Part VII. Appendices

Note: This is an excerpt from “*Guidance for Pre- and Post-Construction Monitoring to Detect Changes in Marine Bird Distributions and Habitat Use Related to Offshore Wind Development”.* The full guidance document is available at www.nyetwg.com/avian-displacement-guidance

Developed by the Avian Displacement Guidance Committee of the Environmental Technical Working Group, with support from the Biodiversity Research Institute

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Photo credit: Nicholas Doherty

Part VII. Appendices

Appendix A. Guidance Development Methods

The recommendations for pre- and post-construction monitoring to detect changes in marine bird distributions and habitat use related to offshore wind development presented in this document were developed via a collaborative effort involving a Specialist Committee of the New York State Energy Research and Development Authority's (NYSERDA) Environmental Technical Working Group (E-TWG), chaired by a representative from the U.S. Fish and Wildlife Service (USFWS), with scientific technical support provided by the Biodiversity Research Institute (BRI).

A.1 E-TWG Specialist Committees

The Environmental Technical Working Group (E-TWG; www.nyetwg.com) was convened by NYSERDA in 2018 to provide input to the state on environmental topics, and advance common understanding among offshore wind stakeholders. The E-TWG assists the State to improve understanding of, and ability to manage for, potential effects of offshore wind energy development on wildlife. This involves the development of transparent, collaborative processes for identifying and addressing priority issues relating to wildlife monitoring and mitigation, with the goals of both improving outcomes for wildlife and reducing permitting risk and uncertainty for developers.

E-TWG Specialist Committees, which are comprised of subject matter experts and a subset of E-TWG members, advance technical work supporting this mission. These Committees are made up of volunteers, with technical and facilitation support from E-TWG support staff (e.g., BRI, the Cadmus Group, and the Consensus Building Institute). The Committees develop collaborative, science-based products focused on priority issues, which are presented to the State of New York and the E-TWG, who provide review and comment.

A.2 Committee Formation

This document was developed in response to a need identified by the E-TWG in 2021 to provide guidance on the survey and monitoring of wildlife around offshore wind development. This is a topic that has been prioritized by other relevant stakeholders in relation to specific taxa, including the Atlantic Marine Bird Cooperative (AMBC) Marine Spatial Planning (MSP) Working Group, which submitted a letter[10] to the Bureau of Ocean Energy Management (BOEM) in 2021 advocating for the development of pre- and post-construction monitoring guidelines to accompany BOEM's existing site characterization survey guidelines for birds (BOEM 2020). Partially in response to this AMBC MSP letter, USFWS staff committed to leading an expert Committee to discuss the development of guidance for conducting pre- and post-construction monitoring for changes in distributions and habitat use of marine birds. The Committee workplan was developed in consultation with the E-TWG, BOEM, and USFWS staff with the goals of developing guidance for the detection (e.g., identification of an effect occurring), characterization (e.g., what species and under what conditions), and degree (e.g., level and variability) of changes in distributions and habitat use patterns of marine birds in relation to OSW development. Committee members were selected for their scientific expertise on marine birds, study design, regional monitoring frameworks, and offshore wind development (Table A-1).

[10] See Atlantic Marine Bird Cooperative Marine Spatial Planning Workgroup's 2021 recommendations to BOEM on the avian survey guidelines.

A.3 Process

The Specialist Committee used existing BOEM guidance for site assessment "Guidelines for Providing Avian Survey Information for Renewable Energy Development" (BOEM 2020) as a starting place, and attempted to clarify and improve on these guidelines, where relevant, to develop guidance specifically for conducting pre- and post-construction research to detect effects for marine birds. This effort was supported with a deep and thorough literature review of previous studies from Europe and elsewhere that have examined displacement, attraction, and macro- to meso-scale avoidance in marine birds (see Appendix C), as well as existing relevant power analysis studies to inform recommendations. BRI provided scientific technical support for the Committee and developed the report, relying on substantial guidance and input from the Specialist Committee at regular intervals. The Specialist Committee met approximately monthly from May 2022 to November 2023 to discuss different aspects of the development of this document and the recommendations within. Specialist Committee members also reviewed written draft products multiple times during their development.

In addition to extensive Specialist Committee member feedback on draft products, the E-TWG reviewed and provided input on Committee products prior to finalization. A stakeholder engagement effort included presentation of the recommendations via an open public webinar and creation of a public feedback survey, to obtain further input on the draft guidance/recommendations prior to finalization of the report. More information on this stakeholder feedback process can be found at www.nyetwg.com/avian-displacement-guidance.

Table A1. *Subject matter experts and support staff involved in the Avian Displacement Guidance Specialist Committee, listed by role and in alphabetical order (last name). Alternate members substituted for working members from their specific organizations when primary working members were unable to participate in Committee meetings.*

Role	Name	Organization
Chair	Caleb Spiegel	US Fish and Wildlife Service
Working member	Evan Adams	Biodiversity Research Institute
Working member	Aonghais Cook	British Trust for Ornithology
Working member	Shilo Felton	Renewable Energy Wildlife Institute
Working member	Carina Gjerdrum	Environment and Climate Change Canada
Working member	Chris Haney	Terra Mar Applied Sciences, LLC, under contract to National Audubon Society
Working member	Juliet Lamb	The Nature Conservancy
Working member	Kim Peters	Ørsted
Working member	Brad Pickens	US Fish and Wildlife Service
Working member	Martin Scott	HiDef Aerial Surveying
Working member	Emily Silverman	US Fish and Wildlife Service
Working member	Jennifer Stucker	Western EcoSystems Technology, Inc
Working member	Ally Sullivan	TotalEnergies
Working member	Julia Willmott	Normandeau
Working member	Arliss Winship	CSS, Inc. under contract to NOAA NCCOS
Alternate	Garry George	National Audubon Society
Alternate	Jeffery Leirness	CSS, Inc. under contract to NOAA NCCOS
Alternate	Brita Woeck	Orsted
Group moderator	Kate McClellan Press	NYSERDA
Support staff	Bennett Brooks	Consensus Building Institute
Support staff	Eleanor Eckel	Biodiversity Research Institute
Support staff	Holly Goyert*	Biodiversity Research Institute
Support staff	Julia Gulka	Biodiversity Research Institute
Support staff	Iain Stenhouse	Biodiversity Research Institute
Support staff	Kate Williams	Biodiversity Research Institute

*Note: Dr. Goyert was a working Committee member through much of the process while working at AECOM, before transitioning to a support role as a BRI employee.

Appendix B. Glossary of Key Terminology

Abundance – The number of animals in a sampled population. "Low abundance," in the context of this document, refers to animals that are uncommon within the geography of interest. See also "Relative Abundance," below. Deriving an unbiased measure of abundance requires accounting for detection and other biases (see 'Availability' and 'Detectability').

Aerial Survey – A method of systematic animal observation that can be used to inform estimates of species abundance and distribution. Can be conducted from the air via airplane, helicopter, or unmanned aerial vehicle (UAV). Surveys may be conducted with visual observers on board (visual aerial survey) or by taking video or photo imagery to capture the presence of wildlife (digital aerial survey). Survey methodologies vary depending on platform and observation technique; for example, human observers often use distance sampling, while digital aerial surveys are often strip transects.

