habitat loss and climate change are broad-scale factors influencing bird populations, several additional anthropogenic stressors directly and cumulatively kill billions of birds each year in the U.S. (Loss et al. 2015). Direct sources of mortality include interactions with oil pits and collisions with buildings, vehicles, power lines, communications towers, and onshore wind turbines. Understanding terrestrial sources of mortality can help put collision risk from offshore wind development into context. However, it is important to note that collisions on land primarily affect songbirds and **raptors**, though coastal facilities also have the potential to affect seabirds; in offshore environments, seabirds and **shorebirds** have greater collision risk relative to other groups of birds (Kaplan 2024). The raw number of mortalities is not the only consideration—how individual effects can influence total population size and how estimates may change over time as industries and the global human population continue to grow should also be considered.

The scale of collision-related mortality in the U.S. varies; hundreds of millions of birds die from collisions with buildings and vehicles every year, tens of millions by collisions with power lines, millions by power line electrocutions and communication tower collisions, and hundreds of thousands by land-based wind turbine collisions (Table 1, Figure 10; Loss et al. 2015). There are variable levels of uncertainty in these estimates, with lower uncertainty for some industries like onshore wind that are more closely monitored compared to collisions with buildings, where estimates are extrapolated from small-scale studies due to lack of large-scale monitoring.

Collision-related mortality estimates are the best available science but are now over a decade old. Thus, mortality estimates are expected to increase as the causes scale with human population growth (e.g., number of buildings, cars)[16] and expanded infrastructure and development (e.g., power generation).[17] The causes of mortality also affect different groups of birds to varying degrees. Collisions with buildings and communications towers primarily affect migratory **passerines**, particularly those that migrate long distances and at night (compared with year-round resident species and those that migrate during the day; Arnold & Zink 2011; Loss et al. 2015). Bird mortality at power lines can occur due to both collisions and electrocutions, and most likely affect larger-bodied species that are less maneuverable (e.g., **waterfowl**, grouse) or species that are more likely to perch on power poles (e.g., raptors; Loss et al. 2014). Relatively few well-designed studies have examined vehicle collisions, so less is known about how various groups are affected, though some studies have found high instances of collision mortality in owls and corvids (e.g., ravens, crows, magpies; Loss et al. 2014).

[16] Statista: Number of motor vehicles registered in the United States from 1990 to 2023
[17] Statista: Number of housing units and annual percentage increase in the United States from 1975 to 2024

Table 1. Estimates of annual collision-related bird mortality from direct anthropogenic stressors in the U.S. and Canada based on quantitative studies. Best estimates are medians or means (latter indicated by *). Ranges represent minimum to maximum values (indicated by *) or uncertainties as 90-95% confidence intervals associated with best estimates. Source: Loss et al. 2015.

Collision Mortality Source	Country	Best Estimate	Range or Uncertainty
Buildings	U.S.	599,000,000	365,000,000–988,000,000
	Canada	24,900,000*	16,100,000–42,200,000*
Automobiles	U.S.	199,600,000	88,700,000–339,800,000
	Canada	25,600,000*	10,100,000–41,200,000
Communications towers	U.S.	6,581,945*	Not available
	Canada	220,650*	Not available
Power line electrocution	U.S.	5,630,000	920,000–11,550,000
	Canada	16,700*	3,330–21,600*
Land-based wind turbines	U.S.	573,093*	467,097–679,089
	Canada	16,700*	13,330–21,600

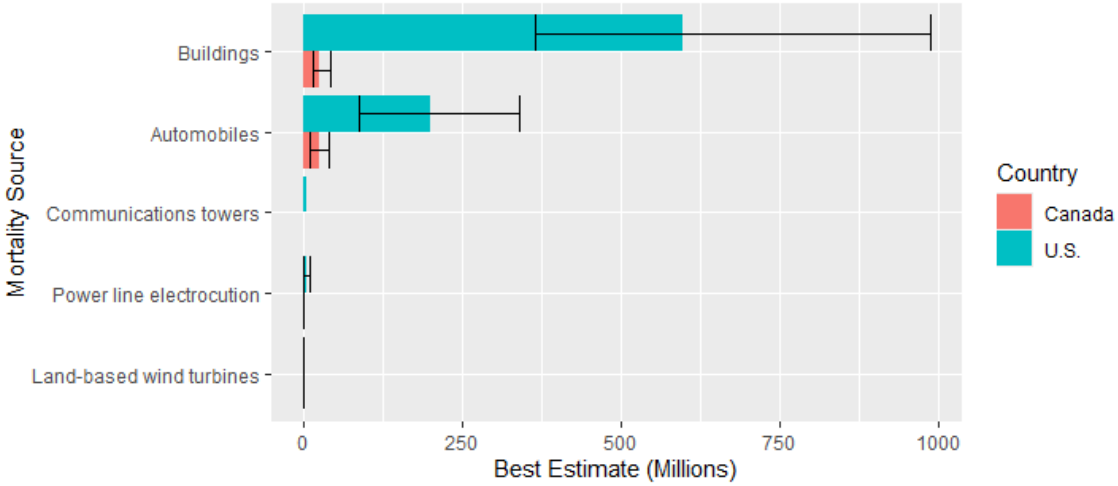

Figure 10. Comparison of major sources of anthropogenic collision-based annual bird mortality estimates for the U.S. and Canada from terrestrial sources. Wind turbines in this figure only include land-based turbines. Error bars (black) represent the estimated uncertainty (see Table 1 for uncertainty type by mortality source). Adapted from Loss et al. (2015).

In the U.S., land-based wind development began in the 1980s, and additional wind facilities continue to be built. In 2022, it was estimated that this industry included 70,800 turbines from approximately 1,500 wind power projects spanning at least 44 states.[18] A review of data from 71 land-based wind facilities estimated annual U.S. mortality at between 420,000 and 644,000 birds (Smallwood 2013). Another study from 67 land-based facilities estimated annual U.S. mortality

[18] U.S. Geological Survey: tracks installed turbines from both land-based and offshore wind projects in The U.S. Wind Turbine Database

from newer monopile (e.g., single pole) turbines at between 140,000 and 328,000 birds (Loss et al. 2013a; see *What are the major components of an offshore wind facility?*). There has been continued growth in the industry since these studies were conducted. For example, U.S. onshore wind capacity grew from 45 GW in 2010 to 147 GW in 2023, representing an average 10% annual increase.[19] Mortality estimates can be expected to have increased accordingly, though changes in various project details (e.g., size of turbines, mitigation measures taken by the industry) may influence the relative change in mortality estimates. Songbirds account for approximately 57% of avian fatalities reported at U.S. wind facilities, while diurnal raptors account for approximately 7% (Erickson et al. 2014). This mortality rate is higher than expected for raptors given their population density. These findings have spurred mitigation responses by government agencies, advocacy groups, and industry, particularly for Bald and Golden eagles given their federal status.

As onshore wind facility bird mortality estimates are over a decade old, continued large-scale research is needed to combine post-construction **monitoring** data across projects and improve our understanding of variability in mortality estimates that inform siting, management, and policy development related to the growing industry. The industry is continuing to monitor and **mitigate** collision risk to birds, following federal guidelines via informed siting of projects to avoid important habitats and technology development, among other efforts (USFWS 2012).

Offshore wind is a much newer industry in the U.S., with only three small-scale operational wind facilities and several others under construction (as of March 2026). However, offshore wind is a well-established industry in Europe and other parts of the world, with more than 13,000 operating offshore wind turbines in 319 operating projects (at the end of 2023; McCoy et al. 2024). Directly measuring rare events of birds colliding with offshore wind turbines and estimating accurate collision mortality in ocean environments is challenging (see *How do we assess the risk of birds colliding with offshore wind turbines?* and *What do we know about frequency of bird collisions at offshore wind facilities?)*. Challenges lead to higher uncertainty in estimates compared to onshore wind, where mortalities are more easily quantified. Several studies at U.S. offshore wind facilities have used cameras and other technologies to try to assess bird behaviors around wind turbines. These studies have not observed any collisions to date, but the spatiotemporal scope of these studies is limited (Robinson Willmott et al. 2023, Skov 2024).

Much of the knowledge about potential collision risk comes from Europe, where the offshore wind industry has been operating for over three decades. In an effort to understand potential cumulative mortality of offshore wind development more broadly, Potiek et al. (2022) estimated the number of collisions that could occur at all operational, planned, and proposed wind facilities in the southern North Sea through 2030 for seabirds (10 species) and migrants (8 species) considered most vulnerable to possible population impacts from collision mortality (see *What factors determine risk to birds from offshore wind development?*). Combined, these models estimated approximately 38,000 collision-based mortalities per year across these 18 vulnerable species across all North Sea projects, which includes over 8,800 turbines across 130 built and planned projects (Potiek et al. 2022). It is important to note that these are modeled estimates, and these statistical models have high levels of uncertainty with little validation ability (see *How do we assess the risk of birds colliding with offshore wind turbines?*). Importantly, the scale of the planned North Sea buildout of

[19] U.S. Energy Information Administration: Preliminary Monthly Electric Generator Inventory

offshore wind turbines is far greater than what is currently planned for U.S. waters (based on existing federal lease areas) and thus the scale of projected collision mortality does not apply equally to the U.S. context.

Fisheries Bycatch

Fisheries bycatch (i.e., the accidental capture of birds in fishing nets) is the human-induced threat affecting the largest number of seabirds worldwide (Dias et al. 2019). Ellis et al. (2013) found that gillnet fisheries were responsible for most seabird bycatch in Canadian waters (Atlantic and Pacific), followed by longline fisheries and bottom otter trawling (a type of fishing net used to catch bottom-dwelling fish and invertebrates by dragging it along the seabed), with approximately 22,000 total annual bird mortalities estimated across gear types. More recently, Hatch (2017) used fisheries observer data from the U.S. Northeast and mid-Atlantic from 1996–2014 to examine seabird interactions (including injuries and mortalities) with commercial fisheries and estimated an average of 2,570 seabird mortalities per year, with more recent recorded bycatch estimates from 2015–2016 and 2017–2019 ranging from 328 to 523 seabirds per year (Sigourney et al. 2019, 2024).

Offshore Oil and Gas Development

In the case of offshore oil and gas development, bird mortality can result from contact with the flames of gas flares, collisions with infrastructure (Sage 1979), and contact with oil from chronic or acute exposures (Fraser et al. 2006, Wilhelm et al. 2007). Ronconi et al. (2015) reviewed existing research on bird interactions with offshore oil and gas structures, including production platforms, drilling rigs, and associated support vessels, and found that in Atlantic Canada, fewer than 100 bird mortalities are reported annually from carcass collections. However, this estimate is based on voluntary incident reporting where recovery rates are unknown and, therefore, reflects a significant underestimate of mortalities (Baillie et al. 2005, Ellis et al. 2013). In the North Sea, some regional estimates of annual bird mortality at offshore oil and gas platforms are as high as 6,000,000 birds (Bruinzeel & van Belle 2010). However, current understanding of the frequency, timing, and duration of bird mortality events in the offshore oil and gas environment is limited (Ronconi et al. 2015).

Invasive Species

Invasive species (i.e., those that are introduced to a new geographic area and cause harm to local **native** species) are a major threat to birds globally (Loss et al. 2015, Dias et al. 2019, Lepczyk et al. 2023). Invasive species can include both wild and domestic animals. There are many examples, particularly on islands, where the introduction of domestic cats, rats, and other **non-native** mammals and reptiles has led to declines and even extinctions of bird populations (Nogales et al. 2013). In the U.S., it is estimated that between 1.3 and 4.0 billion birds are killed annually by domestic cats, making this by far the greatest source of direct mortality for landbird species (Loss et al. 2013b). Invasive species also greatly threaten seabirds (Figure 11); many seabirds breed on historically mammal-free islands and, therefore, have not evolved defensive behaviors. Many seabirds are ground-nesting, mature slowly, and produce few offspring, making them particularly vulnerable to disturbances (Croxall et al. 2012, Jones et al. 2016). Rats and other introduced mammals (e.g., cats, mice, pigs, foxes) feed on seabird eggs, chicks, and adults, and are thought to be responsible for numerous seabird **extirpations** and population declines (Jones et al. 2008). Dias et al. (2019) estimated that more than 175 million seabirds globally are at risk from invasive species, including ~25 million seabirds from globally threatened populations (e.g., listed as Critically Endangered, Endangered, or Vulnerable under IUCN Red List criteria).

Other Sources of Mortality

Birds face many other threats from anthropogenic sources, including chemical pollution and pesticide exposure, plastic ingestion, recreational hunting and trapping, light pollution, interactions with oil pits, and loss of prey/food resources due to human activities (e.g., overfishing and climate impacts; Trail 2006, Dias et al. 2019). Changes in behavior (e.g., avoidance, attraction), habitat use, and resources from offshore wind development and other offshore activities, also have the potential to indirectly affect bird populations (see *What are the types of potential effects to birds from offshore wind development?)*, which is more challenging to quantify than direct mortality but also important to consider. Different effects can combine and potentially interact to negatively influence bird populations.

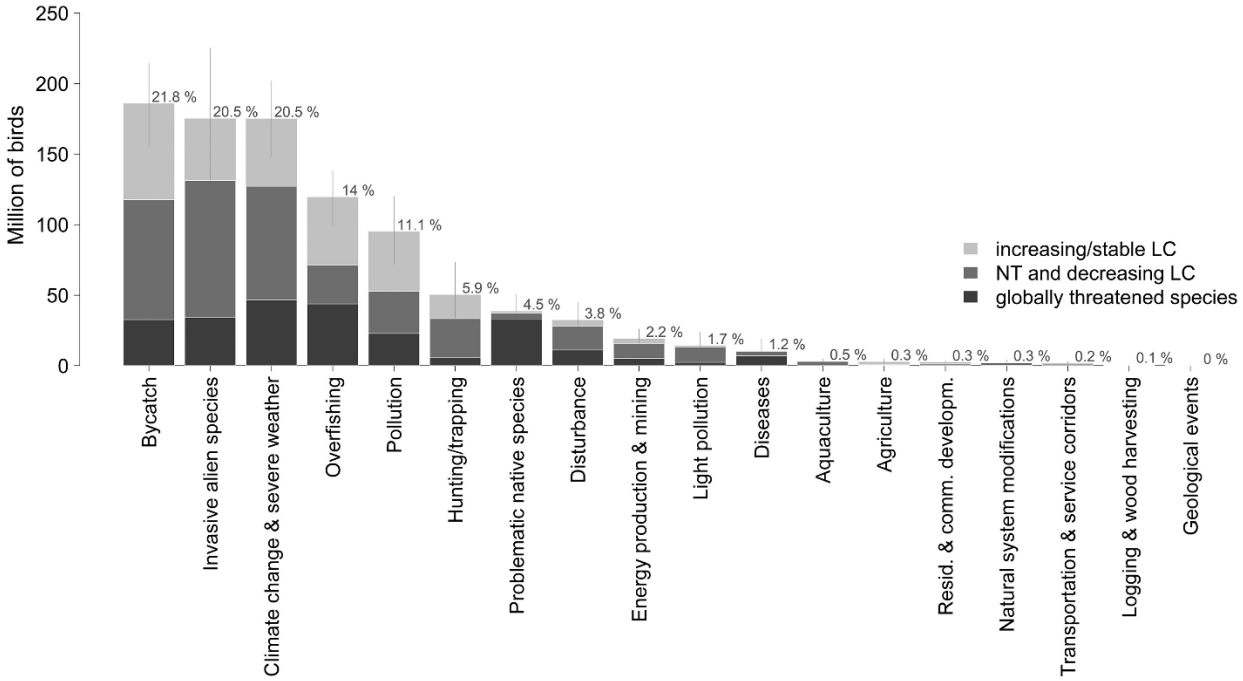

Figure 11. Estimated total number of seabirds exposed to various threats on a global scale. Error bars represent 95% confidence intervals. Values above bars indicate percentage of total number of seabirds affected. LC = IUCN Least Concern, NT = IUCN Near Threatened. Source: Dias et al. 2019. *Note: This study calculated exposure based on population size and proportion of the population exposed; while this is a relative indicator of the impact of various threats, these values do not represent mortality estimates per se. Energy production and mining includes mining and quarrying, oil and gas drilling, and renewable energy.*

Limitations in Estimates

The mortality estimates above are just that—estimates. Calculating accurate bird mortality numbers associated with a given source is complex for reasons that vary by the type of threat. Indirect threats like climate change and habitat loss are especially challenging to quantify, given the difficulty of disentangling their effects from other human-induced pressures. Direct mortality sources, such as collisions and invasive predators, can be more straightforward to measure, though uncertainty persists, particularly where comprehensive monitoring is limited. For example,

estimates for highly dispersed collision-related causes like buildings and vehicles typically rely on small-scale studies extrapolated to larger regions and/or longer time periods. This approach is often the best method available for developing broad mortality estimates for dispersed mortality sources but it can be difficult to assess potential sources of variation influencing mortality rates or **statistical bias** in study design. In addition, mortality events are often episodic and may affect individuals at different life stages (i.e., adults and juveniles) differently, making it challenging to understand the true numbers of mortalities occurring across various stressors and how these values vary (Loss et al. 2015). In some cases, significant efforts have been made to understand mortality rates and address potential bias in mortality estimates, such as at land-based wind facilities, where decades of monitoring have aided in the development of models to more accurately estimate bird collision risk. However, in many cases, further research is needed to improve mortality estimates, particularly as human populations and offshore industries continue to grow.