Attraction – The process by which individuals respond to an object or stimulus by moving towards it, also known as "taxis". In the offshore wind context, this may include attraction to individual structures or to the entire wind energy facility for perceived food, shelter, or other resources. It may also include attraction to other features of offshore wind infrastructure, such as artificial lighting (e.g., phototaxis). In the context of this document, attraction is used to refer to changes in both movement behavior and habitat use.

Automated Radio Telemetry – Digitally coded radio tracking technology in which transmitters attached to wildlife are detected by receiving stations at fixed locations. Commonly this term is synonymous with the Motus Wildlife Tracking System (brand names include "nanotags" and "lifetags," among others); other platforms include the ATLAS system.

Availability – The probability that animals using a survey area are in a detectable state. Availability bias is systematic error in a survey caused by animals in the population of interest using a survey area but unavailable to be detected. For diving species, the greater the frequency and length of foraging dives (which remove the animal from a space detectable by the observer), the greater the likelihood of availability bias in abundance and distribution estimates. See also "Detectability".

Avoidance – Changes in movements, such as migration or daily movements, in which an individual animal takes evasive action to maintain a certain distance/separation from a wind facility or its components. Avoidance may occur at the scale of the wind facility (macro-avoidance), at the scale of the turbine, cable, or other structure (meso-avoidance), or at the scale of the turbine blade, e.g., a last-minute evasion to prevent collision (micro-avoidance; NYSERDA 2020, May 2015). See also "Barrier Effects" and "Displacement."

BACI – Before-After Control-Impact. An experimental design for studying the effects of a stressor such as displacement. In this design, one or more control sites are paired with one or more impact sites (i.e., sites where the stressor will operate). These are monitored both before and after the start of the stressor. The paired design allows changes due to the stressor (which should affect only the impact site) to be distinguished from background changes (which should affect both control and impact sites). Control sites must be carefully chosen to ensure they are physically and ecologically similar to impact sites but are located outside the zone of potential impacts.

BAG – Before-After-Gradient. An experimental design for studying the effects of a stressor, such as displacement, using methods such as observational surveys or radar. In this design, monitoring is conducted pre- and post-construction within the wind facility itself, as well as in a buffer area around the facility, to assess possible relationships between impact and distance from the facility. Buffer size must be carefully chosen to ensure it encompasses the full zone of potential impacts. This study design allows for non-linear relationships, incorporation of some types of environmental covariates, and a more informative assessment of effect size than BACI designs.

Behavior – A response of an individual or group in response to internal or external stimuli (Levitis et al. 2009). In the context of effects, behavioral change may indicate response to OSW activities.

Baseline – Characterization of the prior states, situations, or conditions (in the absence of a particular activity) that can be used as a reference when determining effects (ROSA 2021). In the context of offshore wind development, collecting baseline data allows potential impacts of a project to be assessed and/or monitored.

Barrier Effects – The effects to animals due to obstacles to movement (such as increased energetic requirements to fly around, rather than through, a wind facility).

Boat-Based Survey – A method of systematic observation of animals from a moving vessel that can be used to inform estimates of species abundance and distribution.

Collision – The instance of an individual striking or being struck by an object, causing potential injury or mortality. In the context of offshore wind development, this includes collisions of volant animals with offshore wind infrastructure (including turbine blades and other structures).

Community – A group of species occupying a habitat.

Control – Selected reference site or condition that is isolated from, but similar to, an affected offshore wind site or condition with regard to biological, physical, and environmental characteristics, as well as other anthropogenic uses (e.g., fishing, shipping activities; ROSA 2021).

Covariate – An independent variable that can influence the outcome of a given response variable, but which is not of direct interest. In the context of marine bird response to offshore wind development, covariates might include environmental conditions and those related to other anthropogenic factors (e.g., proximity to shipping lanes).

Cumulative Impacts – Impacts on a species, population, or community that add to, or interact with, other impacts on a similar temporal and/or spatial scale to produce population or community-level consequences.

Data Management – The process of gathering, organizing, vetting/reviewing, storing, and sharing data. This includes topics related to data transparency and standardization.

Data Transparency – Sharing data or otherwise making it available to other users, whether publicly or on request. May include sharing of summary information and/or derived data products, such as model outputs, as well as sharing of original datasets.

Density – The number of a specified organism per unit area.

Detectability – The extent to which an animal can be perceived by an observer or camera. The specific features of some animals make them more or less detectable depending on environmental conditions, survey platform and methodology, and other factors. Biases in detectability may be introduced with factors such as platform height, distance, sea state, light conditions, clutter, or image resolution.

Developer – Private-sector entity involved in the planning, construction, and/or operation of offshore wind development(s).

Development Phase – Phase(s) of the development of an offshore wind energy project, including pre-construction activities (such as seismic surveys), construction activities, operation and maintenance, and decommissioning.

Diet – The combination of foods typically consumed by a species or group of organisms. May vary by age class, sex, breeding stage, location, and other factors.

Displacement – The result of macro-scale avoidance that causes functional habitat loss. Displacement effects may be of varying duration. In this document "displacement" is generally used to refer to changes in distribution/habitat use, while "avoidance" is generally used to refer to changes in movement behavior. As such, "attraction" may refer to changes in either distribution/habitat use or movement behavior.

Distribution – The pattern by which taxa, species, or individuals are spatially arranged (NYSERDA 2020).

Disturbance – Disruption of the structure of an ecosystem, community, population, or individual organism, causing changes to the physical environment, resources/habitat, physiology, behavior, or life history (White and Picket 1985).

Ecosystem – A biological community of plants and animals and their physical environment.

Ecological Drivers – The natural or human-induced factors that directly or indirectly induce changes to individuals, communities, or ecosystems. Often used to refer to environmental and oceanographic conditions that may influence distributions, movements, or behaviors.

eDNA – DNA released by organisms into the environment, which can be monitored using molecular methods to detect species presence over a short temporal scale.

Effect – A change or response in a receptor that is linked to (1) an exposure to specific conditions or stimuli (e.g., an offshore wind-related activity) and (2) sensitivity of the receptor to that activity, including both individual and population sensitivity. Effects represent a departure from a prior state, condition, or situation (called the "baseline" condition; Hawkins et al. 2020). While National Environmental Protection Act (NEPA) regulations consider effect and impact synonymous, for the purposes of this effort, effect and impact are defined differently (see "Impact"), unless in reference to an "Environmental Impact Assessment".

Effect Size – An index of the magnitude of the effect that one variable or set of variables has on another variable, including a slope parameter and associated uncertainty. Effect size can be used to determine the statistical significance of a receptor's response to specific conditions and stimuli and represents the basic unit of observation in a meta-analysis.

Effects Surveys – Surveys conducted to detect potential effects to marine birds caused by an offshore wind development. Generally conducted both pre- and post-construction to compare differences in distributions, abundances, or behaviors between the two time periods. Can be conducted using either BACI or BAG designs (see respective definitions, above).

Energetics – The energy-related properties of animals. Animals have energy budgets, in which they must take in sufficient energy to perform necessary activities, such as foraging, reproducing, and migrating. Energetic impacts, or disruptions to these energy budgets, may have short- or long-term influences on individual reproductive success and/or survival.

Exposure – The frequency, duration, and intensity of contact or co-occurrence between an offshore wind stressor or activity and an environmental receptor that may allow the stressor to act on the receptor in some way (Goodale and Milman 2016). Marine bird exposure to offshore wind stressors is dictated by their abundance, distribution, and behavior.

Facility – An offshore wind energy development project, including all infrastructure and development and maintenance activities. Also referred to as a "project".

Focal Taxa/Taxon – A species or group of species that are the focus of research.

[Project/Facility] Footprint – The project footprint includes areas of offshore wind projects containing turbine and substation structures. The project footprint represents part of the project site (see also "Project" and "Site-specific Scale").

Forage Fish – Small, schooling fish species such as herring and menhaden, which occupy a key role in the marine food web, transferring energy from lower to higher trophic levels.

Geolocator – Light-level geolocators are small archival tracking devices that can be attached to animals to record ambient light levels in their vicinity, which provides an approximate location. Data must be physically downloaded from the device (e.g., the device must be recovered). These tags are generally used to broadly map migration routes and identify important habitat use areas; location accuracy limitations can be substantial and vary by location, species, tag attachment technique, and other factors.

Gray literature – Reports produced by organizations outside of academic and/or peer-reviewed publishing, including government and commercial industry reports.

Habitat – The array of physical factors (e.g., temperature, light) and biotic factors (e.g., presence of predators, availability of food) present in an area that support the survival of a particular individual or species.

Hypothesis – An explanation for an observable phenomenon, usually expressed in a testable manner. In the context of offshore wind development, a hypothesis represents a potential explanation for a receptor's response or a relationship between variables.

Impact – An effect that results in a change whose direction, magnitude, and/or duration is sufficient to have biologically significant consequences for the fitness of individuals or populations (Hawkins et al. 2020). While National Environmental Protection Act (NEPA) regulations consider effect and impact synonymous, for the purposes of this effort, effect and impact are defined differently (see "Effect").

LiDAR – Light Detection and Ranging is a remote sensing method that, for purposes of wildlife monitoring, is typically deployed from a survey plane. The system uses light in the form of a pulsed laser to measure distance and, when combined with other equipment, to generate three-dimensional spatial information.

Lighting – The use of artificial lights to illuminate infrastructure, vessels, planes, and other objects, with the potential to cause attraction in some animals (see "Attraction").

Magnitude – The size or extent of something. In the context of changes in marine bird habitat use, the magnitude of an effect relates the strength and distance of change from a population perspective, and proportion of individuals and/or behaviors from an individual perspective.

Marine Bird – In this context, marine birds are defined as all birds that interact 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 definition.

Marine Radar – Electronic instruments that use a rotating antenna to emit microwaves along the water's surface; microwaves reflect off nearby objects and generate an image of the radar's surroundings. Marine radars can also be operated vertically to reflect off objects directly above the radar. X-band or S-band marine radars can be used to detect birds and bats flying through the atmosphere. The detectable size of flying animals depends in part on the wavelength emitted by the radar, as well as the amount of interference presented by weather and other objects in the vicinity.

Monitoring – A subset of research that involves collecting systematic observations to inform understanding of effects.

Movement – A change in the spatial location of an individual organism over time.

Nanotag – A small (0.2–3 g) digitally coded VHF or UHF radio transmitter that is attached to an animal to automatically record their presence as they pass within range of receiver antennas.

NEXRAD – Next Generation Radar, also known as WSR-88D weather surveillance radar. A network of these S-band Doppler weather radars is operated across the U.S. by the National Weather Service. They are designed to detect precipitation in the atmosphere by transmitting radio waves (wavelengths ~ 3–10 cm) and receiving back the electromagnetic energy scattered by precipitation particles. Weather surveillance radars also regularly detect "bioscatter," or reflectivity of the electromagnetic energy caused by biological entities in the atmosphere, such as birds, bats, and insects. With distance from the radar station, the average height of the volume of air sampled by the radar beam increases in altitude and the power of the beam weakens, so it can be difficult to detect low-altitude and low-density objects with increasing range from a radar unit.

Occurrence – Basic information on the distribution, abundance, and temporal habitat use of receptors, including seasonal and interannual variability and elements of behavioral, movement, and acoustical ecology, among other characteristics (Southall et al. 2021). Used to inform understanding of exposure (above).

Population Dynamics – How a population (i.e., a group of individuals of the same species that occupy a specific area over a certain period of time) changes in abundance or density over time. In an ecological context, often used specifically to refer to factors influencing reproductive success, survival, and/or immigration/emigration.

Population Sensitivity – The properties of the global or regional population of a species related to demography (e.g., survival, reproduction) and conservation status that informs the degree to which pressures from offshore wind development could influence the size of the population.

Power Analysis – Statistical methods that estimate *a priori* the minimum sample size required to detect a specified magnitude of change with a given degree of confidence (NYSERDA 2020).

Productivity – The rate of generation of new biomass in an ecosystem. Primary productivity is the creation of energy from sunlight (photosynthesis) by plants and algae that form the basis of the food chain; productivity for upper trophic levels, such as seabirds, refers to recruitment of new individuals into the population via sexual reproduction.

Project (also "Offshore Wind Project") – Geographic space and infrastructure that comprise an offshore wind energy facility. Includes both onshore and offshore areas. Also includes areas in which environmental effects from the facility occur, including areas potentially outside the actual footprint of the facility (see "Footprint," above).

Radar – see "NEXRAD" and "Marine radar," above.

Raw Data – Original data following QA/QC procedures such that errors have been removed but the data is not summarized, manipulated, or processed in any way that would hinder the ability to replicate or re-analyze the data. Metadata should be included that, among other things, clearly details the QA/QC processes.

Receptor – Individual animal, group, population, or community that has the potential to be affected by exposure to a stressor. In the context of marine birds and OSW, typically used to refer to the individual animal.

Regional Scale – Geographic extent that includes data collection focused outside of offshore wind project areas, instead of (or in addition to) focusing on wind project areas alone. Examples of regional-scale research include examination of broad-scale (e.g., Atlantic) or smaller scale (e.g., New York Bight) population characteristics, such as demography or regional distributions, or the examination of interactive effects across multiple industries.

Relative Abundance – How common or rare a species is relative to others in a certain location or community, or how common or rare a species is in a given location relative to other locations. Relative abundance indices may be used as proxies of true abundance.

Research – Any type of hypothesis-driven scientific study that improves our understanding of populations and ecosystems, either generally or in relation to the effects of offshore wind development. Monitoring is considered a subset of research.

Response – How receptors may be influenced by or react to exposure to an activity, on either acute or long-term time scales. Responses can include measurable changes in physiological condition or behavior (e.g., communication, navigation, movements, habitat use) of an individual, group, population, or community (Southall et al. 2021).

Risk – The intersection of the probability of an effect, and the consequence or severity of that effect (Copping et al 2021). See "Effect". "Risk assessments" or "impact assessments" are a typical part of the regulatory process prior to construction of OSW facilities.

Sensitivity – Properties of an organism or system that influence relative susceptibility to a stressor (Goodale and Stenhouse 2016). This encompasses sensitivity to effects as well as population sensitivity. See also" Vulnerability".

Sensitivity to Effects – Includes the expected response of receptors to a stressor (in this case an offshore wind development-related stressor), at both the individual/local scale.