For More Information

- The Guardian: The Biodiversity Crisis in Numbers
- American Bird Conservancy: Major Threats to Birds
- BirdLife International: Threats to Seabirds

What non-regulatory actions are being done to better understand how birds interact with offshore wind development and support bird conservation?

- Collaborative research efforts like Project Wildlife and Offshore Wind (WOW) bring together cross-sector expertise and resources to address research questions about potential effects of regional offshore wind development on marine wildlife, including **seabirds**. Organizations also invest in developing, testing, and validating new technologies to monitor bird interactions at and around offshore wind facilities.
- Through specialist working groups and committees like the Offshore Wind Environmental Technical Working Group, organizations share knowledge and engage with each other to identify research priorities and to develop guidance, products, and studies that address knowledge gaps about bird interactions with offshore wind development.
- Conferences and workshops like State of the Science on Offshore Energy, Wildlife, and Fisheries and the Conference on Wind Energy and Wildlife Impacts facilitate cross-sector knowledge exchange and engagement among government agencies, the scientific community, conservation groups, and offshore wind developers to share research findings and identify data gaps.
- Many offshore wind developers are also voluntarily committed to achieving net positive impacts. For example, developers conduct conservation or restoration efforts that generate greater ecological benefits than negative environmental effects related to their offshore wind project(s).

Detailed Answer

Understanding bird interactions with offshore wind energy development is a challenging research endeavor given the logistics of working in offshore marine environments and studying highly mobile wildlife. At individual wind facilities, many different methods are used to **monitor** diverse bird species (see *How is bird monitoring conducted at offshore wind facilities?*) to understand potential effects on their densities, **distributions**, and behaviors (see *Does offshore wind development alter birds' behavior, movement patterns, and habitat use?)*.

Beyond monitoring at individual facilities, organizations involved in offshore wind, including developers, academic scientists, conservation organizations, and government agencies, participate in various efforts, including (1) collaborative regional research projects, (2) specialist working groups and committees, (3) conferences and workshops, and 4) voluntary net positive impact (NPI) projects, all of which are aimed at better understanding how birds interact with offshore wind facilities, identifying ways to **mitigate** potential impacts, and supporting bird conservation.

Collaborative Regional Research and Development

Given the potential effects to birds from offshore wind development (see *What are the types of potential effects to birds from offshore wind development?)*, various organizations have recognized a need to better understand bird interactions with offshore wind facilities at a regional scale in the U.S. Atlantic. Voluntary collaborative research projects bring together technical expertise from diverse partners and help maximize resources, standardize data collection so that results are comparable across studies, and address questions across multiple facilities and at regional scales.

One example is Project Wildlife and Offshore Wind (WOW),[20, 21] funded by the U.S. Department of Energy and the Bureau of Ocean Energy Management (BOEM). Led by independent researchers, Project WOW focuses on understanding the effects of the first commercial-scale offshore wind developments in the U.S. Atlantic on **seabirds** and other marine wildlife. This work is facilitated through coordination with and in-kind contributions from offshore wind developers to help with research logistics (e.g., provide site access, deploy equipment, collect and share data, etc.). Project outcomes are intended to provide frameworks for **environmental assessments** at both site-specific and regional scales, supporting the responsible design, development, and management of offshore wind energy in the U.S.

Long-term collaborative initiatives to improve research efforts around offshore wind development have been the product of the more mature offshore wind industry in Europe. For instance, the UK Offshore Renewables Joint Industry Programme (ORJIP) for Offshore Wind[22] supports the funding and logistics of research projects designed to evaluate bird interactions with offshore wind facilities, among other topics. A 2018 ORJIP study[23] characterized different avoidance behaviors of five seabird species of concern around an operational wind facility (Skov et al. 2018). A more recent

[20] Project WOW: https://offshorewind.env.duke.edu/
[21] Tethys Stories: WOW! A Collaboration to Study the Impacts of Offshore Wind on Wildlife
[22] Carbon Trust: ORJIP Overview
[23] Carbon Trust: Bird Collision Avoidance Study

ORJIP project[24] aims to synthesize existing data and develop methods and recommendations to study changes in seabird distributions (i.e., displacement) in relation to offshore wind development and other factors.

Working Group and Committee Engagement

Organizations (e.g., research and conservation organizations, offshore wind developers, state and federal agencies, others), also participate in specialist working groups and committees focused on environmentally responsible offshore wind development, marine environmental topics, and/or birds, which support knowledge and resource sharing among interested groups, help identify broader research or guidance needs, and collaboratively develop informational products or research studies related to offshore wind and its potential environmental impacts. Examples include the Offshore Wind Environmental Technical Working Group,[25] the Regional Wildlife Science Collaborative,[26] the Atlantic Marine Bird Cooperative's Marine Spatial Planning Working Group,[27] and The Wildlife Society's Renewable Energy Working Group,[28] among others.

As an example, the Regional Wild Science Collaborative (RWSC) is a voluntary multi-sector forum comprised of (1) U.S. federal agencies like BOEM, U.S. Fish and Wildlife Service, and National Oceanic and Atmospheric Administration, (2) U.S. Atlantic coast states, (3) offshore wind energy developers, and (4) environmental conservation organizations. The RWSC has developed a science plan to inform ongoing research and data collection efforts centered on topics of offshore wind, wildlife, and **habitat** in U. S. Atlantic waters (Regional Wildlife Science Collaborative 2024). The RWSC is also a coordination hub for facilitating research, identifying data and research needs, and providing a framework for selecting projects to fund through the RWSC. As part of this forum, specialist subcommittees[29] meet regularly and form expert working groups and committees to address specific topic areas and accomplish defined goals. For example, there are two working groups within the RWSC Bird & Bat Subcommittee focused on developing guidance related to assessing changes in **marine bird** distributions and using tracking technology to understand changes in bird movement and behavior in relation to offshore wind development.

Dedicated Conferences and Workshops

Several dedicated conferences and workshops provide opportunities to share research findings and to promote engagement, regional coordination, and collaboration between federal and state agencies, academic institutions, conservation organizations, and energy developers. Examples of recurring conferences include the U.S.-based State of the Science on Offshore Energy, Wildlife, and Fisheries[30] and the Europe-based Conference on Wind Energy and Wildlife Impacts.[31] Conferences and workshops provide collaboration opportunities on efforts to understand, minimize, and **mitigate** the environmental impacts of offshore wind development. Meetings also

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[24] Carbon Trust: Offshore Renewables Joint Industry Programme (ORJIP) for Offshore Wind: Improving understanding of distributional change for relevant seabird species (ImpUDis)
[25] New York State Environmental Technical Working Group: https://www.nyetwg.com/
[26] Regional Wildlife Science Collaborative: https://rwsc.org
[27] Atlantic Marine Bird Cooperative: Working Groups
[28] The Wildlife Society Renewable Energy Working Group: https://wildlife.org/rewg/
[29] Regional Wildlife Science Collaborative: Subcommittees
[30] New York State Environmental Technical Working Group: State of the Science Workshops
[31] Conference on Wind Energy and Wildlife Impacts: https://www.cww2025.org/welcome

help facilitate engagement with organizations involved in international industry who are further along in the wind energy development process and can offer lessons learned based on long-term monitoring datasets and research studies.

Net Positive Impacts

In addition to site-specific monitoring, engaging with regional research projects, and participating in committees and conferences, many offshore wind energy development companies have committed to voluntary "net positive impact" (NPI) efforts aimed at generating ecological benefits or **biodiversity** gains that exceed potential negative environmental impacts or losses due to offshore wind development. These NPI efforts exist in addition to required compensation-based mitigation, which is focused on "no net loss" outcomes for protected species and habitats (see *What is compensatory mitigation and how does it apply to birds and offshore wind?*). NPI approaches can include habitat enhancement, management, or protection to reduce **anthropogenic** pressures and boost **populations** of affected species. NPI efforts have been implemented for UK offshore wind projects and for land-based wind projects in multiple regions. There may also be opportunities to apply NPI in the U.S. offshore wind industry (Jedele et al. 2023). For birds, NPI projects may include **invasive species** removal on critical seabird nesting islands (Croll et al. 2022), managing vegetation at nesting sites, supporting stewardship activities like beach nest monitoring and signage (Seavy et al. 2025), or reducing marine debris and fisheries **bycatch** that generally benefits birds and the marine environment (Jedele et al. 2023). NPI activities aim to benefit bird populations by broadly increasing **reproductive success** and/or survival of individuals.

For More Information

- U.S. Fish and Wildlife: Offshore wind generates new opportunities to track migratory wildlife
- Orsted: Introducing Ørsted's biodiversity measurement framework
- UK Government, Department of Environment, Food, and Rural Affairs: Consultations on the Principles of Marine Net Gain
- UN Global Compact Ocean Stewardship Coalition: Net-Positive Biodiversity in Offshore Renewable Energy: Minimum Criteria and Recommendations for Action

Potential Offshore Wind Effects on Birds

What are the types of potential effects to birds from offshore wind development?

- Potential effects of offshore wind energy development on birds include reducing the detrimental impacts of **climate change**, further physical **habitat** changes, and behavioral changes in birds.
- **Seabird** habitats and prey availability may change with new physical structures in the ocean and disturbance to the seafloor from offshore wind turbine and cable installation, changes to other human activities like fishing, and potential changes in **oceanography**.

- Birds may change their behavior in response to offshore wind structures and activities primarily through attraction or avoidance at various scales.
- Bird collisions are difficult to detect offshore, so **collision risk models** are generally used to estimate collision probability while direct detection methods are developed and validated.
- A combination of these effects, or repeated exposure to one or more effects at one offshore wind facility, or at multiple facilities, may potentially have cumulative effects on birds over space and time.

Detailed Answer

A reduction in greenhouse gas emissions is expected to lessen the consequences of **climate change** (e.g., shifting food webs, altered migration timing and patterns), thereby preserving **habitat** quality over the long term ((Allison et al. 2019, Seavy et al. 2025). Thus, the development of renewable energy sources, including offshore wind, with lower emissions relative to predominant energy sources is critical to reduce bird vulnerability to climate stressors globally and with long term benefit (see *How does offshore wind development compare to other sources of bird mortality?* and *Why should we care about birds and offshore wind development?)*. Regionally and locally, however, the construction of offshore wind turbines can potentially have both positive and negative effects on birds.

As a major component of the marine ecosystem, marine birds are sensitive to changes in the marine environment above and below the sea surface. Terrestrial species that migrate over the ocean, like **shorebirds** and **songbirds**, may also be affected by offshore wind development, primarily due to the presence of above-water structures. The type and extent of potential effects relevant for particular bird species depends on its degree of exposure to a specific **effector** and its vulnerability to that effector (Figure 12; see *What factors determine risk to birds from offshore wind development?*). To be adversely impacted, a species must be both exposed (i.e., be in the same place) and vulnerable (i.e., be sensitive to the effector in a way that poses negative effects on the species). To be positively impacted, a species must be exposed to the effector and measurably benefit from that exposure.

Additional Habitat Changes

Habitat-mediated effects are the result of changes in seabird habitat and prey due to (1) the introduction of new hard surfaces (e.g., turbine foundations) on which barnacles, mussels, and other biofouling organisms can grow, (2) changes in other **anthropogenic** activities in response to offshore wind facility development (e.g., fishing), (3) disturbance to the seabed from turbine and cable installation, and (4) changes in **oceanographic** dynamics, such as currents, wakes, and **upwelling** (Hammar et al. 2016, Methratta & Dardick 2019, Gill et al. 2020, Van Berkel et al. 2020).

Offshore wind facilities can increase local secondary productivity, which includes the density, number of species, and **biomass** of benthic organisms and fishes (Methratta & Dardick 2019, Dannheim et al. 2020, Zupan et al. 2023, Dannheim et al. *in review*). Changes to local benthic and fish communities are driven, in part, by the attachment of fouling organisms (e.g., mussels, barnacles, sea anemones) to submerged sections of turbine structures, which can attract other species (e.g., benthic fishes) to the wind facility by providing new prey resources; this is termed the "artificial reef effect" (Degraer et al. 2020). Although artificial reef effects are well documented, it is unclear if local increases in predators are due to overall increases in their populations or attraction

of existing predators from the surrounding area (Wilhelmsson & Malm 2008, Inger et al. 2009, Mavraki et al. 2020, Zupan et al. 2023). The reduction of specific fishing activities (i.e., trawling) within the wind facility, as is common in European waters, can also change benthic and fish community abundances by reducing repeated habitat disturbance and local fishing pressure (Coates et al. 2016, Buyse et al. 2022).

Offshore wind developments can also indirectly alter seabird distributions via shifts in prey distributions or oceanographic changes. For example, seafloor disturbance due to turbine construction and cable installation may impact the presence, abundance, and/or distribution of species like sand lance, a critical **forage fish** for many seabirds. The presence of offshore wind structures can also alter **stratification** patterns, suspended matter in the water column, and wind- and ocean-wake effects within the wind facility, which can disturb and/or redistribute plankton and smaller prey items and ultimately cause shifts in seabird distributions (Vanhellemont & Ruddick 2014, Floeter et al. 2017, Djath et al. 2018, Platis et al. 2018, Schultze et al. 2020, Hofmann et al. 2025). The ecological implications of oceanographic changes caused by the introduction of offshore wind infrastructure are not well explored but are monitored throughout the development process.