Site Characterization Surveys – New observational surveys of an OSW project site, generally conducted by the developer, that are designed to describe avian use of the project site to inform permitting processes (e.g., Construction and Operations Plan, Impact Assessments), project design, effect minimization measures, and the development of pre- and post-construction monitoring plans.

Site-specific Scale – Geographic extent within which effects and responses occur in relation to individual turbines or a single offshore wind project.

Stressors – Physical, chemical, or biological factors that may affect the health and productivity of a species or ecosystem. Offshore wind-related stressors include noise, artificial light, and the physical presence of structures, among others.

Study Design – A well-structured plan for implementing research, including data collection methods, sample sizes, and analytical approaches, informed by power analyses. Part of a larger research plan that should also identify study objectives, research questions, focal taxa, testable hypotheses, and data sharing and coordination plans.

Study Methods – Set of tools, procedures, and approaches used to collect and analyze data to test a specific hypothesis (De Vaus 2001).

Technology – Man-made methods, systems, or devices. In the context of offshore wind environmental research needs and data gaps, technologies are generally machines or other devices that allow for or improve the data collection, analysis, and storage of data, or that aim to mitigate the effects of offshore wind activities on wildlife or ecosystems.

Telemetry – The measurement of location data at a remote source and transmission of data (e.g., via radio waves or satellite) to a monitoring station. Used to track animal movements.

Variable – A measured attribute associated with research. Includes independent or "explanatory" variables, dependent or "response" variables, and confounding variables (extraneous variables that relate to the study's independent and dependent variables and should be controlled for in study design and post-hoc analyses to constrain variance and potential bias of results).

Vessel – A boat that could be used for a variety of purposes, including conducting observational surveys, as well as other purposes unrelated to offshore wind development (e.g., fishing, shipping). In the context of research on offshore wind development's effects on marine birds, large vessels (>30–100 m length with >15 day at sea endurance) are typically used only for broadscale baseline studies, while small vessels

(<30–50m, <5 day at sea endurance) represent the type of vessel that would primarily be used for surveys at the individual offshore wind project scale.

Vulnerability – The combination of individual sensitivity to a particular effect and population sensitivity, encompassing the degree to which a receptor or system is expected to respond to their exposure to a stressor.

Appendix C. Literature Review: Macro- to Meso-Scale Changes in Marine Bird Distributions and Habitat Use

As an initial step in developing recommendations for pre- and post-construction monitoring of marine birds, we conducted a literature review of existing studies focused on marine bird displacement, attraction, and macro- to meso-scale avoidance, the methods and results of which are summarized in this appendix. This literature review had three inter-related goals:

- Aid in the identification of questions that various monitoring methods (e.g., surveys, telemetry, radar) are designed to answer and the strengths and limitations of each method (informing Sections 4 and 6 of this document).
- Quantify the degree of attraction/displacement expected to occur for various avian taxa during relevant life history stages in the U.S. Atlantic, based on previous studies (informing Section 5).
- Develop recommendations for when to use, and how to design, observational surveys that are intended to detect displacement, attraction, and avoidance (Sections 6–7 and 10).

In addition to the summary presented here, members of the Specialist Committee and support staff have used the database of studies developed during this effort to conduct a quantitative meta-analysis of studies that used observational survey methods (Lamb et al. 2024).

C.1 Methods

C.1.1 Source Identification

Several recent review papers have examined aspects of displacement, attraction, and macro- to meso-scale avoidance of marine birds at offshore wind facilities, including Dierschke et al. (2016) and Cook et al. (2018), which were used as key resources to identify source documents (*n*=35) for this literature review. Additional potential source documents were compiled via a Google Scholar search (*n*=88) and a search of the Tethys Knowledge Base (*n*=15 additional sources) and via expert elicitation with the Specialist Committee (*n*=6; Figure C1). Google Scholar search terms included: Avian/birds/seabirds + "offshore wind"/"offshore wind farm"/"offshore wind energy"/"marine wind"/"marine wind farm" + displacement/attraction/avoidance. The Tethys Knowledge Base was filtered based on the following filters: Wind energy/fixed offshore wind/floating offshore wind +attraction/avoidance/displacement + birds/seabirds. Following compilation of sources from review papers and online searches, the Specialist Committee reviewed the sources and identified additional potential sources for consideration. Compiled studies primarily drew from the scientific literature, but also included gray literature, where applicable (e.g., government reports and monitoring reports from individual wind facilities in Europe).

Following compilation, source documents were screened for relevance, and studies were included in the literature review if they used empirical data from field studies to directly examine displacement, attraction, macro-avoidance, or meso-scale avoidance of offshore wind facilities by marine birds. Sources that were excluded from further review included those focused on methods development, risk assessments (e.g., from Construction and Operations Plans), monitoring or mitigation plans, and publications on effects irrelevant to displacement (e.g., micro-avoidance, collision risk). Sources were also excluded if their data were redundant with another study. In instances of duplicative data (e.g., multiple monitoring reports from the same OSW project site), the more inclusive study was used. The final list of sources included 24 journal articles and 30 reports, in addition to one conference abstract (Table C1). The initial literature review was conducted in April 2022, with several additional sources added in May 2023.

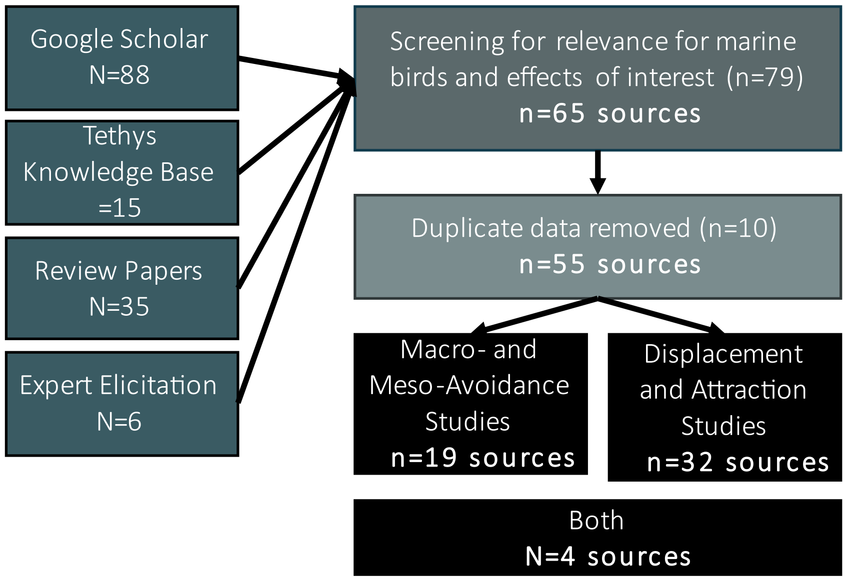

Figure C1. *Process for collation of sources for literature review on displacement, attraction, and macro- to meso-scale avoidance of marine birds at offshore wind facilities.*

C.2.2 Data Extraction

Results from the 55 identified sources (Table C1) were manually extracted, including:

- Research question or hypothesis that the study aimed to address.
- Focal species/taxa.
- Species group (e.g., Auks, Gannets, Gulls, Terns, Cormorants, Waterfowl, Loons, Jaegers/Skuas, Tubenoses, All; see Table C3 for list of species included in each group).
- **Field study methods** (e.g., boat-based survey, visual aerial survey, digital aerial survey, combined survey methods, satellite telemetry, GPS telemetry, geolocator, radar, visual observations, and camera tracking system).
- Stage in annual cycle (e.g., breeding, non-breeding, migration, year-round).
- Distance from study colony (only applicable to telemetry studies conducted during the breeding season).
- Life history stage (e.g., juvenile, adult, all).
- Type of study – definitions modified from Methratta (2021). Options included:
    - Before-after control-impact (BACI) study – A single impact area, defined as the project footprint or project footprint + buffer, is compared with a (theoretically unimpacted) control area both before and after construction of the project in the impact area. Does not include multiple buffers for comparison (see distance-stratified BACI, below);
    - Before-after gradient (BAG) - comparison of impact area + buffer before and after construction to looks at differences in distributions and abundance in relation to distance from the nearest turbine - this may include a stratified gradient (i.e., distance bands);

Table C1. *Sources used in literature review on displacement/attraction (D/A) and macro- and meso-scale avoidance (Avoid) of marine birds in relation to offshore wind development. Links to source documents are included in literature cited when available.*

Citation	D/A	Avoid	Methods
Aumuller et al. 2013	X	X	Visual Observations
Blew et al. 2008		X	Radar, Visual Observations
Camphuysen 2011		X	GPS telemetry
Canning et al. 2013	X		Boat-based surveys
Christensen and Hounisen 2005		X	Radar, Visual Observations
Clewley et al. 2021	X		GPS telemetry
Degraer et al. 2021	X		GPS telemetry
Desholm and Kahlert 2005		X	Radar
Garthe et al. 2017		X	GPS telemetry
Gill et al. 2008	X		Visual Aerial surveys
Goddard et al. 2017	X		Digital aerial surveys
Guillemette et al. 1998	X		Visual Aerial surveys, Visual observations
Heinanen et al. 2020	X		Digital aerial survey, Satellite telemetry
Johnston et al. 2022	X		GPS telemetry
Kahlert et al. 2004	X		Radar
Krijgsveld et al. 2011		X	Radar, Visual Observations
Lane et al. 2020		X	GPS telemetry
Larsen and Guillemette 2007		X	Visual observations
Leopold et al. 2013	X		Boat-based survey
Masden et al. 2009	X		Radar
Mendel 2012	X		Visual aerial survey
Mendel et al. 2019	X		Combined survey methods
Nilsson and Green 2011	X	X	Radar, Boat-based survey, Visual aerial survey
PMSS 2006	X		Boat-based survey, Visual aerial survey
Percival 2013	X		Boat-based survey
Percival et al. 2014	X		Boat-based survey
Perrow et al. 2006	X		Boat-based survey
Perrow et al. 2015		X	Visual observations
Peschko et al. 2020a	X		GPS telemetry
Peschko et al. 2020b	X		Combined survey methods
Peschko et al. 2021	X	X	GPS telemetry
Petersen and Fox 2007	X		Visual aerial survey
Petersen et al. 2006	X	X	Visual aerial survey, Radar
Petersen et al. 2011	X		Visual aerial survey
Petersen et al. 2014	X		Visual aerial survey
Pettersson 2005		X	Radar, Visual Observations
Plonczkier and Simms 2012	X	X	Radar
Rehfisch et al. 2014	X		Digital aerial survey
Rehfisch et al. 2016	X		Combined survey methods
Rexstad and Buckland 2012	X		Boat-based survey
Rothery et al. 2009		X	Visual observations
Skov et al. 2012a		X	Radar
Skov et al. 2018		X	Radar, Camera tracking system
Thaxter et al. 2015	X		GPS telemetry
Thaxter et al. 2018		X	GPS telemetry
Trinder et al. 2019	X		Digital aerial survey
Tulp et al. 1999		X	Radar
Vallejo et al. 2017	X		Boat-based survey
Vanermen et al. 2015a	X		Boat-based survey
Vanermen et al. 2016	X		Boat-based survey
Vanermen et al. 2020	X	X	GPS telemetry
Vilela et al. 2021	X		Combined survey methods
Welcker and Nehls 2016	X		Boat-based survey

- After gradient (AG) - similar to BAG design but only includes data collection after impact (e.g., examines post-construction distributions relative to the wind facility using a gradient sampling design), rather than comparing gradients before and after construction;
- After control-impact (ACI) - similar to BACI design, but only includes data collection after impact. This category includes studies that don't have a pre-defined "control" area but make comparisons between "inside" vs. "outside" of the wind facility;
- Distance-stratified (DS) BACI – BACI study that includes comparison of a control area with locations at multiple distances from the centroid of the "impact area", which can include both the wind facility and buffer area. Must have data both before and after construction, and must have a control;
- Distance-stratified CI – control-impact study that only includes data collection after impact and compares a control with locations at multiple distances from the centroid of the impact area. Must have a control; and
- Before-After Impact (BAI) - comparison of the impact area pre- vs. post-construction, with no control, no buffer area, and no gradient sampling design.

- Scale of inference – in most cases, this includes the area around the wind facility for which data was collected and inference was made. For surveys, this includes the OSW project footprint(s) and buffer areas; for observational studies, the scale of inference includes the wind facility(s), the location(s) from which observations were made, and size of the area observed; and for tracking studies, it includes information on sample size.
- Response type detected – displacement, attraction, no displacement/attraction, macro-scale avoidance, no macro-scale avoidance, meso-scale avoidance, no meso-scale avoidance. Avoidance is defined as changes in directed movements, while displacement includes changes in habitat use for activities such as foraging and roosting (Appendix B).
- Metric used in reporting the results.
- Response value, if available, and whether it was statistically significant (if tested).
- Offshore wind facility characteristics, if available, including name, distance to shore (measured as closest edge of the project footprint to nearest coastline), footprint area, maximum water depth within the footprint, number of turbines, turbine height, latitude, and region.

If multiple research questions, field study methods, focal species, or wind facilities were included in the same source and results were reported separately, results were summarized separately for the literature review and considered as separate 'studies'. Source documents did not consistently report wind facility characteristics; thus, these metrics were extracted from Cook et al. (2018) and other sources where needed[11]. In a few cases, where distance metrics were not reported in source documents and could not be extracted from other available sources, distances/areas were measured on maps in source documents using the Adobe Acrobat Pro Measure Tool (Adobe Acrobat Pro 2017). In instances where multiple wind facilities were included in a single study without separately reported results, characteristics were summarized across wind facilities, with the summary statistic varying by characteristic: distance to shore (mean), footprint size (sum), number of turbines (sum), maximum water depth (mean), turbine height (mean), and latitude (mean).

[11] Additional sources of wind farm information included thewindpower.net, Wikipedia, and websites of individual wind facilities.

To help inform recommendations on study design and choice of focal species (Sections 5–7), we summarized results across studies to examine whether factors such as taxonomic group, study type, study design, and location influenced the likelihood of detecting effects.