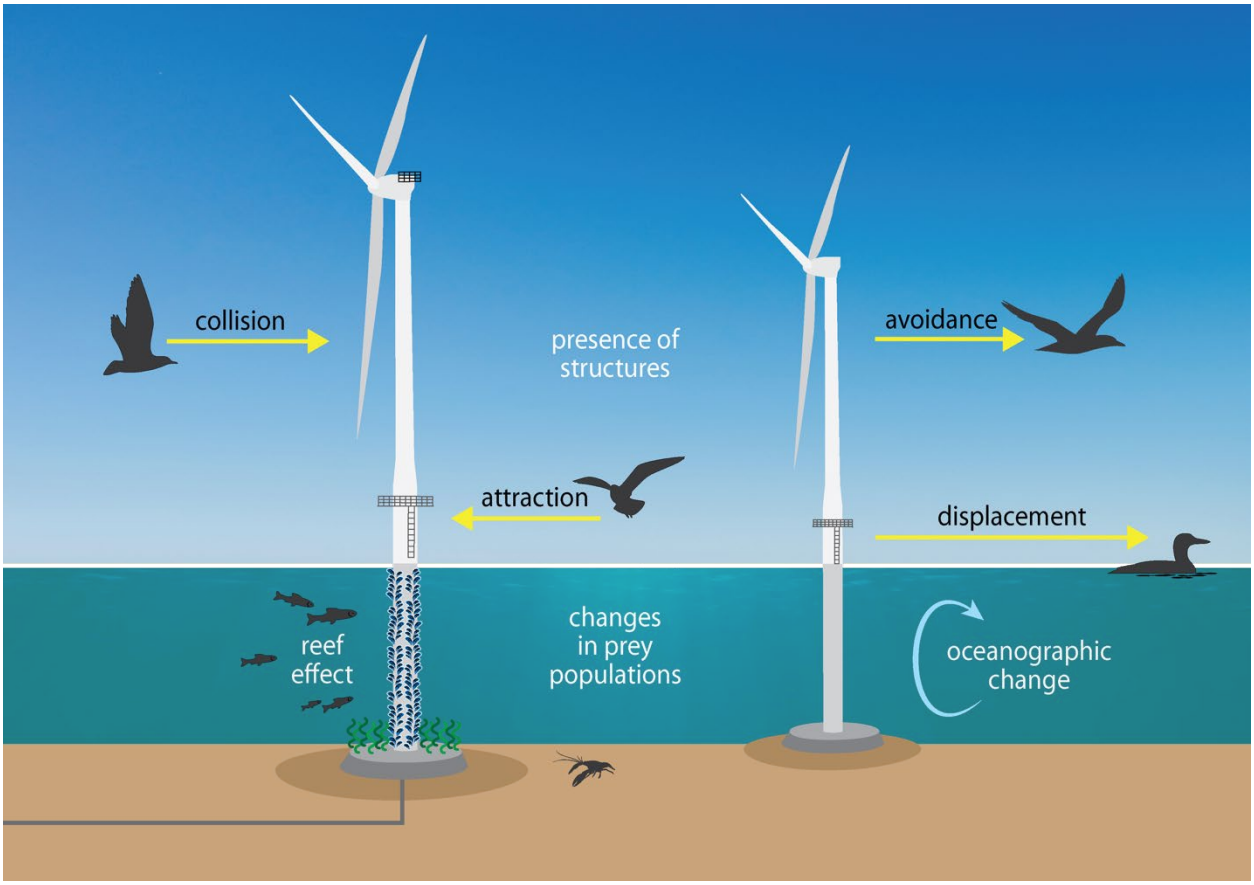

Figure 12. Selected potential effects from offshore wind development on birds. For additional information on the components of an offshore wind facility, see *What are the major components of an offshore wind facility?* Source: Biodiversity Research Institute.

Attraction

Some birds are attracted to offshore wind developments, either intentionally (e.g., to exploit a resource) or inadvertently (e.g., drawn to lights), and attraction can increase collision risk. Some species, such as gulls, cormorants, and some **raptors**, may use turbine structures as perching sites for either roosting or hunting (Leopold et al. 2011, Skov et al. 2016, Welcker & Nehls 2016, Robinson Willmott et al. 2023). Some marine birds may be attracted to prey visible at night under artificial lighting (Burke et al. 2005).

Coastal and offshore structures that are lit at night for human safety are known to attract nocturnally migrating songbirds and nocturnally active seabirds, which can lead to exhaustion or collisions (Hope Jones 1980, Russell 2005, Montevecchi 2006, Hüppop et al. 2006, Van Doren et al. 2017). While lighting at operational offshore turbines is designed to minimize bird attraction ([BOEM] Bureau of Ocean Energy Management 2021), flood lighting during construction remains a concern (E-TWG Bird and Bat Specialist Committee 2020). In addition to specific lighting characteristics (e.g., color, intensity, duration; Evans et al. 2007, Poot et al. 2008, Gehring et al. 2009, Cook et al. 2011), natural factors like weather conditions, cloud cover, and moon phase can also influence bird sensitivity to artificial lighting on any given night (Montevecchi 2006, Kerlinger et al. 2010, Ronconi et al. 2015).

Collision Risk

Bird collisions with turbines and other offshore wind energy structures may lead to injury or mortality. The public is generally aware of these effects due to the number of collisions reported at some land-based wind facilities. Collisions at offshore sites are thought to be much less common than on land (see *What do we know about the frequency of bird collisions at offshore wind facilities?*; Cook et al. 2018, Skov et al. 2018).

However, collisions are difficult to measure offshore. Doing so requires **monitoring** technology that can detect collisions, identify species involved, measure levels of avoidance, and cover a large enough area over time to obtain adequate sample sizes to inform an understanding of potential effects. Available technologies have logistical challenges, cannot always reliably detect or identify individual birds to species level, and often lack third-party validation of system capabilities (Dirksen 2017, Courbis et al. 2024; see *How do we assess the risk of birds colliding with offshore wind turbines?)*. While birds are also known to collide with a range of other human structures, including infrastructure like offshore oil and gas platforms (Ellis et al. 2013), these data are not especially useful for predicting risks from offshore wind due to differences in the specific effectors (e.g., physical structure design, lighting, etc.) created by each type of structure.

Avoidance

Avoidance of offshore wind developments by birds may occur at multiple spatial scales: (a) wind facility-scale (“macro-avoidance”), where individuals avoid the entire wind facility; (b) turbine-scale (“meso-avoidance”), where individuals maneuver within a wind facility to avoid turbines; and (c) blade-scale (“micro-avoidance”), where individuals make last-minute maneuvers (<10 m distance) to avoid turbine blades (Cook et al. 2018).

Macro-scale avoidance may lead to changes in broad movement patterns, where birds fly around rather than through areas of offshore wind development. For certain birds that are unable or reluctant to fly between turbines, wind facilities may pose barriers to bird movements, such as for

migratory birds passing during migration or for breeding birds regularly flying between their colony and feeding areas. Studies in Europe have demonstrated wind facility-scale avoidance by not only **waterfowl** such as geese (Plonczkier & Simms 2012) and sea ducks (Dierschke & Garthe 2006, Masden et al. 2009), but also by various **seabird** species (Vanermen et al. 2015).

These forced flight trajectory changes can lead birds to spend more time and energy flying via less direct paths to their intended destinations (i.e., breeding/feeding grounds). Models suggest that the energetic effects to long-distance migrants are generally minor, though the highest **energetic costs** likely occur in species with high wing-loadings (ratio of weight to wing area). Energetic impacts may also be higher for birds conducting frequent **foraging** flights in specific areas (Masden et al. 2010).

Displacement

Displacement is a specific type of avoidance behavior that occurs when individuals adjust their **habitat** use due to the introduction of a new development or repeated disturbance. Permanent displacement leads to effective habitat loss when birds no longer access a specific area or interact with prey or other resources present there. Displacement has been widely studied at European offshore wind projects, though the scale, degree, and duration of response vary greatly among species, wind facilities, and studies (Dierschke et al. 2016). Several marine bird species have been displaced from offshore wind facilities in Europe (Petersen et al. 2006, 2014, Leopold et al. 2011, Lamb et al. 2024), where offshore wind turbines are often clustered and tightly spaced. For example, Red-throated Loons are consistently displaced at distances of up to 15 km from offshore wind facilities in Europe (Petersen et al. 2006, 2014, Dorsch et al. 2019, Mendel et al. 2019), and are expected to display similar behaviors across their range.

Various factors are thought to influence patterns of displacement, such as the presence and spacing of turbines, increases in vessel activity, and changes in habitat characteristics. Researchers have observed a degree of **habituation** in some sea ducks after 2–5 years, where birds return to previous distributions; this occurrence is thought to be related to food resource availability but habituation over time has not been observed in other marine bird species (Petersen et al. 2006, Drewitt & Langston 2006, Leonhard et al. 2013).

Cumulative Effects

The various potential effects described above can also accumulate over time and/or space in several ways: (a) a combination of several effects at one time, (b) repeated encounters of a single effect at a single facility, or (c) repeated encounters of a single/multiple effects across multiple facilities—all of which can lead to greater overall impact than any one effect or facility, resulting in a cumulative effect (Goodale & Milman 2018). Cumulative effects may also result from a combination of offshore wind and non-offshore wind related sources. Scientists and regulators are often most concerned with cumulative effects, since combined or repeated effects, either anticipated or unexpected, may have the greatest potential to impact species at the population level.

Does offshore wind development kill birds?

- Research trials using remote technologies at offshore wind facilities in Europe and the U.S. indicate that bird collisions with offshore turbines are rare.
- Careful planning and a range of **mitigation** measures are designed to reduce offshore wind development's effects on birds, including potential bird collisions.
- Compared with land-based wind energy facilities, observing the interactions of birds with offshore turbines and measuring collisions offshore is more challenging, so some uncertainty remains.
- Renewable energy generation through offshore wind is designed to reduce a myriad of known **climate change**-driven impacts to birds, and the number of birds killed by offshore wind energy development is a small fraction of those killed by other known threats, such as domesticated cats and glass-fronted buildings, which can kill hundreds of millions of birds in the U.S. each year.

Detailed Answer

The placement of infrastructure in the flight paths of birds, such as buildings, communication towers, and wind turbines, will ultimately kill *some* birds directly due to collisions (see *What are the types of potential effects to birds from offshore wind development?*). In general, the density of birds observed offshore is much lower than that on land, and the number of birds killed by offshore wind appears to represent a small fraction of those killed by known land-based threats, such as domesticated cats and glass-fronted buildings (Loss et al. 2015), each of which can kill billions of birds each year (see *How does offshore wind development compare to other sources of bird mortality?*). At sea, marine birds face many other human-caused threats including oil spills, chemical contaminants, plastic pollution, fisheries **bycatch**, and a rapidly changing climate (Dias et al. 2019). Overall, the generation of renewable energy through offshore wind is expected to reduce a myriad of known **climate change**-driven impacts to birds (see *Why should we care about birds and offshore wind development?*).

Compared with surveys at land-based wind facilities, observing the interactions of birds with offshore turbines, and measuring collisions or injuries offshore, is challenging (see *What do we know about the frequency of bird collisions at offshore wind facilities?*). However, regulators require offshore wind developers and their operators to document and report all bird carcasses found on turbine platforms, substations, and associated construction and maintenance vessels, as part of their post-construction **monitoring** (see *How is bird monitoring conducted at offshore wind facilities?*). Species of conservation concern (i.e., federally listed species) must also be reported to the appropriate wildlife agency (e.g., the U.S. Fish and Wildlife Service) within a specified period. Notably, most of the area underneath offshore turbines is open water, where carcass collection is difficult.

Where human observers and remote technologies, such as radar and thermal or infrared camera systems, have been deployed in research trials at offshore wind facilities in the U.S. and Europe (e.g., Skov et al. 2018, Normandeau Associates 2022, Tjørnløv et al. 2023, Skov 2024), results to date suggest that bird collisions with offshore turbines are rare (see *What do we know about the frequency of bird collisions at offshore wind facilities?*).

Beyond direct collision mortality, offshore wind facilities may also affect birds indirectly through avoidance, displacement, and altered food availability. While these effects are not immediately lethal, the resulting increases in long-term **energetic costs** could ultimately impact survival (Fox & Petersen 2019), especially for long-lived species like **seabirds**. Currently, however, there is no evidence linking the effects of offshore wind development to measurable impacts at the **population** level.

Throughout the planning process for offshore wind energy projects, considerable effort is made to avoid known areas of high bird use, and a range of research and development projects are underway to develop purpose-built, commercial scale technologies to improve the measurement of potential impacts to birds at offshore wind facilities through pre- and post-construction monitoring. In the current absence of direct collision data, **collision risk models** are used during permitting to assess the risks of offshore wind development to protected species (see *How do we assess the risk of birds colliding with offshore wind turbines?*). A range of **mitigation** measures are also being developed and implemented to reduce offshore wind's effects on birds (*see What is compensatory mitigation and how does it apply to birds and offshore wind?*).

Does offshore wind development alter birds' behavior, movement patterns, and habitat use?

- Yes, offshore wind development has the potential to change bird behavior, movement patterns, and **habitat** use. Not all bird species appear to respond to offshore wind energy development, but the most common responses are avoidance and attraction.
- Avoidance can occur at multiple scales. Birds can avoid an entire wind facility ("macro-avoidance"), avoid individual turbines ("meso-avoidance"), or make last-minute maneuvers around turbine blades ("micro-avoidance"). Macro-avoidance of wind facilities can lead to displacement and functional habitat loss.
- Some birds may be attracted to offshore wind facilities due to increased perching, roosting, and **foraging** opportunities on and around offshore structures and vessels. Some birds may also be attracted to and disoriented by artificial lighting at night.
- While research in Europe has shown behavioral responses, with some species (e.g., loons) more likely to avoid and/or be displaced by offshore wind, and others (e.g., cormorants) more likely to be attracted to offshore wind facilities, transferability of these results to the U.S. wind context is uncertain. Variation in local species presence, wind facility layout, and geography likely influence how species respond.

Detailed Answer

Many species of birds use the offshore environment, including **seabirds**, **shorebirds**, **wading birds**, and migratory **songbirds**. Some only use the offshore environment during migration, when they fly over the ocean (see Where and when are birds found in U.S. Atlantic offshore environments?). Others (e.g., seabirds) may use marine areas during their entire life cycle (breeding and non-breeding) or most of the year. Activities related to offshore wind construction and the presence of new structures during construction and operations have the potential to affect bird behavior in a variety of ways, including avoidance and attraction to structures/activities (Robinson Willmott et al.

2023), as well as changes in avian movements and **habitat** use relating to shifts in resources such as prey (Williams et al., 2024; see *What are the types of potential effects to birds from offshore wind development?*). Much of the knowledge about these responses comes from Europe, where offshore wind development has been occurring for over 40 years. While it is still unclear how much of this knowledge is applicable to the U.S. context given differences in species presence and **life history**, environmental conditions, and wind facility locations and characteristics, insights can be gained from other regions where these effects have been studied for multiple decades.

Avoidance and Displacement

Avoidance behavior may occur at multiple spatial scales (Figure 13). Birds may avoid offshore wind facilities altogether by changing movement patterns to fly around rather than through a wind facility. This is considered macro-scale avoidance (sometimes called a "barrier effect"), with wind facilities acting as barriers to migratory or daily movements. Avoidance behavior may vary over time depending on behavior, life history, and environmental conditions. Studies in Europe have demonstrated macro-scale avoidance for various seabird and waterbird species, including Pink-footed Geese, scoter species, Common Eiders, Northern Gannets, Common Murres, and Razorbills (Dierschke & Garthe 2006, Masden et al. 2009, Plonczkier & Simms 2012, Vanermen et al. 2015).

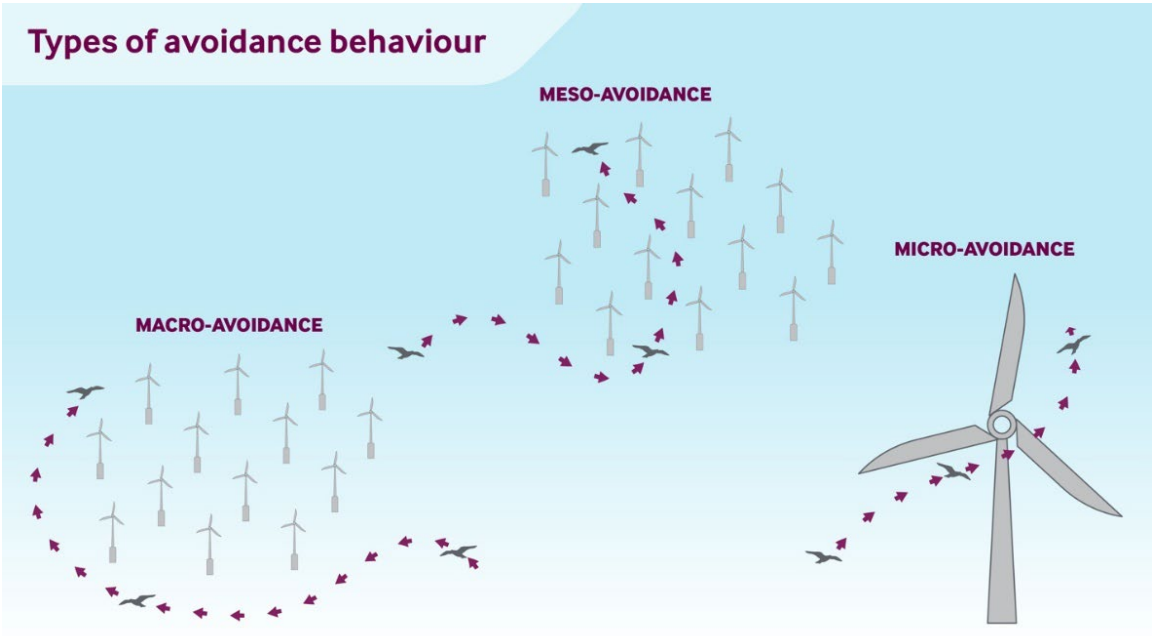

Figure 13. Scales of avoidance behavior by birds, including macro-avoidance, meso-avoidance, and micro-avoidance. Source: RPS Group.

These changes in movement patterns may potentially increase birds' energy expenditure. The **energetic costs** of flying around one wind facility once are likely relatively small, but may add up over multiple encounters, either for birds encountering multiple wind facilities during migration, or those that encounter the same wind facility regularly when commuting between **foraging** and breeding or roosting locations (Drewitt & Langston 2006, Masden et al. 2009, 2010). Functional habitat loss can also arise via macro-avoidance whereby birds are displaced from previously used habitat (Cook et al. 2018). European studies have shown that **marine bird** species, including sea

ducks, Red-throated Loons, Northern Gannets, and auks, show varying degrees of displacement (Leopold et al. 2011, Petersen et al. 2014, Dierschke et al. 2016, Welcker & Nehls 2016, Mendel et al. 2019). In the most extreme cases, like the Red-throated Loon, **populations** have consistently been displaced up to 15 km from wind facilities (Lamb et al. 2024). Multiple factors, like the spacing of turbines, boat traffic, and the amount of available natural habitat, may contribute to the degree of displacement (Williams et al. 2024). Of note, offshore wind development in the U.S. Atlantic is occurring further offshore (40+ km compared to median 27 km globally) with greater spacing of turbines (average ~1850 m compared to average 700 m spacing in Europe) in comparison to many European offshore wind facilities (U.S. Department of Energy 2023, Jung & Schindler 2023), which may influence macro-scale behavioral responses. Research from the first commercial-scale facilities in the U.S. Atlantic region will be key to understanding the degree of transferability of these findings from Europe.

Avoidance may also occur at smaller spatial scales when birds enter the wind facility but avoid turbines ("meso-avoidance") or where birds make last-minute maneuvers to avoid turbine blades ("micro-avoidance"; May et al., 2015). Studies using radar have shown strong horizontal meso-avoidance by individual birds, with most avoiding areas within 50 m of individual turbines (Krijgsveld 2014). Multiple factors may affect the level of observed meso-avoidance, including distance to the center of the wind facility and operational status (e.g., with birds avoiding turbines more strongly when blades are spinning; Cook et al., 2018). Micro-avoidance has primarily been examined using camera systems mounted on individual turbines; these studies have found, on average, 95% of individual birds adjusted their behavior to avoid colliding with turbine blades (Skov et al., 2018). Quantifications of avoidance across scales (including macro, meso, and micro) suggest an overall avoidance rate above 99% for individuals of common seabird species (gulls, gannets, kittiwakes; Skov et al., 2018). Avoidance rates are generally high across spatial scales and can inform our understanding of collision risk (see *How do we assess risk of birds colliding with offshore wind turbines?* and *What do we know about the frequency of bird collisions at offshore wind facilities?*).

Attraction and Habitat-Mediated Changes

Some bird species may be attracted to offshore wind development due to the presence of new perching and roosting opportunities (primarily on turbine platforms or substations) or increased foraging opportunities with new underwater structures (e.g., turbine foundations) acting as artificial reefs. Some species may also be attracted due to increased vessel presence, often due to associations with fishing vessels (Christensen et al. 2001, Petersen 2005, Leopold et al. 2011), and artificial lighting on offshore wind infrastructure and vessels (Rodríguez et al. 2014, Gjerdrum et al. 2021; Figure 14).

Perching/roosting: At the Coastal Virginia Offshore Wind pilot turbines in Virginia, Peregrine Falcons and Merlins (both **raptor** species) were observed preying on migrating **passerines** (Robinson Willmott et al. 2023). In Europe and at the Block Island Wind facility in Rhode Island, cormorants were attracted to offshore wind facilities, using them for perching/resting opportunities (Dierschke et al. 2016, Stantec 2020). In Europe, Great Cormorants and Lesser Black-backed Gulls used turbine platforms to roost, especially near the edges of wind facilities (Petersen et al. 2006, Leopold et al. 2013, Vanermen et al. 2013, Dierschke et al. 2016). It is also possible that perching/roosting opportunities lead to a "stepping stone" or "opportunity effect" that enables birds to access more remote offshore foraging locations (Vanermen et al. 2013).

Figure 14. Bird behaviors (yellow text) associated with potential attraction to offshore wind facilities. Source: Biodiversity Research Institute, adapted from COMET3T.

Artificial reef effects: Turbine foundations and scour protection layers create hard underwater substrate in areas that may have previously been comprised of softer sediment. As a result, these structures are colonized by species like mussels and barnacles. Fish that feed on these organisms can be attracted to the wind facility, creating an "artificial reef effect," similar to what is observed at shipwrecks. New and concentrated food sources on and around offshore wind structures can increase potential foraging opportunities for certain species of marine birds. In Europe, gulls, sea ducks, and diving birds (e.g., loons, gannets) forage around turbine foundations (Dierschke et al. 2016).

Vessel activity: Some bird species may avoid vessels (including construction and crew transfer vessels) while other species, like gulls, gannets, and fulmars that are often associated with fishing vessels, may be attracted to them (Camphuysen 2001, Petersen 2005, Leopold et al. 2011).

Artificial lighting: Phototaxis is when animals change their movements in response to light, either via attraction or avoidance (Adams et al. 2021). Based on inference from other coastal and offshore industries, lighting on vessels and turbines during construction and operation could potentially attract nocturnal seabirds and migrants (Montevecchi 2006, Hill et al. 2014, Rodríguez et al. 2014,

Gjerdrum et al. 2021). Lighting may also cause disorientation to birds, which in turn can deplete energy and fat stores. Turbine lighting used for marine navigation and air traffic safety is generally minimized using systems like aircraft detection lighting systems, which are sensor-based systems that automatically activate red aviation safety lighting on turbines only when an aircraft is nearby. Therefore, the main lighting sources from offshore wind development occur during construction, when turbine blades are not yet operational. However, given the limited lighting for these structures, the degree to which attraction might occur and influence collision risk remains uncertain.

Consequences

It is complex to link how behavioral changes affect an individual over its **life history**, and how individual changes impact populations overall. It is possible that individual birds may need to use more energy to fly around wind facilities and/or have reduced access to food resources. However, birds that are attracted to wind facilities may benefit energetically from more concentrated food resources and resting sites. Both positive and negative consequences can then lead to changes in individual survival and **reproductive success**, which may sum to larger population-level effects. The consequences of these changes may be species- and context-specific. For example, even though migrant songbirds and shorebirds may only encounter offshore wind development during a short period of the year, these species may be particularly sensitive to longer flight times and energetic costs that come with flying around wind facilities, as these birds rely heavily on stored fat as their source of energy during migration (Landys et al. 2005). Other bird species that forage throughout migration may be less sensitive to potential changes to their movements caused by offshore wind development (Klaassen et al. 2012).

It is challenging to disentangle the potential effects of avoidance and attraction from other environmental factors that impact bird energetics, survival, and reproduction, and seabirds may be able to adjust their movement patterns and habitat use without major fitness consequences (Pereira et al. 2020, Cerveira et al. 2020). Given the difficulty in directly studying energetics and fitness, scientists primarily rely on models, such as population viability analysis (Searle et al. 2023) and other tools like SeabORD,[32] an individual-based model of seabird movement, behavior, and **demographics**, to estimate the cost of displacement to individual birds. There are many factors that influence whether individual changes in behavior and movement patterns translate into measurable population change, including life history, population status, spatial overlap of development with important breeding and foraging locations, and cumulative impacts from other stressors, such as interactions with fisheries, disease, and **climate change** (see *How does offshore wind development compare to other sources of bird mortality?* and *What factors determine risk to birds from offshore wind development?*).

For More Information

- SEER Factsheet: Bat and Bird Interactions with Offshore Wind Facilities

[32] Scottish Government: Finding out the Fate of Displaced Birds - SeabORD Tool

How many birds are impacted by offshore wind development in the U.S. Atlantic?

- Many millions of birds use the waters off the U.S. Atlantic coast, but not all species using or migrating over this region will be affected by offshore wind development.
- To date, most data on effects on birds from offshore wind energy are from European studies. Bird collisions with offshore turbines appear to be rare, but effective **habitat** loss has been observed when birds avoid specific areas of offshore wind development (i.e., displacement). However, impacts from collisions and displacement are difficult to measure at the **population** scale (see *What do we know about the frequency of collisions at offshore wind facilities?*).
- Improving our understanding of potential impacts to bird populations from offshore wind development is a focus of ongoing research globally.

Detailed Answer

Each year, and across each season, tens of millions of **seabirds** use the waters off the U.S. Atlantic coast. Some are year-round residents, while others use the region during specific seasons, arriving and departing via major ocean migration routes (i.e., marine flyways; Morten et al. 2025). Millions more landbirds, coastal waterbirds, and **shorebirds** migrate back and forth along the Atlantic Americas Flyway,[33] potentially bringing them into contact with offshore wind activities off the Atlantic coast. Throughout offshore wind development planning and permitting processes, federal and state agencies, researchers, environmental organizations, and developers collectively focus considerable effort and attention on limiting impacts to wildlife, including birds. Informed siting to avoid high-use areas is a key strategy for avoiding and minimizing potential negative effects.

The risk of impacts on each bird species is dependent on how its presence overlaps with offshore wind activities (i.e., exposure to **effectors**/stressors), and its level of sensitivity to effectors/stressors introduced by offshore wind development (i.e., vulnerability; see *What factors determine risk to birds from offshore wind development?*). Seabirds are often aggregated around offshore shoals, shelf edges, and marine fronts, but in general, as distance to shore increases, the abundance and number of species present offshore tends to decrease (Williams et al. 2015, Winship et al. 2023). Because both species diversity and overall bird abundance are typically lower in areas located offshore relative to inland or coastal locations, overall risk in these areas may be generally lower. While this is dependent on the extent of overlap between species' **habitats** and development areas, as well as **life history** characteristics, not all bird species or individuals of a species using or migrating over Atlantic coast waters will be exposed to or at risk from offshore wind development.

It is difficult to establish the extent of effects such as collisions or displacement, and potential changes to prey **distributions** can be even more challenging to assess. Several remote **monitoring** systems using video and/or radar are in development or currently being tested to improve observations of offshore collisions, but studies at offshore wind facilities in Europe suggest bird

[33] BirdLife International: Atlantic Americas Flyway

collisions with offshore wind turbines are rare (see *What do we know about the frequency of collisions at offshore wind facilities?*).

Offshore wind-related displacement, when animals alter their movements or activities to intentionally avoid their usual habitats due to new disturbances, can occur in several marine bird groups, such as sea ducks (e.g., scoters) and auks (e.g., murres) (Lamb et al. 2024). Red-throated Loons in Europe are known to be particularly vulnerable to displacement (Petersen et al. 2014, Heinänen et al. 2020). Other species, such as cormorants and gulls, do not consistently exhibit displacement and may even be attracted to offshore wind facilities to roost on structures (Lamb et al. 2024). Shifts in bird distributions caused by displacement could have long-term **energetic costs** (e.g., increased energy expenditure due to longer **foraging** flights or reduced access to preferred habitat) for certain species (Duckworth et al. 2020). However, displacement is influenced by many factors and may also change over time due to **habituation** or changes in prey availability (Leonhard et al. 2013). For additional details on displacement, see *What are the types of potential effects to birds from offshore wind energy development?*).

Overall, knowing how many birds will interact with offshore wind development activities and predicting or identifying potential broad impacts to bird **populations** is complex and estimates have inherent uncertainty. However, offshore wind is an important component of efforts to combat **climate change**, which is a driver of the global **biodiversity** crisis and is known to negatively impact birds globally (see *Why should we care about birds and offshore wind development?* and *How does offshore wind energy development compare to other sources of bird mortality?*). Understanding and minimizing risk to birds from offshore wind development activities is an area of active, ongoing research around the globe, involving a wide range of field studies, statistical modeling, risk assessments, and industry monitoring, all designed to better understand and mitigate potential negative effects to birds from offshore wind (see *How do we assess the risk of birds colliding with offshore wind turbines?*).

Collisions

How do we assess the risk of birds colliding with offshore wind turbines?

- Bird collisions with offshore wind structures are difficult to measure. Assessing collision rates at other human structures, like tall buildings and land-based wind facilities, is typically done by repeatedly counting carcasses underneath the structures. This is not possible in the ocean as bird carcasses sink, float away, or are scavenged. Thus, direct observations or remote **monitoring** technologies such as cameras and thermal sensors must be used.
- Monitoring bird collisions in the offshore environment (whether via direct observation or remote monitoring) presents significant logistical and technical difficulties, particularly for smaller-bodied birds and species that migrate at night. Thus, while there are several key studies that have used a combination of human observers, camera systems, and radar to

count collisions at offshore wind facilities, this type of data collection at scale is expensive and technically demanding.

- Prior to construction, **collision risk models** (CRMs) are used during the permitting process to estimate the likelihood of bird collisions at a given wind facility site. Such models use wind facility characteristics (e.g., turbine height) and species-specific parameters (e.g., **distribution**, avoidance behavior, **morphology**) to predict potential collision rates. However, there are limited data available to validate predictions from these models, and more field research is needed to improve confidence in model outputs. In the face of limited data, however, CRMs can help inform risk assessments and possible **mitigation** strategies.

Detailed Answer

On land, avian collisions with human-made structures, such as wind turbines and buildings, are measured by searching for carcasses near the structures. This method is not effective in the marine environment, as carcasses that fall into the water do not persist in the area for any length of time (and may be quickly consumed by other marine organisms; Drymon et al. 2019). At U.S. offshore wind facilities, energy company personnel are required to report carcasses found on turbine platforms and vessels (BOEM 2024), but during turbine operations, in-person visits to turbines for maintenance activities are infrequent (due in part to human safety concerns), and the area of the platform underneath the turbine is a small fraction of the total area underneath the turbine **rotor-swept zone**, limiting the utility of such searches for assessing collision rates.

Consequently, measuring collisions at offshore wind turbines is typically conducted via human observers who visually watch for collisions in real time, or by deployment of remote **monitoring** technology. Remote monitoring technologies usually include multiple systems operating in tandem, such as marine radar systems that can detect animals in the airspace from long distances (a kilometer or more; Skov 2023), as well as thermal and visual cameras that may allow for species identification and can track animals close to turbines (Figure 15). Some systems, for example, use radar to detect an animal from a distance, and then direct a camera towards the animal to get finer-scale movement data and to try to obtain species information (Skov 2023). Turbine monitoring systems developed over the last 10–20 years have incorporated multiple complementary technologies (Courbis et al. 2024).

While remote monitoring is safer and can operate in a wider range of weather conditions than human observers (as well as at night), both methods can be logistically challenging and expensive to deploy. For example, interference from the moving turbine blades makes it essentially impossible to detect collisions using radar alone, and radar does not allow for identification to species, while camera systems typically have a very limited field of view (Skov 2023, 2024, Courbis et al. 2024). Additionally, multi-method remote monitoring at the Block Island Wind facility in Rhode Island had challenges associated with the systems: 34 months of monitoring effort yielded less than 18 months of data where both the radar and camera systems were correctly functioning concurrently (Skov 2024). Such systems also generate large amounts of data, including video files, which can be difficult to transfer remotely to shore or store in computers on site due to large file sizes (Courbis et al. 2024). Furthermore, many technologies cannot reliably detect or identify individual birds to species level, particularly smaller-bodied animals such as bats and some **songbirds**, and often lack third-party validation of system capabilities (Dirksen 2017, Courbis et al. 2024).

Figure 15. Thermal camera mounted on an offshore wind turbine to detect birds. Photo credit: Vattenfall.