C.3 Results

Studies included a wide range of field methods (Table C2), analytical approaches, and reporting. Almost all studies were from the North Sea (*n*=42), with a smaller number from the Baltic Sea (*n*=12) and Celtic Sea (*n*=4; Figure C2). Sources included studies that used observational surveys, individual tracking, radar, and visual observations (Table C2). Most sources examining displacement/attraction used observational surveys (boat-based surveys *n*=12, visual aerial surveys *n*=9, digital aerial surveys *n*=4, combined survey methods *n*=4), with various study designs (BAG, BACI, DS-BACI, ACI), though several studies also used visual observations (*n*=2), radar (*n*=3) or GPS/satellite telemetry (n=8). Macro and meso-scale avoidance studies primarily used radar (*n*=11), visual observations (*n*=8), and GPS telemetry (*n*=6), with one study involving a camera tracking system. In many cases, sources examined effects on multiple taxa (Figure C3).

In some cases, source studies also examined multiple taxa and/or multiple offshore wind facilities. The results reported separately were considered separate 'studies' within source documents and summarized as such. Studies focused on a variety of marine bird taxa, with a majority focusing on auks, cormorants, gulls, gannets, terns, loons, and waterfowl, with a few studies of skuas and of petrels (e.g., Manx Shearwater, Northern Fulmar; Table C3). The type of observed response varied by taxon (Table C3) and by individual study. For all groups, variation in the type of response across studies likely related to study conditions and study design. Even for species with common behavioral responses to offshore wind development, there were also findings of null effects from many studies, often related to study design choices such as selection of buffer zone size (Table C4) as well as other factors.

Table C4. *Sample size of study methods represented in the source studies. In some cases, the same study used multiple methods (Table C1), and therefore the number of sources in the table does not add up to the total number of sources included in the literature review.*

Method Type	Total sources (*n*)
Boat-based surveys	12
Digital aerial surveys	4
Visual aerial surveys	9
Multiple survey methods	4
GPS Telemetry	11
Satellite Telemetry	1
Visual observations	9
Radar	13
Camera tracking system	1

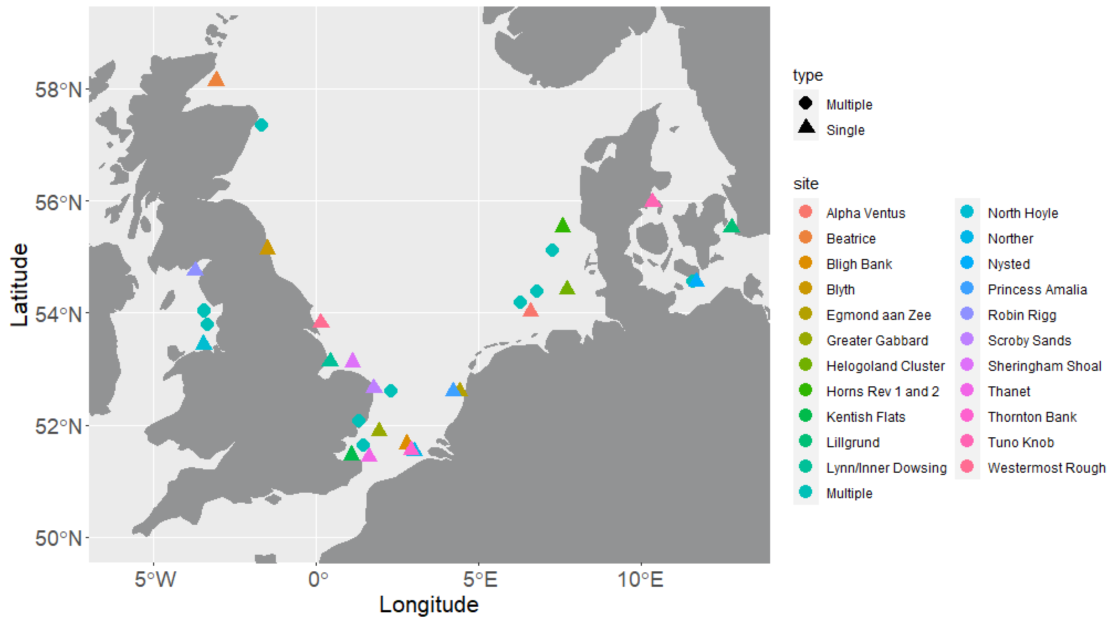

Figure C2. *Locations of studies included in the literature review of displacement, attraction, and macro- to meso-scale avoidance of marine birds to offshore wind facilities. Colors indicate studies at different offshore wind development facilities, including individual projects (triangles), or across multiple project sites (circles). For the latter, the latitude and longitude across wind facilities were averaged.*

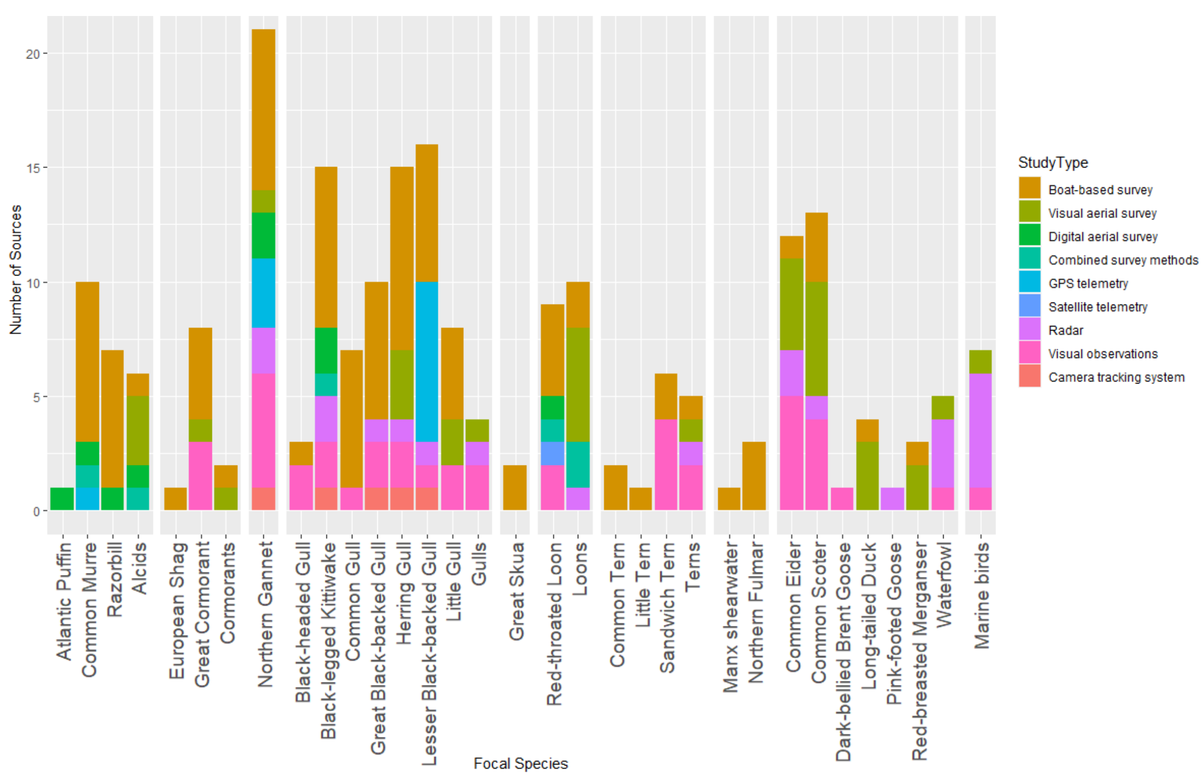

Figure C3. *Number of sources by marine bird species and study method. Individual sources may have examined effects on multiple marine bird species or groups or utilized multiple study methods.*

Of the taxonomic groups examined in the literature review, auks and loons exhibited the most consistent evidence of displacement and macro-avoidance; Northern Gannets and waterfowl also tended to exhibit displacement as well as macro- and meso-avoidance. Cormorants generally exhibited attraction, while gulls and terns showed the most variable responses, including both attraction and displacement as well as inconsistent macro-avoidance responses across studies (Table C3). However, in the few studies in which meso-avoidance was examined, this response was identified consistently across species. Finally, the effects on skuas and on petrels were inconclusive, due to their underrepresentation in the reviewed studies.

Table C2. *Number of studies (by focal taxon) that found different types of responses. Studies examining displacement and attraction found responses of displacement (-), no effect (0) or attraction (+), while macro- and meso-avoidance studies either found evidence of avoidance (-) or no avoidance (0).*

		Displacement and/or Attraction			Macro-avoidance		Meso-avoidance	
Taxa Group	Focal Species	-	0	+	-	0	-	0
Auks	Atlantic Puffin	1						
	Common Murre	7	4					
	Razorbill	5	3					
	Auk spp.	3	3					
Cormorants	European Shag			1				
	Great Cormorant		3	3	1	3		
	Cormorant spp.		1					
Gannets	Northern Gannet	8	2	1	9	1	1	
Gulls	Black-headed Gull		1			2		
	Black-legged Kittiwake	5	6	1	2	2	1	
	Common Gull		6	1		1		
	Great Black-backed Gull		4	2	1	2	1	
	Herring Gull	2	6	4	1	2	1	
	Lesser Black-backed Gull	4	5	4	2	2	3	
	Little Gull	3	3	1	1	1		
	Gull spp.		1		4			
Skuas	Great Skua		2					
Loons	Red-throated Loon	4	3		2			
	Loon spp.	8	3		1			
Terns	Common Tern	1	2					
	Little Tern		1					
	Sandwich Tern		2		1	3	1	
	Tern spp.	2			3			
Petrels	Manx Shearwater		1					
	Northern Fulmar		3					
Waterfowl	Common Eider	5	2		5	2	1	
	Common Scoter	4	4	1	4	2		
	Dark-bellied Brent Goose				1			
	Long-tailed Duck	4						
	Pink-footed Goose				1			1
	Red-breasted Merganser	2		1				
	Waterfowl spp.		1					
All	Marine birds	2			5	1		

C.3.1 Displacement and Attraction

Auks, loons, gannets, and waterfowl exhibited strong evidence of displacement effects from offshore wind facilities in Europe, while cormorants showed evidence of attraction. Across and within gull species, there was high variability in observed responses, in some cases with similar numbers of studies showing displacement, no change, and attraction (e.g., Lesser Black-backed Gull). Other groups, including terns, petrels, and skuas, had few studies making it difficult to draw conclusions on potential patterns of responses. Atlantic Puffins and Black-headed Gull were excluded from further assessment of the types of study designs that produced different effects findings (Table C4; Table C5) as there was only one study for each species. For Atlantic Puffins, the one study found evidence of displacement, while for Black-headed Gull there was no evidence of displacement or attraction.

There was variation in observed responses (e.g., whether or not displacement or attraction effects were detected in studies) that related to factors including season, location, and inclusion of construction period data. While most studies examined year-round changes in distributions (primarily utilizing observational surveys or individual tracking), one study compared effects between the non-breeding and breeding season and found a greater change (e.g., stronger displacement effect) during the non-breeding season compared with the breeding season for Common Murres, while there was a significant displacement effect in Black-legged Kittiwakes only during the breeding season but not with all seasons combined (Peschko et al. 2020b).

This review suggests that there may also be environmental and/or location-related factors influencing variation in response at the species level, such as turbine characteristics, distance to shore, level of habitat use prior to construction, or other factors. Multiple sources used the same study design to compare displacement effects across multiple wind facilities with varying results. Leopold et al. (2013) found evidence of displacement at a larger OSW project further offshore for Razorbills and the opposite for Lesser Black-backed Gulls, with displacement effects only detected in the latter species at the smaller, more coastal project. Similarly, Petersen et al. (2006) only found evidence of displacement in Common Eiders at a smaller, nearshore wind facility as compared with a larger facility located farther offshore, where displacement was not detected. Individual-level responses may also vary. For both Northern Gannets and Common Murres, individual tracking studies found evidence that, while most individuals completely avoided project footprints, a small percentage (gannets 11%, Peschko et al. 2021; murres 17% Peschko et al. 2020a) entered the wind facility regularly (gannets) or on a few occasions (murres) with evidence of foraging behavior, suggesting individual variation in responses within species.

The inclusion of data during the construction period may have contributed additional variation in responses for some studies. For Northern Gannets, while most studies found evidence of displacement effects, one study found significant evidence of attraction when comparing pre- and post-construction; however, evidence from the latter study suggested that gannets were attracted to the wind facility during construction and were displaced following construction but to a smaller degree, resulting in an overall net finding of attraction when comparing pre- and post-construction periods (PMSS 2006). The same study found evidence of attraction in Black-legged Kittiwakes during construction, while all other studies of the species found either displacement or no effect, though all but one of those studies (Percival et al. 2013) lacked data during construction. As most studies focused on the pre- and post-construction periods, with little data available during construction, more evidence is needed draw conclusions related to attracted to construction activities. However, gannets have shown attraction to fishing vessels (Votier et al. 2010), and kittiwakes are particularly vulnerable to fisheries associations,

Table C3. *Summary of attraction/displacement findings by taxon and study design. For studies with evidence of displacement ('displacement results'), summary includes percentage of studies that detected displacement, the size of buffer zones examined for these studies (observational surveys only), and study design (BAG=Before-After-Gradient, BACI=Before-After-Control-Impact, ACI=After-Control-Impact, DS-BACI=Distance-stratified Before-After-Control-Gradient; all methods). If studies examined/reported the distance at which displacement was observed, values and number of studies is reported in the "Dist. Observed" column along with the buffer distances used in those studies. The buffer zone size range and study design are also reported for studies that found null effects or evidence of attraction. All distances and ranges are in kilometers.*