Ideally, remote monitoring systems should be able to detect collisions, measure avoidance, identify individuals to species level, and be implemented at a large enough scale (both relative to the coverage of individual turbine rotor-sweep zones, as well as coverage of multiple turbines across a wind facility) to provide a representative sample to quantify collision rates (Williams et al. 2024). In practice, studies at wind facilities in the UK that have provided the best available data on avoidance behaviors and collision risk to **seabirds**, such as gulls (Skov et al. 2018, Tjørnløv et al. 2023), have only been able to partially monitor rotor-sweep zones at 1–2 turbines over time, and methods have been best suited to examining larger birds during periods of good visibility. Thus, such studies tend to have small sample sizes.

Existing data indicate that collisions at offshore turbines are relatively rare (see *What do we know about frequency of collisions of birds at offshore wind facilities?*). Given the lack of validated technology to directly measure collisions at offshore wind facilities at a large scale, **collision risk models** (CRMs) are widely used to estimate the likely number of collisions for a given species at a particular wind facility.[34] These estimates may be used by regulators to inform project permitting or identify **mitigation** requirements. CRMs are generally variations on the Band Model (Band 2012), first developed for use at land-based wind turbines in the United Kingdom (Band 2000, Band et al. 2007) and later expanded for offshore use (Masden & Cook 2016). There are now numerous variations of these models (e.g., Smales et al. 2013, Masden 2015, McGregor et al. 2018, Adams et al. 2022, Goyert et al. 2024), which incorporate information about the bird species of interest (e.g., spatial distribution, body size, flight behaviors, flight height) and wind facility characteristics (e.g.,

[34] Forthcoming FAQ: *How do different collision risk models compare to each other and how are they used to determine take estimates?*

location, number of turbines, size and altitude of the turbine rotor-swept area, percentage of time turbines are spinning) to estimate the number of collisions that might be expected for a particular species at a given wind facility over a specified time period (Figure 16). A CRM for several federally endangered bird species has been developed for the U.S. Atlantic (Adams et al. 2022, Goyert et al. 2024).

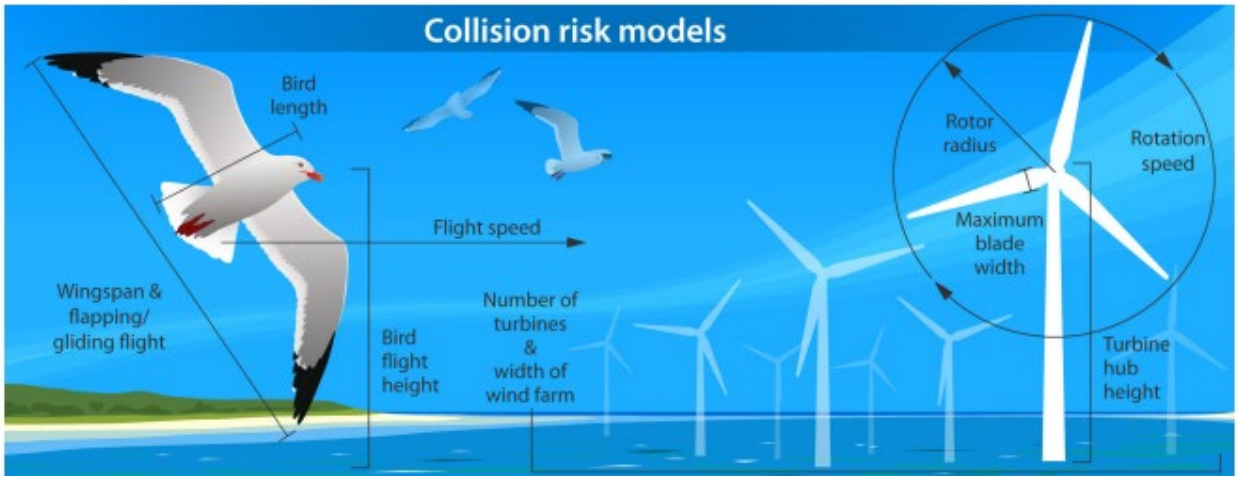

Figure 16. Information commonly used in collision risk models (CRMs). Source: National Renewable Energy Laboratory. Modified from Cook and Masden 2016.

There is significant uncertainty in the accuracy of estimates from CRMs. **Empirical** validation is limited because there are still relatively few published scientific studies presenting results from collision monitoring systems, and studies that do exist tend to have low sample sizes. As a result, there is limited real-world data to refine and validate statistical models of collision risk. One key challenge is accurately quantifying avoidance behavior; birds tend to strongly avoid turbines (including micro-avoidance of turbine blades, where birds are within about 10 m of the rotor-sweep zone), and this variable is highly influential in determining collision risk estimates in CRMs (Cook et al. 2018). Quantifying species-specific avoidance rates is difficult due to technological limitations (as discussed above) and the very low sample sizes of many field studies. This leads to substantial uncertainty in avoidance rate estimates, which in turn affects confidence in overall collision risk predictions.

The few studies that have tried to retroactively determine the accuracy of pre-construction risk assessments (e.g., by collecting carcasses during turbine operations at onshore wind facilities) have shown mixed accuracy, and suggest that variation in predicted versus realized mortality of **raptors** may related to a range of environmental factors beyond just species abundance (De Lucas et al. 2008, Cook et al. 2025). In general, current CRM structures are simplified models of reality, and three-dimensional **habitat** use patterns and avoidance behaviors are likely species- and site-specific complicating factors (Fielding et al. 2024, Cook et al. 2025). Despite these simplifications, CRMs represent important planning and mitigation tools, recognizing that more research is needed to improve and validate estimates derived from CRMs (Cook et al. 2025).

Despite these challenges, CRMs remain the best available tool for assessing likely collision risks at offshore wind facilities. They also help inform potential mitigation measures, such as adjusting

turbine locations, height, or numbers during project design to minimize expected risk. For example, since many marine birds fly relatively close to the water's surface most of the time, some offshore wind facilities have increased the "air gap" (the distance between the water's surface and the bottom edge of the rotor-swept zone) to reduce altitudinal overlap of turbine blades with bird flight activity. In some countries, including the U.S., CRMs are also used by government regulators to help determine if offshore wind facilities should be required to implement compensatory mitigation measures to support bird populations that may be affected by wind facility construction and operation (see *What is compensatory mitigation and how does it apply to birds and offshore wind?*; Adams et al. 2022, Goyert et al. 2024, Cook et al. 2025).

What do we know about the frequency of bird collisions at offshore wind facilities?

- Collisions of birds with offshore structures such as turbines are difficult to measure. Direct observations or remote **monitoring** technologies must be used, as opposed to carcass collection used at land-based wind facilities.
- Much of the available body of knowledge comes from a few large-scale studies in Europe that found marine bird collision events were rare, ranging from 0–7 collisions detected over 14–20 months of monitoring at individual turbines.
- While the applicability of these results may vary across locations, conditions, and species, collisions with offshore wind turbines are thought to be rare events that are infrequent in comparison to other human threats to birds.

Detailed Answer

Collisions of birds with offshore wind turbine structures are important to consider given the potential to cause injury and mortality. While there is a high level of uncertainty in the frequency of occurrence of these events offshore given difficulty in measuring collisions directly, they are generally thought to be rare events (Vlietstra 2007, Cook et al. 2018, Skov et al. 2018). Available evidence suggests collisions at offshore wind turbines are substantially less common than collisions at land-based wind facilities, which in turn are infrequent in comparison to other **anthropogenic** threats (see *How does collision mortality from offshore wind facilities compare to other sources of bird mortality?*).

Unlike land-based wind facility **monitoring**, carcass searches cannot be conducted in the ocean to detect bird mortalities resulting from collisions. As such, observational data from humans or remote technology, such as radar and thermal and visual camera/video systems, may be used to detect collisions, though many of these technologies lack commercial readiness and have limitations, particularly in terms of spatial coverage and species-level identification ability (Desholm et al. 2006, Courbis et al. 2024). These approaches can also be logistically challenging and expensive (Skov 2024, Courbis et al. 2024; see *How do we assess the risk of birds colliding with offshore wind turbines?*). Knowledge about bird collisions at offshore wind facilities primarily comes from a few large-scale studies at wind facilities in Europe that have combined multiple technologies. A 2018 study in the UK that focused on monitoring five large-bodied species (Northern Gannet, Black-legged Kittiwake, Lesser Black-backed Gull, Herring Gull, Great Black-backed Gull) at a range of scales within a wind facility detected five collisions of gulls and one

Kittiwake (out of 2,595 tracks recorded with radar and laser rangefinders) in 20 months of monitoring at two offshore turbines (Skov et al. 2018). This study concluded that these species exhibit high levels of avoidance of entire wind facilities (macro-scale), turbines within wind facilities (meso-scale), and individual turbine blades (micro-scale).

Most birds have been shown to implement avoidance responses before entering the turbine **rotor-swept zones**, leading to avoidance rates of >98–99% (Desholm & Kahlert 2005, Cook et al. 2018, Skov et al. 2018; for a graphic showing the different parts of a turbine, including the rotor-swept zone, see *What are the major components of an offshore wind facility?*). In another study, Tjørnløv et al. (2023) conducted daytime monitoring with marine radar and visual camera systems at an offshore wind facility in Scotland and detected no collisions over 14 months of monitoring. This study tracked over 3,000 marine birds including gulls, fulmars, skuas, and other species thought to be at high collision risk. A recent report from the Block Island Wind facility in Rhode Island also indicated that no collisions occurred in approximately 18 months of radar and camera monitoring at two turbines (Skov 2024), though it is important to note that technological challenges resulted in the system functioning for only approximately 18 out of 34 months of monitoring, highlighting challenges associated with technology for detecting collisions offshore (see *How do we assess the risk of birds colliding with offshore wind turbines?*). Information from coastal onshore wind facilities, where carcass searches can be conducted, can also provide information about potential collision risk to some **seabirds** and other species that occur offshore. A study of five turbines in Atlantic City, New Jersey found 23 bird carcasses over the course of a year of monitoring; 10-minute point-count surveys during this time detected over 12,000 birds in the area (New Jersey Audubon Society 2008). A study of one turbine in Buzzard's Bay, Massachusetts detected no collisions of terns during eight months of monitoring (253 terns were detected in the areas during monitoring), and only a single Laughing Gull carcass was suspected to have collided with the turbine during this period (Vlietstra 2007). Combined with the offshore studies described above, current research suggests that collisions with offshore turbines are rare events.

However, many data gaps remain in our understanding of bird collisions with offshore wind turbines, including how various factors contribute to the frequency of collisions. Turbine location appears to be an important factor in predicting avoidance and collision rates. For example, placing turbines in important **habitat** use areas logically leads to more collisions than placing turbines in areas where birds are seldom naturally present. Likewise, many birds migrate at night, and available evidence suggests birds are more likely to approach and collide with structures in periods of poor visibility, including at night and in inclement weather (Desholm & Kahlert 2005, Huppop et al. 2006, Drewitt & Langston 2008). This makes it particularly important for collision detection systems to operate during these periods, though this can be challenging from a technological standpoint. Site-specific specifications such as turbine size and the vertical distance between the sea surface and the lower edge of the rotor-swept zone (i.e., the "air gap") are also thought to affect collision rates at both land-based and offshore turbines, though evidence to date is mixed (Garvin et al. 2024, Gulka et al. 2024). A large-scale project in Europe, the PrediCtOr project (2024–2026), aims to reduce uncertainty around bird collision risk and improve post-construction monitoring at offshore wind facilities by establishing best practices and a robust data framework.[35] As

[35] Carbon Trust: Prevalence of Seabird Species and Collision Events in Offshore Wind Farms (PrediCtOr)

technologies advance and more studies are conducted, understanding of bird collision risk can continue to improve. Nevertheless, currently available data suggest bird collisions with offshore wind turbines are relatively rare.

Mitigation and Monitoring

How is bird monitoring conducted at offshore wind facilities?

- Various approaches are used to monitor birds around offshore wind facilities. Depending on the specific objective, methods may include individual bird tracking, visual and digital observational surveys, acoustic surveys, remote imaging, radar, and prey sampling. Bird **monitoring** often focuses on assessing potential collisions, behavioral responses, and changes to **habitat** and prey.
- Bird monitoring around offshore wind facilities may be conducted by scientists from academic institutions, government agencies, tribal governments, conservation organizations, and industry consultants working for offshore wind developers.
- Overall, bird monitoring around offshore wind facilities can clarify how birds interact with and may be affected by offshore wind facilities, support risk and impact assessments, inform the design of potential **mitigation** measures, and evaluate compliance with permitting requirements.

Detailed Answer

Bird **monitoring** at offshore wind facilities often focuses on assessing three main categories of potential effects: (1) collision with turbine blades and structures, (2) behavioral responses like avoidance, displacement, and attraction, and (3) changes to **habitat** and prey availability (see *What are the types of potential effects to birds from offshore wind development?*; Williams et al. 2024). Various methods can be used to monitor birds with respect to offshore wind development depending on the specific monitoring or research objective. Key methods include individual bird tracking, visual and digital observational surveys, acoustic (i.e., sound recording) surveys, radar and camera systems, and prey sampling (Figure 17, Table 2).

Monitoring Collisions

It is difficult to directly measure how often birds collide with offshore wind turbines and how many of those collisions result in serious injury or mortality (see *How do we assess the risk of birds colliding with offshore wind turbines?*). At land-based wind facilities, bird mortalities from collisions are typically measured by collecting carcasses on the ground, which is largely impractical in offshore environments as carcasses that fall into the water can float away, sink, or be quickly scavenged by other wildlife. Instead, remote technologies (including radar, thermal imagery, and cameras) mounted on turbines can be used to monitor for bird collisions with offshore wind turbines. Given the complicated logistics and financial cost of these methods, limited numbers of turbines are equipped with remote monitoring systems and, depending on the system, it may only be able to monitor a small portion of a turbine's **rotor-swept zone**. In Europe, human observers stationed at turbine platforms can also be used to monitor for collisions over short periods of time, though this practice is not permitted at U.S. offshore wind facilities. Any bird carcasses found on

turbine platforms or project vessels also inform the understanding of collisions and must be documented and reported to regulators. To determine the cause of death, each instance may be investigated to differentiate between various factors, including disease, migration-related exhaustion, collision, and predation.

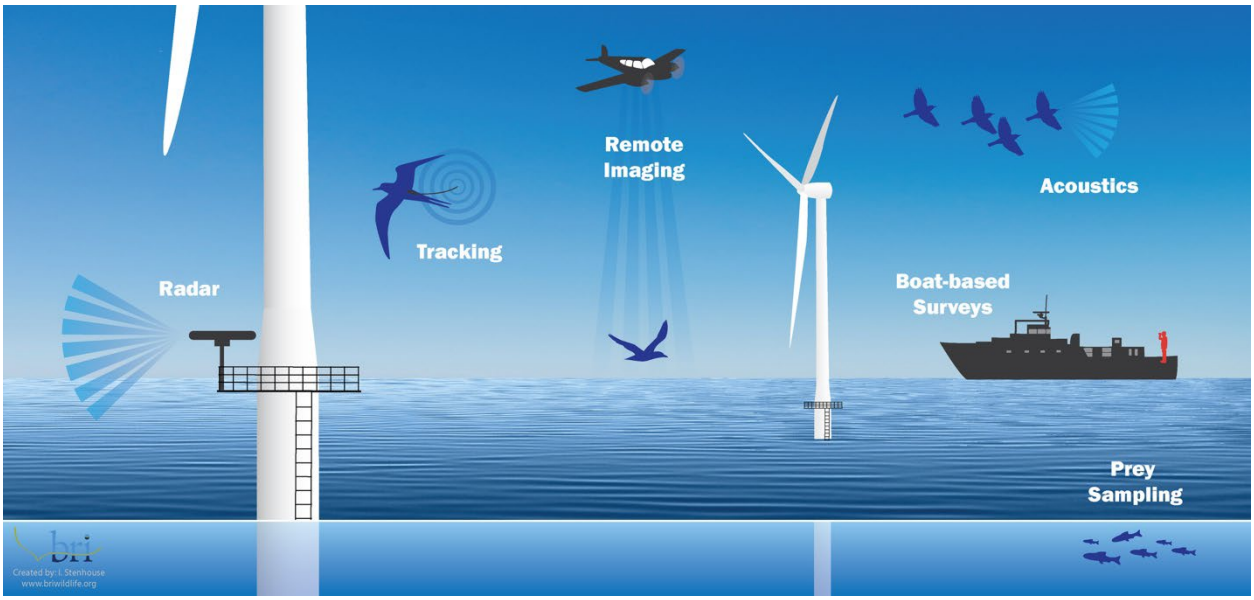

Figure 17. Key bird monitoring approaches for offshore wind development. Source: Biodiversity Research Institute.

Monitoring Behavior and Movement

Technologies for tracking individual birds (e.g., radio telemetry and satellite tags) can be used to monitor behavioral responses at various spatial and temporal scales (Davies et al. 2024; Peschko et al. 2020; see *Does offshore wind development alter birds' behavior, movement patterns, and habitat use?*). Stationary observers on vessels can be used to monitor fine-scale bird movements (e.g., avoiding turbines/blades or attraction to turbines for perching). Observational surveys of birds in marine areas follow standardized transects, using either a boat or an airplane (either with human observers or, in the case of some aerial surveys, digital camera/video systems), to collect data on species presence and numbers. These data can be used in analytical frameworks to assess changes in bird abundance, densities, and **distributions** (Winship et al. 2018, 2023) in and around offshore wind energy areas and to characterize potential bird displacement over broad geographic and temporal scales (e.g., Welcker & Nehls 2016). Some radar, acoustics, and imaging (e.g., photographic imagery on turbine structures) can also capture aspects of bird behavior such as macro- to micro-avoidance (see *Does offshore wind development alter birds' behavior, movement patterns, and habitat use?*) and can be used to detect bird presence within or near a wind facility. Each method has limits in its ability to identify individuals to species, determine the number of individuals present, and/or monitor a large enough airspace to effectively answer research questions. Using multi-method arrays can compensate for the limitations of individual approaches, providing a more complete and robust dataset (Courbis et al. 2024). Guidance is available for effectively monitoring bird behavioral responses before and after offshore wind facility

construction, along with recommended data collection and reporting standards (Camphuysen et al. 2004, Avian Displacement Guidance Committee 2024, Regional Wildlife Science Collaborative 2024).

Table 2. Summary of methods that can be used to monitor birds at offshore wind facilities, adapted from Williams et al. (2024) Supplementary Material and Avian Displacement Guidance Committee (2024).

Category	Example methods	Types of data collected	Research applications
Individual tracking	Radio telemetry, GPS, satellite telemetry, geolocators	Presence or location data (at specified intervals), movement direction and/or flight altitude data (in some cases)	• Assess potential collision risk • Assess potential exposure and spatial overlap in bird habitat use/movement patterns with wind facilities • Characterize behavior, including avoidance, displacement, and attraction
Observational surveys	Boat-based observers, digital/visual aerial surveys	Species identification, species presence, frequency of occurrence, flight height, avoidance and attraction behavior	• Characterize fine-scale avoidance and attraction near/on turbines • Integrate surveys in distribution models to assess meso- and macro-scale avoidance and displacement
Acoustics	Passive acoustic monitoring	Bird vocalizations	• Identify species-specific presence at wind facilities
Remote imaging	Photographic, videographic, thermographic sensors on turbines	Species identification, flight height, speed, and direction	• Evaluate bird presence and behavior in/around offshore wind turbines • Inform potential collision risk, attraction, and/or avoidance
Radar	Marine radar, weather surveillance radar	Passage rates; flight speed, altitude, and direction	• Characterize general bird movements and their frequency in/around wind facilities • Inform potential collision risk (not species-specific)
Prey sampling	Hydroacoustic surveys, fish trawls, plankton tows, environmental DNA, underwater video, multi-sensor arrays	Prey abundance, composition, and distribution	• Estimate prey distributions and link to seabird distribution and behavior data from other methods • Characterize prey-related mechanisms of attraction or avoidance, effects of wind facilities on bird prey availability

Monitoring Prey Resources

Offshore wind development may alter **seabird** movements and diet via potential changes to prey distributions and abundance (see *What are the types of potential effects to birds from offshore wind development?*). Changes to prey distributions and abundance can be monitored using underwater acoustics, physical sampling (e.g., trawls, grab and scrape sampling, environmental DNA), and visual methods (e.g., underwater videos and drop cameras) in and around offshore wind facilities. These data can also be combined with seabird tracking data to link changes in prey to changes in seabird movement and behavior.[36] Opportunistically observed feeding events of birds offshore (e.g., during a boat-based survey) can provide some insight into prey sources, though these observations may be rare. Scientists can also assess changes to bird diet using **visual observations** of feeding events, examining dropped food, and analyzing stomach and pellet contents at island or coastal nesting colonies. If visual feeding observations or stomach/pellet samples are limited, other sampling methods (e.g., tissue analysis of blood and feathers, DNA analysis of feces) can be used to help infer potential changes to bird diet associated with offshore wind development. However, it can be challenging to separate the effects of offshore wind from other environmental factors on prey distributions and diet. Shifts in offshore prey availability may occur above the water as well; recent remote multi-sensor monitoring efforts have characterized insect activity around offshore wind turbines, which offers insight into these important prey for migrating passerines (Robinson Willmott et al. 2023).

Combining and Developing Methodologies

No single approach is considered "best" for monitoring birds at offshore wind facilities, as each method has strengths and limitations, and method selection is driven by the research objective. Thus, multiple monitoring methods are frequently used together to inform knowledge of bird interactions with offshore wind development. For example, bird distribution data derived from large-scale observational surveys conducted via boat or plane provide a "snapshot" in time and are well-suited for assessing changes to bird behavior at macro-scales (i.e., avoidance of an entire wind facility) and meso-scales (i.e., avoidance of rows of turbines; Garthe et al. 2023). Individual bird tracking methods (e.g., satellite tags, radio telemetry) can be used to monitor behavior on macro-, meso-, and micro-scales depending on the data resolution, and allow for data collection over a longer time period and geographic area (e.g., Johnston et al. 2022; Pollock et al. 2024). Combined, observational and tracking approaches can provide a more holistic understanding of potential changes to bird behavior around offshore wind development at various spatial and temporal scales[37] (e.g., Heinänen et al. 2020).

As another example, radar can identify when and how many birds are moving through a wind facility, but species identification is usually not possible with this method alone. In this case, radar may be combined with camera systems, acoustic monitoring, and/or human observations, which can identify specific species (e.g., Plonczkier & Simms 2012). Some tools are being developed to automatically collect and analyze these data types concurrently,[38] and using multiple methods can allow scientists to overcome the limitations of any single approach and build a more comprehensive understanding of how birds interact with offshore wind facilities (Robinson Willmott

[36] PrePARED: Fish and Seabird Response to Offshore Wind Farm Development
[37] Carbon Solve: ORJIP: Integration of tracking and at-sea survey data (InTAS)
[38] DHI: Multi-sensor Bird Detection Application

et al. 2023, Courbis et al. 2024). This information, in turn, can support more accurate risk assessments, inform the design of potential **mitigation** measures, and support permitting compliance evaluations.

Bird monitoring at offshore wind facilities can be challenging due to the scale of the wind facilities, their remote locations, and harsh, variable marine weather conditions. Although much progress has been made to date, additional technologies are still being developed to further improve monitoring efforts, including automated bird detection systems, new types of radar, and new thermal imaging systems (see *How do we assess the risk of birds colliding with offshore wind turbines?*). For example, there are eight offshore bird monitoring technologies listed as "in development" as of August 2025 by the international collaborative Wind Energy-Environmental Research and Engagement Network[39] to study bird-turbine collisions, attraction, and avoidance.

Monitoring Groups

Bird monitoring at and around U.S. offshore wind facilities is conducted by offshore wind developers, scientific consultants, academic institutions, government agencies (state, tribal, federal), and conservation organizations. The U.S. federal Bureau of Ocean Energy Management (BOEM) requires offshore wind developers to conduct monitoring both to inform pre-construction site assessment and to monitor effects following wind facility construction. The exact components of monitoring may vary by project but are described in federal guidance (BOEM 2020), supplemental guidance documents developed by expert scientists and other stakeholders (Avian Displacement Guidance Committee 2024), and permitting documents for individual wind facilities, including site assessment plans (Tetra Tech 2018), **construction and operations plans** (Biodiversity Research Institute 2022), and post-construction monitoring plans (Tetra Tech Inc 2014, Goodale et al. 2023). To conduct this site-specific monitoring, offshore wind developers have biologists on staff and often contract with third-party scientific consultants to conduct monitoring using various methods depending on the interaction/effect being studied (Normandeau-APEM 2019, 2021, Normandeau Associates 2024). In addition to required project monitoring, scientists from academic institutions, conservation groups, and offshore wind developers often collaborate on site-specific and regional research projects to monitor birds in different ways around one or across multiple offshore wind facilities, such as Project Wildlife and Offshore Wind[40] (WOW), which is a regional project aimed at understanding the effects on marine mammals and seabirds from the first U.S. commercial-scale offshore wind facilities (see What non-regulatory actions are being done to better understand how birds interact with offshore wind facilities and support bird conservation?). Since 2010, federal agencies including the National Marine Fisheries Service, BOEM, U.S. Fish and Wildlife Service, and the U.S. Navy have also coordinated to conduct coast-wide boat and aerial visual surveys of seabirds, sea turtles, and marine mammals in offshore areas as part of the Atlantic Marine Assessment Program for Protected Species.[41] More information about bird monitoring efforts related to U.S. Atlantic offshore wind development (e.g., methods used, who is involved, locations) can be found in the Regional Wildlife Science Collaborative's Research Database.[42]

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[39] Tethys: Wind Energy Monitoring and Mitigation Technologies Tool
[40] Tethys Knowledge Base: Project WOW Update on Results and Plans
[41] U.S. Navy: Marine Species Monitoring / AMAPPS
[42] RWSC Research Database: Ongoing bird or bat-offshore wind projects

For More Information

- Regional Wildlife Science Collaborative: Science Plan Chapter 4 - Birds
- New York State Environmental Technical Working Group: Guidance for Pre- and Post-Construction Monitoring to Detect Changes in Marine Bird Distributions and Habitat Use Related to Offshore Wind Development
- Wind Energy-Environmental Research & Engagement Network: Wind Energy Monitoring and Mitigation Technologies Tool

What is compensatory mitigation and how does it apply to birds and offshore wind?

- When federally protected species or **habitats** may be at risk from human activities, regulators may seek to mitigate potential harm through a tiered approach of first avoiding harm, then reducing harm, and finally, compensating for harm when it cannot be avoided or minimized, to ensure any negative impacts are balanced by ecological benefits.
- Compensatory **mitigation** for birds in the U.S. offshore wind context refers to federally required conservation or restoration efforts under the Endangered Species Act that offset unavoidable harm to protected bird species or their habitats.
- U.S. offshore wind projects may be required to implement compensatory mitigation if federal regulators determine that construction or operation is likely to harm protected birds or damage important habitats. As of 2025, this has been applied to three species in the U.S. Atlantic: Red Knots, Piping Plovers, and Roseate Terns, with a focus on addressing potential collision risk.
- Compensatory mitigation involves supporting restoration or conservation actions that benefit affected bird populations and habitats in measurable, lasting ways. Specific approaches for birds in relation to U.S. offshore wind are still in development. Examples may include improving or protecting key existing habitats, as well as controlling disease or **invasive species** at breeding colonies.

Detailed Answer

Compensatory Mitigation & the Endangered Species Act

When federally protected species or **habitats** may be at risk from human activities, regulators seek to mitigate potential harm through a tiered approach of avoiding harm, reducing harm, and compensating for harm when it cannot be avoided or minimized to ensure any negative impacts are balanced or exceeded by ecological benefits for protected species (sometimes described as "no net loss"). This tiered approach is referred to as the "**mitigation** hierarchy" and applies to a range of industries and human activities, including energy, real estate, agriculture, transportation, etc.

Under the Endangered Species Act (ESA; see *What federal environmental laws and international agreements protect birds?*), industries and federal agencies are required to assess whether proposed activities, such as constructing and operating offshore wind facilities, are likely to result in unintentional "**take**" of ESA-listed species or their designated critical habitat. Take is defined in the ESA as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (see *What does "take" mean for birds?*), and is prohibited. If

unintentional take under the ESA is likely, proposed projects may be required to implement compensatory mitigation measures to lawfully proceed.

While the ESA does not explicitly define "compensatory mitigation," it grants authority to the U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration (NOAA) Fisheries to ensure that federal actions "are not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of [critical] habitat of such species."[43] Using this authority, USFWS adopted a formal Compensatory Mitigation Policy (2016; revised in 2023),[44] and both USFWS and NOAA Fisheries issued final rules in 2024[45] clarifying how compensatory mitigation may be required under the ESA. Under these policies and rules, compensatory mitigation offsets residual impacts to protected species and habitats after all practical steps have been taken to avoid and minimize harm. Compensatory mitigation provides ecological benefits (for example, through restoration, enhancement, or protection of habitats) that replace lost function, value, or services due to human activities. Compensatory mitigation must:

1. Measurably improve baseline ecological conditions for the protected species (e.g., more or better habitat, larger or healthier **populations** than if no mitigation action were taken), and
2. Deliver long-term benefits that last at least as long as expected negative impacts.

These two elements are formally referred to as additionality and durability, respectively. The main approaches to compensatory mitigation include:

1. *Conservation banks:*[46] Permanent, protected habitat areas managed by federally approved third parties. Developers can buy credits from these banks to offset their project's impact.
2. *In-lieu fee programs:* Developers pay a fee to a government or non-profit conservation group, which then carries out habitat restoration work on their behalf.
3. *Proponent-responsible mitigation:* Developers plan and complete their own conservation or restoration project and are responsible for ensuring its success.

Specific approaches for birds in relation to U.S. offshore wind are still in development (see below). However, ESA-driven compensatory mitigation has already produced measurable benefits for protected bird species in the U.S. land-based wind energy context. For example, 12 endangered California condors have been successfully reared at the Oregon Zoo, and many have subsequently been released into the wild, as a result of compensatory mitigation for the Manzana Wind Power Project in southern California.[47, 48, 49] These new additions have contributed to net growth of the condor population relative to potential unavoidable, unintentional, permitted losses associated with this specific instance of wind energy development (in this instance, potential losses were due to potential collision risk). Furthermore, as of November 2025, there have been no reported

[43] Endangered Species Act online version: Interagency Cooperation Section 7(a)(2)
[44] USFWS: ESA Compensatory Mitigation Policy (2023)
[45] NOAA Fisheries: Final Revisions to ESA Implementing Regulations (2024)
[46] USFWS: Conservation banking
[47] USFWS: Balancing Wind Energy Development with Condor Recovery
[48] Oregon Zoo: Wind developer-funded condor hatches and releases (2024)
[49] Avangrid: Press release on Condor Conservation Plan (2024)

negative impacts to condors associated with this project, and no California condor collisions have been recorded at any wind energy projects.

Compensatory Mitigation & U.S. Offshore Wind

For U.S. offshore wind, compensatory mitigation refers to conservation or restoration measures required under specific regulatory frameworks of the ESA (described in the section above) to offset unavoidable negative impacts to protected species and their habitats from offshore wind development. Bird species currently listed under the ESA (as of 2025) that may be exposed to offshore wind development because they use offshore areas in the U.S. Atlantic include the Red Knot, Piping Plover, and Roseate Tern. For these three species, concerns about impacts from offshore wind are related to potential collision risk (Williams et al. 2024).

When offshore wind projects are predicted to cause unintentional take of listed species that cannot be fully avoided or minimized, federal agencies may require developers to submit a compensatory mitigation plan before construction begins. The plan details how the project will financially support or directly carry out conservation efforts either at the wind project site or elsewhere (including internationally), provided the effort would benefit affected populations. Compensatory mitigation may include efforts like protecting nesting areas, restoring coastal habitats, or managing other disturbances and threats (predators, **invasive species**, pollution, etc.). Specific approaches for bird compensatory mitigation associated with U.S. offshore wind are still in development. Compensatory mitigation projects, put forward in 2024, have included habitat restoration to improve spawning success of key prey species (horseshoe crabs and mussels), **shorebird** rehabilitation after toxic algal blooms, and establishing new protected areas to safeguard/improve existing habitats, among other ideas.[50] For Roseate Terns, compensatory mitigation may include approaches such as disease and invasive plant species control at breeding colonies, as well as spatial protections for **forage fish** hotspots.[51] As of November 2025, there are no agency-approved conservation banks or in-lieu fee programs for the three ESA-listed bird species that are most likely to be exposed to operational U.S. Atlantic offshore facilities.

For More Information

- BOEM: State of the Science Compensatory Mitigation for Offshore Wind Workshop (2024)
- Special Initiative on Offshore Wind: Birds and Bats / Compensatory Mitigation (2025)

Regulatory Context and Requirements

What federal environmental laws and international agreements protect birds?

- The National Environmental Policy Act (1969), the Migratory Bird Treaty Act (1918), and the Endangered Species Act (1973) are the primary federal laws protecting birds in the context of U.S. offshore wind development.

[50] 2024 BOEM Mitigation Workshop: Avian mitigation planning
[51] 2024 BOEM Mitigation Workshop: Roseate and Common Tern Mitigation Considerations

- These laws and their implementing regulations lead to protections for birds by prohibiting physical injury, disturbance, transport, capture, and trade of certain species (i.e., "**take**"), safeguarding key **habitats**, and establishing mandatory procedures for assessing and reducing potential effects to birds and other wildlife from human activities.
- The U.S. is also party to a suite of international agreements, like the North American Bird Conservation Initiative (NABCI 1999), which promote international cooperation to protect **migratory bird** species and/or their critical habitats. However, these agreements are not legally enforceable, nor are they explicitly considered in the U.S. offshore wind regulatory context.

Detailed Answer

In the context of offshore wind and other types of energy development in the U.S., several federal laws protect birds and other wildlife via three mechanisms:

- prohibition of "**take**," which generally forbids physical injury, disturbance, capture, transport, and trade of certain species without prior **authorization** (see below for legal definitions);
- protection of designated critical **habitat**; and
- required environmental review and impact assessment.

Key federal laws include the National Environmental Policy Act, the Migratory Bird Treaty Act, and the Endangered Species Act:

National Environmental Policy Act (NEPA) of 1969[52]

NEPA establishes a formal assessment and review process to understand potential environmental impacts of federal actions, including to birds and their habitats, before federal agencies can issue permits or authorize projects like offshore wind energy development in **federal waters** (42 U.S.C. § 4321 et seq.). The NEPA process[53] requires implementing agencies of large-scale projects to scientifically evaluate effects of proposed federal actions on the environment and wildlife through initial **Environmental Assessments** (EA) and/or more comprehensive **Environmental Impact Statements** (EIS). Historically, this process has been overseen by the Council on Environmental Quality (CEQ) and included public input and an analysis of the potential negative effects of the action on all birds, including endangered species, as well as critical habitats. The Bureau of Ocean Energy Management (BOEM), which oversees offshore energy development, has relied on the NEPA process to assess potential risks to birds from offshore wind facilities.[54, 55] In early 2025, a presidential executive order (E.O. 14154[56]) revoked CEQ's authority to regulate federal agency compliance with the NEPA process, and CEQ has subsequently withdrawn its implementing regulations.[57] These new changes may allow for different interpretations of NEPA's environmental review requirements across federal agencies in the future.

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[52] Council on Environmental Quality: NEPA website and read NEPA (full text)
[53] EPA: What is the NEPA Review Process?
[54] BOEM: NEPA Implementing Procedures
[55] BOEM: NEPA and Offshore Renewable Energy for offshore wind EAs and EISs
[56] Executive Order 14154: Unleashing American Energy
[57] Federal Register: Removal of NEPA Implementing Regulations

Migratory Bird Treaty Act (MBTA) of 1918

The overarching goal of the MBTA is to ensure the sustainability of all **migratory bird** species in the U.S.[58] The law specifically prohibits take (see *What does "take" mean for birds?*) of protected migratory bird species without prior **authorization** by the U.S. Fish and Wildlife Service (16 U.S.C. §§ 703-712). In the context of the MBTA, take of migratory birds, including nests and eggs, is defined as:

> "*...to pursue, hunt, take, capture, kill, attempt to take, capture, or kill, possess, offer for sale, sell, offer to barter, barter, offer to purchase, purchase, deliver for shipment, ship, export, import, cause to be shipped, exported, or imported, deliver for transportation, transport or cause to be transported, carry or cause to be carried, or receive for shipment, transportation, carriage, or export...*"

The MBTA currently protects 1,106 migratory bird species from over 80 taxonomic families;[59] 89 of these species are also listed as "Threatened" or "Endangered" under the U.S. Endangered Species Act. The MBTA only applies to migratory bird species **native** to the U.S. or its territories.[60]

Endangered Species Act (ESA) of 1973

The ESA prohibits take of endangered and threatened species. Take is defined as, "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to [do so]" (16 U.S.C. §§ 1531-1544).[61] (see *What does "take" mean for birds?*). The ESA also requires federal agencies to conserve listed species and consult with relevant entities (i.e., U.S. Fish and Wildlife Service or NOAA Fisheries) to determine if a proposed action would jeopardize the existence of listed species or destroy or modify critical habitats. The ESA prohibits the funding, authorization, or execution of proposed actions determined to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat after a formal consultation process. However, for those projects that may result in incidental take, an **Incidental Take Statement** or Incidental Take Permit may be issued to allow for an exemption under the take prohibition under Section 7 and Section 10 of the ESA respectively. Under the ESA, "Endangered" is defined as "any species in danger of extinction throughout all or a significant portion of its range," and "Threatened" is defined as "any species likely to become endangered within the foreseeable future." Endangered species are automatically granted the strongest, broadest protections under the ESA, but protections for threatened species can be customized on a case-by-case basis, provided the activity does not negatively affect survival of the species.[62] "Critical habitats" are defined as areas occupied by listed species where there are essential physical or biological features that may need protection or special management considerations, or similar areas not currently occupied by listed species but deemed essential for their conservation. As of June 2025, the ESA lists almost 100 bird species in the U.S. and its territories as Threatened (*n*=26) or Endangered (*n*=67), as well as over 200 other bird species from around the world.[63]

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[58] USFWS: Migratory Bird Treaty Act of 1918
[59] National Archives: CFR Title 50 Part 10.13
[60] Migratory Bird Treaty Reform Act: https://www.congress.gov/bill/108th-congress/house-bill/4114
[61] USFWS: Read the ESA (full text)
[62] NOAA Fisheries: ESA Threatened Species Protections
[63] USFWS: Listed U.S. Species by Taxonomic Group (Birds)

Several other federal laws may provide incidental benefits for marine **shorebirds** and **seabirds** through protections for coastal habitats used by and/or important for bird species and their prey, such as the Coastal Zone Management Act (1972),[64] the Coastal Barrier Resources Act (1982),[65] and the National Marine Sanctuaries Act (1972).[66] Federal laws protecting other marine taxa (mammals and fisheries species) and their habitats, like the Marine Mammal Protection Act (1972)[67] and the Magnuson-Stevens Fishery Conservation and Management Act (1976),[68] may also indirectly benefit birds via incidental habitat and prey species protections.

Table 3. Examples of statutes* for U.S. Atlantic coast states. *Visit respective state wildlife and environmental agency websites to learn more about these laws. Note that even though some states may have no direct equivalents for certain federal laws, they often add additional state-level protections through rules and regulations rather than formal statutes.

State	State-Level ESA Equivalent	State-Level NEPA Equivalent
Maine	ME Endangered Species Act	ME Natural Resources Protection Act
New Hampshire	NH Endangered Species Conservation Act	*No direct equivalent*
Massachusetts	MA Endangered Species Act	MA Environmental Policy Act
Rhode Island	RI State Endangered Species Act	*No direct equivalent*
Connecticut	CT Endangered Species Act	CT Environmental Policy Act
New York	Environmental Conservation Law of NY	NY State Environmental Quality Review Act
New Jersey	NJ Endangered and Nongame Species Conservation Act	Executive Order No. 215 of 1989
Delaware	*No direct equivalent*	*No direct equivalent*
Maryland	MD Nongame and Endangered Species Conservation Act	MD Environmental Policy Act
Virginia	*No direct equivalent*	*No direct equivalent*
North Carolina	NC Endangered Species Act	NC State Environmental Policy Act
South Carolina	SC Nongame and Endangered Wildlife Species Act	*No direct equivalent*
Georgia	GA Endangered Wildlife Act	GA Environmental Policy Act
Florida	FL Endangered and Threatened Species Act	*No direct equivalent*

In addition, many states in the U.S. have enacted laws that protect birds through state legislation (Table 3) similar in spirit and structure to the federal Endangered Species Act and National Environmental Policy Act, which require state entities and agencies to protect threatened or endangered wildlife and formally consider potential impacts of human activities on wildlife,

[64] NOAA Office for Coastal Management: CZMA
[65] USFWS: Coastal Barrier Resources Act FAQs
[66] NOAA: National Marine Sanctuaries History
[67] NOAA Laws and Policies: MMPA
[68] NOAA Laws and Policies: MSA

including birds. These laws become relevant when offshore wind development occurs in **state waters** and for developing coastal infrastructure linking offshore wind activities in federal waters offshore to facilities on land.

International Agreements

The U.S. is party to international agreements for bird conservation like the North American Bird Conservation Initiative (NABCI, 1999).[69] Through a formal committee that includes government agencies and non-governmental organizations, the U.S. participates in the NABCI with Canada and Mexico to protect North American migratory birds and advance biological, social, and scientific conservation priorities. The U.S. committee, NABCI-U.S., provides a forum for developing focused efforts to improve bird **monitoring**, promote conservation design, and support international partners. Specifically, NABCI-U.S. aims to expand bird conservation partnerships, increase financial resources available for conserving birds within and beyond the U.S., and enhance the effectiveness of those resources and partnerships by facilitating integrated bird conservation.[70] Although international agreements like NABCI promote cross-border bird conservation, they are non-binding (i.e., not enforceable by U.S. law except when specifically codified) and not explicitly considered in the U.S. regulatory framework for offshore wind energy development.

For More Information

- USFWS: Migratory Birds: A Brief Conservation History (video)
- National Audubon Society: Migratory Bird Treaty Act and MBTA: The Bird Protection Law (videos)
- USFWS: Endangered Species Act Overview and ESA 101 (videos)
- Farmers for Monarchs: The ESA 4(d) Rule and Critical Habitat Explained
- Environmental Law Institute, People Places Planet Podcast: NEPA, Explained

What does "take" mean for birds?

- "**Take**" is a legal concept used in federal wildlife protection laws to describe actions that injure, kill, or otherwise negatively impact protected species, including birds.
- The Endangered Species Act (ESA) defines take as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."
- The Migratory Bird Treaty Act (MBTA) defines take of **migratory birds** as "to pursue, hunt, take, capture, kill, attempt to take, capture, or kill, possess, offer for sale, sell, offer to purchase, purchase…transport or cause to be transported."
- Federal entities must assess whether their own activities, or those of developers, could result in take under the ESA. Developers must work with federal agencies to acquire **authorizations** if needed, and implement **monitoring** and measures to avoid, reduce, and offset potential impacts to protected species. Though not required, developers are encouraged to coordinate with the U.S. Fish and Wildlife Service to identify and minimize risks to migratory birds under the MBTA.

[69] NABCI: https://nabci-us.org
[70] NABCI: U.S. Charter

Detailed Answer

"**Take**" is a legal concept used in federal wildlife protection laws, such as the Endangered Species Act (ESA) and the Migratory Bird Treaty Act (MBTA), to describe actions that injure, kill, or otherwise negatively impact protected species, including birds (see *What federal environmental laws and international agreements protect birds?*). The exact definition of take varies slightly across environmental laws and regulations.

Endangered Species Act

The ESA specifically defines take as:

"…to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." (16 U.S.C. § 1532(19)) The U.S. Fish and Wildlife Service (USFWS) has further clarified that "harm" includes significant **habitat** modification or degradation that kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Furthermore, "harass" refers to actions that create the likelihood of injury by disturbing wildlife to such an extent as to disrupt normal behavior. The ESA prohibits take in all forms, whether intentional or unintentional, unless specifically authorized through a formal **consultation** and permitting process.[71]

Federal interpretations of regulatory terms like take may change over time through mechanisms including legal opinions (**M-Opinions**) and formal **rulemaking** (following the **Administrative Procedure Act**; Figure 18). For example, in April 2025, the USFWS and NOAA Fisheries proposed through rulemaking procedures to rescind the regulatory definition of harm as described above.[72] Before it becomes effective, this change must go through public notice and comment, and the agencies must consider feedback. If the ESA definition of harm is determined to no longer apply to habitat modification and degradation as proposed, it is unclear how future actions will be regulated with respect to negative effects on listed species' habitats. Regulatory interpretations will likely continue to change in the future. Federal agencies are permitted to update how they interpret and enforce laws, but their decisions must be reasonable, based on evidence, and explained clearly. If agencies make changes without adequate justification, ignore important information, or act inconsistently with a law's intent, courts can block those actions.[73]

Take related to offshore wind development is considered incidental because it occurs unintentionally as part of otherwise lawful activities. When federal agencies work with offshore wind developers, they must assess whether development activities are likely to affect ESA-listed bird species or their designated critical habitat. If so, the agency must initiate consultation with the U.S. Fish and Wildlife Service. The offshore wind project may be required to pursue permits, **mitigation**, and conservation measures to lawfully proceed (see *What is compensatory mitigation and how does it apply to birds and offshore wind?*).

Generally, potential effects associated with a proposed federal action for large-scale development (such as permits for offshore wind energy development projects) are initially assessed through a **Biological Assessment** (BA) prepared by the proposing agency (e.g., Bureau of Ocean Energy

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[71] NOAA Fisheries: ESA Section 7 Consultations
[72] Federal Register: Definition of Harm under the ESA
[73] Library of Congress: An Introduction to Judicial Review of Federal Agency Action

Management [BOEM]). If the BA determines the action is likely to adversely affect ESA-listed bird species or critical habitat, the USFWS conducts a formal consultation and issues a **Biological Opinion** (BiOp) analyzing the effects of the proposed action. A BiOp determines whether the action is likely to jeopardize the continued existence of ESA-listed species or adversely modify critical habitat; if that determination is reached, the project must be altered in a way to ensure a no-jeopardy finding. If incidental take is anticipated, the BiOp includes an **Incidental Take Statement** (ITS) specifying required **reasonable and prudent measures** the proposing agency (e.g., BOEM) and collaborating entities (e.g., offshore wind developers) must implement to minimize incidental take. BiOps may also include additional conservation recommendations.

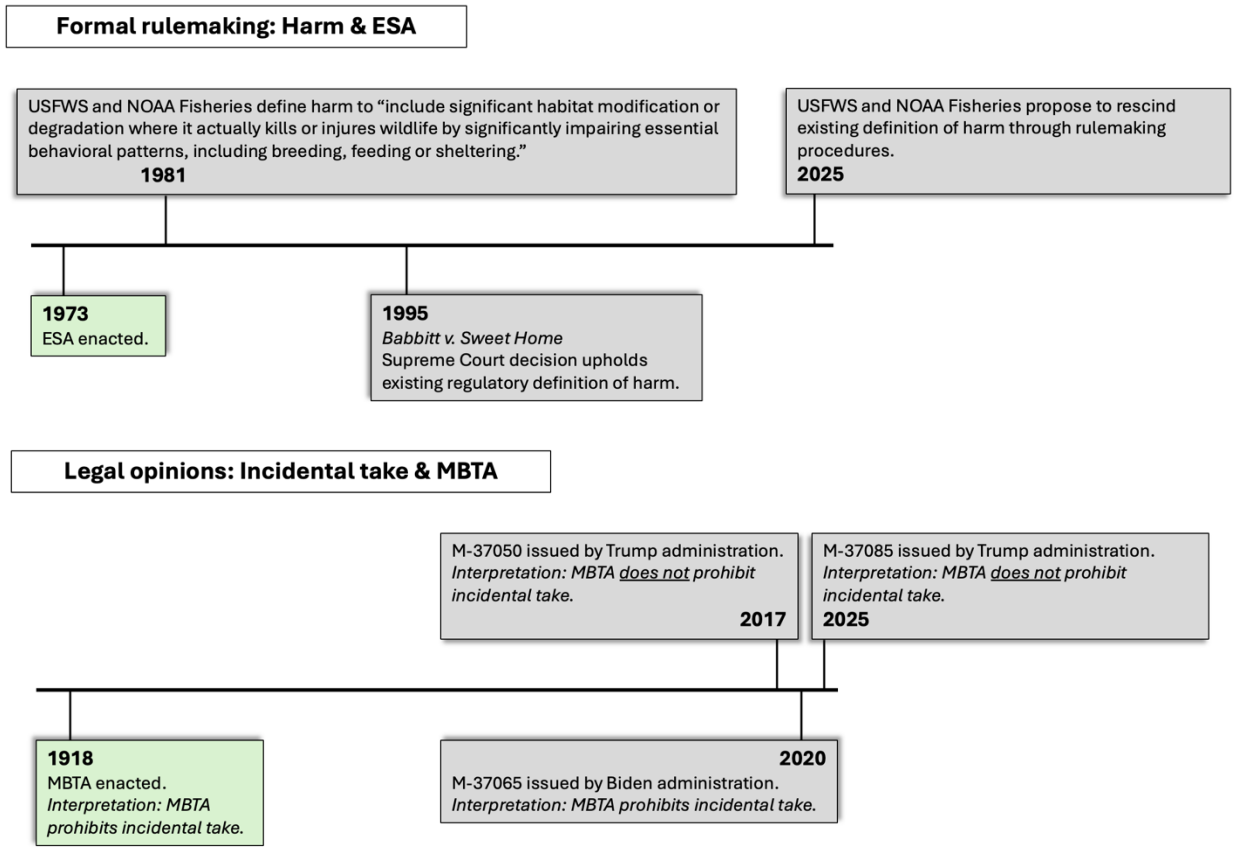

Figure 18. Timelines of changing regulatory definitions under the ESA via rulemaking (top) and MBTA via legal opinions (bottom).

Migratory Bird Treaty Act

The MBTA prohibits the following take with respect to **migratory birds**, in whole or part, including nests and eggs:

"…to pursue, hunt, take, capture, kill, attempt to take, capture, or kill, possess, offer for sale, sell, offer to purchase, purchase…transport or cause to be transported…" (16 U.S.C. §§ 703–712).

Unlike the ESA, the MBTA does not have a formal consultation or permitting process to authorize incidental take. However, offshore wind developers are encouraged to voluntarily coordinate with

the U.S. Fish and Wildlife Service (USFWS) for technical assistance to identify and minimize risks to migratory birds. While incidental take is prohibited under the MBTA (see below), enforcement is discretionary. The USFWS may pursue enforcement if it determines that foreseeable risks were not addressed and reasonable measures to avoid or minimize harm to migratory birds were not implemented. [74]

Federal interpretations of regulatory terms such as take may change over time through mechanisms including legal opinions (M-Opinions) and formal rulemaking (following the Administrative Procedure Act; Figure 18). In April 2025, the Department of the Interior reinstated a 2017 legal opinion [75] concluding that MBTA prohibitions on take do not include accidental or incidental killing or taking of migratory birds. Unlike rulemaking mechanisms, changes to enforcement, permitting, and policy based on M-Opinions go into effect immediately without a required formal notice, comment, and revision period. Interpreting the scope of take under the MBTA is further complicated because different federal appellate courts are split on whether incidental take is prohibited,[74] which means the risk of enforcement may vary regionally. Regulatory interpretations will likely continue to change in the future. Federal agencies are permitted to update how they interpret and enforce laws, but their decisions must be reasonable, based on evidence, and explained clearly. If agencies make changes without adequate justification, ignore important information, or act inconsistently with a law's intent, courts can block those actions.

[74] National Law Review: The Pendulum Swings Back (Again) on Prohibition of Incidental Take under the Migratory Bird Treaty Act
[75] U.S. Dept of the Interior: Opinion M-37050

Glossary of Terms

This glossary defines and provides additional details on terms used in the Bird Communications FAQ document.

Administrative Procedure Act (APA) – Law that establishes the procedures federal agencies must follow when creating, amending, or repealing regulations, as well as how the public can participate in the rulemaking process, to ensure transparency, accountability, and consistency in agency decision-making.

Anthropogenic – Effects, processes, objects, or materials derived from human activities.

Authorization – Permit or approval from the federal government to conduct a specified action, which includes strict limits and requirements that must be complied with when conducting the action.

Biodiversity – Variety of life as applied to ecosystems, habitats, different species, or genetic variations within a species.

Biological Assessment – Document prepared by a federal agency to assess whether a proposed action (such as a development project or federal permit) may affect endangered or threatened species or their habitat. Determines whether formal consultation and a Biological Opinion with the U.S. Fish and Wildlife Service or National Marine Fisheries Service is required.

Biological Opinion – Document issued by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service under the Endangered Species Act (ESA) that states whether a federal action is likely to jeopardize the continued existence of a listed species or destroy or adversely modify its critical habitat. If jeopardy is found, the opinion will specify reasonable and prudent alternatives to avoid harm.

Biomass – Total mass, usually expressed as weight (e.g., grams, kilograms, metric tons), of living organisms per unit area. Can refer to all living organisms or specific taxonomic group(s).

Bycatch – Individuals unwanted/accidentally caught during commercial fishing for a different species.

Climate change – Long-term shifts in environmental conditions such as temperatures and weather patterns. Shifts can be natural, due to changes in the sun's activity or large volcanic eruptions. Since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels like coal, oil, and gas.

Collision Risk Model (CRM) – Predictive tool used to estimate the likelihood of birds or bats colliding with man-made structures like wind turbines. These models incorporate factors like species behavior, movement patterns, and environmental conditions.

Construction and Operations Plan (COP) – Plan that an offshore wind energy developer submits to the Bureau of Ocean Energy Management (BOEM) for approval to request a permit to build an offshore wind project. Includes substantial detail on project components and specifications, baseline survey efforts, and other data to inform BOEM's permitting decision.

Consultation – Process in which a federal agency seeks input from other entities, such as government agencies, stakeholders, or experts, to assess the potential impacts of a proposed action on protected species or critical habitats. Consultation ensures that the action complies with environmental laws and identifies measures that can minimize or avoid environmental harm.

Demographic – Statistical data and characteristics such as a population's growth rate or age structure. Individual characteristics such as age and sex are input for estimating demographic **parameters**.

Distribution – Species' occurrence in three-dimensional space (e.g., latitude, longitude, and altitude) within a particular time frame.

Ecosystem services – Direct or indirect benefits that ecosystems provide to humans to sustain livelihoods and well-being.

Effector – Any physical, chemical, biological, or acoustic factor (anthropogenic or environmental) that can affect the behavior, health, or functioning of an organism, population, or ecosystem (e.g., wind facility attributes and site characteristics).

Empirical – Data/evidence that are derived from real-world measurements, experiments, or direct observations.

Energetic cost – Increases in an animal's energy expenditure (e.g., metabolic, caloric) due to factors such as longer foraging trips or reduced access to preferred habitat.

Environmental Assessment (EA) – Document prepared by federal agencies under the National Environmental Policy Act (NEPA) to determine if an applicable federal action will have significant environmental impacts. An EA includes a brief discussion of the purpose and need for a proposed action, alternative actions, environmental impacts of the proposed action and alternatives, and a list of agencies and individuals that were consulted. Regulatory requirements for an EA are less detailed and rigorous than the requirements for an Environmental Impact Assessment (EIS). Any action that is not categorically excluded and does not require an EIS, has uncertain impacts, or has unresolved environmental issues, requires an EA.

Environmental Impact Statement (EIS) – Document prepared by federal agencies under the National Environmental Policy Act (NEPA). An EIS is prepared if a proposed major federal action is determined to significantly affect the quality of the human environment. Regulatory requirements for an EIS are more detailed and rigorous than the requirements for an Environmental Assessment (EA). The document details the purpose and need for a proposed action, reasonable alternatives to the proposed action, the affected environment, environmental consequences, and summarizes public comments on a draft document.

Extirpation – Complete elimination of a population from a specific geographic area but the species still occurs elsewhere.

Federal waters – Marine waters controlled by the U.S. federal government. Typically, this area extends from the boundary limit of state waters (3 nautical miles from the shoreline for states in the Atlantic Ocean) to a maximum of 200 nautical miles from shore or to the boundary of other countries' waters.

Forage fish – Small to medium-sized fish that form large groups and serve as food sources (prey) for predatory fish, marine mammals, seabirds, and other wildlife. Forage fish typically have highly variable reproductive success that results in boom-and-bust cycles in population size.

Foraging – Act of searching for food or eating.

Habitat – Physical, biological, chemical, and meteorological conditions that support the specific needs of a population or individual's survival and reproduction. Habitat may be constant or variable across space and time. For example, many birds undergo seasonal migrations from breeding grounds in the Arctic tundra to wintering grounds in the southern U.S., Caribbean, or South America. Across these different spaces at different times of year, the properties of the species' habitat vary, supporting different stages of the life cycle.

Habituation – Process by which wildlife becomes accustomed to new (typically anthropogenic) structures or activities in their natural environment.

Incidental Take Statement (ITS) – Statement issued by the U.S. Fish and Wildlife Service or National Marine Fisheries Service as part of a Biological Opinion that allows for the unintentional take of endangered species during otherwise legal activities. It sets conditions under which incidental take is allowed and requires the implementation of mitigation measures to minimize harm.

Invasive species – Species that is introduced into a new environment and also causes harm. Invasive species can outcompete or otherwise harm existing species in the habitat, change habitat function, and/or disrupt ecosystems.

Life history – Pattern of survival and reproductive events occurring throughout an organism's lifespan, including key time periods (such as breeding or migration) and biological traits (such as age at maturity, number of offspring, size at birth, and lifespan), all of which are shaped by evolutionary processes operating in conjunction with environmental conditions.

Marine bird – Any bird that interacts with the offshore marine environment at or below the water's surface for foraging, roosting, loafing, and/or other behaviors. This includes all seabirds, as well as waterbirds and waterfowl that utilize the ocean during parts of their life cycle, and other species, such as phalaropes, that forage or roost on the water's surface. Species whose only interaction with the offshore marine environment is to fly over it during migration (e.g., most songbirds and shorebirds) are not included in this category.

M-Opinion – Legal opinion issued by the Solicitor's Office within the Department of the Interior, interpreting the meaning of a law or regulation.

Migratory bird – Any bird that engages in movements over long distances for various purposes, including relocating to breeding or feeding habitats at different times of the year.

Mitigation – Efforts to avoid, minimize, restore, or offset environmental impacts caused by human activity. Mitigation of offshore wind energy-related effects to birds may include activities such as siting projects to avoid key habitat use areas and reducing artificial lighting on offshore infrastructure.

Monitoring – Repeated, systematic observations of birds or their habitat and ecosystems. Monitoring can be conducted for several purposes, including as part of scientific research, management, or to inform and enact mitigation measures.

Morphology – Physical characteristics and anatomical structure of an animal. Morphological measurements may include wing length, weight, or other information.

Native species – Species that occur in specific places due to natural dispersal, migration, and/or evolution and were not (intentionally or unintentionally) introduced to a specific environment by humans.

Non-native species – Species that is either intentionally or unintentionally introduced into a new environment by humans but does not cause harm. Non-native species can become invasive species.

Oceanographic – Physical, chemical, and/or biological aspects of the ocean.

Parameter – Summary number used in statistics to define the measure of a population-level characteristic such as the birth rate, average age, or proportion of juveniles in a population.

Phytoplankton – Microscopic organisms at the base of the food chain that live in oceans, bays, and freshwater bodies. Phytoplankton require sunlight to live and grow.

Pile driving – The process of installing structural columns into the seabed via a large hammer located on a barge. Pile driving is used across a range of industries, including for the installation of some types of offshore wind turbine foundations. Monopile foundations (in which a single steel tube is installed in the seabed and comprises a large part of the turbine foundation) are the most common type of offshore wind turbine foundation globally, since they are relatively inexpensive and easy to install in shallow waters. However, there are multiple turbine foundation types that do not use monopiles (e.g., jacket foundations, floating foundations), and several newer pile–driving technologies that do not involve the use of a hammer (to reduce noise generation during turbine construction).

Population – Group of organisms of a specific species. Can be defined geographically (e.g., present within a specific area) or by the degree of connectivity to other groups within a species (e.g., if certain subsets of a species have different breeding locations or migration patterns). A negative "population-level impact" to a species reduces the average survival or reproductive success of individuals such that the overall size of the population or species is reduced to a measurable extent.

Raptor – Also known as a "bird of prey," raptors are predatory birds with hooked beaks and sharp talons for hunting (e.g., eagles, hawks, falcons, owls).

Reasonable and Prudent Measures – Steps deemed by federal agencies to be necessary and appropriate to minimize, monitor, document, and report the impacts of incidental take of threatened and endangered species. These measures are listed in the Biological Opinion produced by U.S. Fish and Wildlife Service (or National Marine Fisheries Service) under the Endangered Species Act to assess the effects of proposed federal actions.

Reproductive success – For birds, this typically encompasses hatching success, the proportion of bird eggs that successfully hatch, and/or fledgling success, the proportion of a bird's chicks that live through the fledgling stage.

Rotor-swept zone (RSZ) – The area in which turbine blades move. The size of this area and where it is located (e.g., altitude above the water's surface) can influence how turbine presence affects birds.

Rulemaking – Process by which a government agency creates, amends, or repeals regulations that explain how laws will be implemented or enforced. Rulemaking is typically guided by the Administrative Procedure Act (APA), which ensures public involvement through notice, comment, and response to comments.

Seabird – Birds adapted to marine environments that only come on land to breed. Seabirds are adapted for both flight and swimming/diving.

Shorebird – Birds found along coastlines, mudflats, and wetlands, often with long legs and beaks for probing the sand (e.g., sandpipers, plovers).

Songbird – Also known as a "passerine," songbirds are small- to medium-sized perching birds that can be found in a variety of land-based habitats. Songbirds are known for their vocalizations and complex songs, and include warblers, finches, and sparrows.

Staging – Temporary gathering of migratory animals.

State waters – Waters controlled by a U.S. state. Atlantic coast states control areas within three nautical miles of the nearest ocean shoreline (including the shorelines of islands). Beyond this boundary, waters are controlled by the federal government, though states may maintain some degree of authority via National Oceanic and Atmospheric Administration-approved state Coastal Zone Management Plans.

Stratification – Natural separation of ocean water into distinct horizontal layers, creating a vertical layering effect primarily driven by physical, chemical, and biological properties such as salinity and temperature. Stratification can impact the movement of nutrients, oxygen levels, and marine life distribution within the ocean ecosystem.

Statistical bias – Difference between an estimate of a **parameter** (e.g., estimated population size from survey data) and the accurate underlying value of the parameter (e.g., true population size). Statistical bias can arise during data collection, analysis, or interpretation. For example, if a boat-based survey is unable to collect observational data in a portion of a study area, the resulting abundance estimate could be statistically biased if appropriate analytical methods were not used to account for the unequal survey coverage.

Take – Under the Endangered Species Act, with respect to any endangered species, take means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." In the context of the Migratory Bird Treaty Act, the definition of "take" of migratory birds, in whole or part, including nests and eggs, means "…to pursue, hunt, take, capture, kill, attempt to take, capture, or kill, possess, offer for sale, sell, offer to barter, barter, offer to purchase, purchase, deliver for shipment, ship, export, import, cause to be shipped, exported, or

imported, deliver for transportation, transport or cause to be transported, carry or cause to be carried, or receive for shipment, transportation, carriage, or export… .”

Upwelling – Oceanographic process in which deep, cold, nutrient-rich water rises to the surface, often due to wind-driven surface currents.

Visual observations – Scientific study method. Applied to the marine environment, visual observations typically occur from boats or aircraft and can either be opportunistic sightings or (more typically) systematic surveys of animals in the marine environment and/or airspace.

Wading bird – Long-legged birds that forage in shallow waters, often using their long beaks to catch fish and invertebrates (e.g., herons, egrets, ibises).

Waterfowl – Birds that primarily live in freshwater or coastal wetlands and are adapted for these habitats with webbed feet and waterproof feathers (e.g., ducks, geese, swans).

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