Focal Species			Displacement Results					No Change Results			Attraction Results		
Group	Species	Total (n)	% of Studies	Buffer Range (km)	Study Design	Dist. Observed (km)	Buffer (km)	% of Studies	Buffer Range (km)	Study Design	% of Studies	Buffer Range (km)	Study Design
Auks	Common Murre	11	64%	4-22	BAG, DS-BACI, ACI	9 (n=1)	22	36%	3-12	DS-BACI, BAG	-	-	-
	Razorbill	77	5757%	3-10	DS-BACI, BAG	0.5 (n=2)	3	43%	3-10	BACI, BAG	-	-	-
	Auk spp.	6	50%	3-6	BAG, ACI	2.5 (n=1)	6	50%	0-4	BACI, DS-CI	-	-	-
Loons	Red-throated Loon	55	6060%	3-20	BACI, DS-BACI	3-15 (n=3)	20	40%	1.5	BAG	-	-	-
	Loons	11	73%	3-30	BACI, DS-BACI	10-16.5 (n=3)	20	27%	4-10	BACI, DS-BACI	-	-	-
Gannets	Northern Gannet	100	800%	3-11	BAG, BACI, DS-BACI, ACI	2-3.5 (n=2)	4-11	10%	3	DS-BACI, BAG	1010%	3	BAG
Waterfowl	Common Eider	66	6767%	2-4	BACI, BAG	2.5 (n=1)	4	33%	0-4	BACI, BAG	-		
	Common Scoter	9	44%	2-16	BAG	3-5 (n=2)	4-16	45%	0-4	BACI, BAG	11%	4	BAG
	Long-tailed Duck	4	100%	2-30	BAG	2 (n=1)	4	-	-	-	-		
	Red-breasted Merganser	3	66%	24	BAG	-	-	-	-	-	33%	4	BAG
Cormorants	Great Cormorant	6	0%	-	-	-	-	50%	1.5-2	BAG	50%	3-10	BAG
	European Shag	1	0%	-	-	-	-	-	-	-	100%	3	BAG
Gulls	Black-legged Kittiwake	12	42%	0.5-22	BAG, BACI, DS-BACI, ACI	-	-	50%	0.5-22	BAG, ACI, DS-BACI	8%	3	BAG
	Common Gull	7	0%	-	-	-	-	86%	0.5-10	BAG, DS-BACI, BACI	14%	3	DS-BACI
	Great Black-backed Gull	6	0%	-	-	-	-	67%	0.5-10	BAG, DS-BACI	33%	0.5	BACI, ACI
	Herring Gull	12	17%	3-4	BAG	-	-	50%	0.5-10	BAG, BACI, DS-BACI	33%	2-24	BAG, DS-BACI
	Lesser Black-backed Gull	13	31%	3-10	BACI, BAG, ACI, AG	2 (n=1)	3	38%	0.5-10	BAG, BACI, DS-BACI, ACI	31%	3	AG, ACI, DS-BACI
	Little Gull	7	42%	0.5-10	BAG, BACI, ACI	1.5 (n=1)	3	44%	0.5-10	BAG, DS-BACI	14%	4	BAG

Table C4. Summary of displacement and attraction studies using observational survey methods (boat-based, visual aerial, digital aerial, or combined survey types) including source, focal species (or taxonomic group), stage in the annual cycle (All=year-round, B=breeding season, NB=non-breeding season, offshore wind facility site name, study design (BAG=Before-After-Gradient, BACI=Before-After-Control-Impact, ACI=After-Control-Impact, DS-BACI=Distance-stratified Before-After-Control-Gradient), type of response observed (indicates statistical significance, lack of * indicates that statistical significance was not tested, such that Displacement*=Significant displacement while Displacement = no statistical test run but evidence of displacement, while No Effect*=If displacement was detected, it was not statistically significant). Buffer indicates the distance around the wind facility surveyed (in kilometers); ~ indicates distance was not reported and was estimated from maps, ranges indicate different sizes of buffers on different sides of the offshore wind facility, and multiple values indicate strata used for DS-BACI approaches. Dist indicates the distance (in kilometers) at which the response was detected (if examined).*

Source	Focal Species	Study Method	Stage	Site Name	Design	Response	Buffer (km)	Dist (km)
Rehfisch et al. 2016	Auk spp.	Combined	NB	Multiple	AG	Displacement*	15	
Petersen and Fox 2007	Auk spp.	Visual aerial	All	Horns Rev 1	BAG	Displacement*	4	
Welcker and Nehls 2016	Auk spp.	Boat-based	All	Alpha Ventus	ACI	Displacement*	3	2.5
Goddard et al. 2017	Auk spp.	Digital aerial	B	Westermost Rough	AG	No Effect*	9	
Gill et al. 2008	Auk spp.	Visual aerial	All	Kentish Flats	BACI	No Effect*	3	
Petersen et al. 2006	Auk spp.	Visual aerial	All	Horns Rev 1	BAG	No Effect*	4	
Leopold et al. 2013	Common Murre	Boat-based	All	Egmond aan Zee	BAG	Displacement*	~4-10	
Leopold et al. 2013	Common Murre	Boat-based	All	Princess Amalia	BAG	Displacement*	~4-10	
Percival 2013	Common Murre	Boat-based	All	Thanet	DS-BACI	Displacement*	0, 0.5, 1, 2, 3	1
Peschko et al. 2020b	Common Murre	Combined	NB	Multiple	BAG	Displacement*	~10-22	9
Peschko et al. 2020b	Common Murre	Combined	B	Multiple	BAG	Displacement*	~10-22	
Vanermen et al. 2015a	Common Murre	Boat-based	All	Bligh Bank	DS-BACI	Displacement*	0, 0.5, 3	
Vanermen et al. 2016	Common Murre	Boat-based	All	Thornton Bank	BACI	Displacement*	0.5	
PMSS 2006	Common Murre	Boat-based	All	North Hoyle	BAG	No Effect*	3	
Vallejo et al. 2017	Common Murre	Boat-based	All	Robin Rigg	BAG	No Effect*	~5-12	
Percival 2013	Common Murre	Boat-based	All	Thanet	DS-BACI	No Effect*	0, 0.5, 1, 2, 3	0.5
Trinder et al. 2019	Common Murre	Digital aerial	B	Beatrice	BACI	No Effect*	2	
Leopold et al. 2013	Razorbill	Boat-based	All	Princess Amalia	BAG	Displacement*	~4-10	
Percival 2013	Razorbill	Boat-based	All	Thanet	DS-BACI	Displacement*	0, 0.5, 1, 2, 3	0.5
PMSS 2006	Razorbill	Boat-based	All	North Hoyle	BAG	Displacement	3	
Vanermen et al. 2015a	Razorbill	Boat-based	All	Bligh Bank	DS-BACI	Displacement*	0.5, 3	0.5
Leopold et al. 2013	Razorbill	Boat-based	All	Egmond aan Zee	BAG	No Effect*	~4-10	
Vanermen et al. 2016	Razorbill	Boat-based	All	Thornton Bank	BACI	No Effect*	0.5, 3	

Source	Focal Species	Study Method	Stage	Site Name	Design	Response	Buffer (km)	Dist (km)
Trinder et al. 2019	Razorbill	Digital aerial	B	Beatrice	BACI	No Effect*	2	
PMSS 2006	Northern Gannet	Boat-based	All	North Hoyle	BAG	Attraction*	3	
Leopold et al. 2013	Northern Gannet	Boat-based	All	Egmond aan Zee	BAG	Displacement*	~4-10	
Leopold et al. 2013	Northern Gannet	Boat-based	All	Princess Amalia	BAG	Displacement*	~4-10	
Petersen et al. 2006	Northern Gannet	Visual aerial	All	Horns Rev 1	BAG	Displacement*	4	
Rehfisch et al. 2014	Northern Gannet	Digital aerial	NB	Greater Gabbard	BAG	Displacement*	~4-11	2
Vanermen et al. 2015a	Northern Gannet	Boat-based	All	Bligh Bank	DS-BACI	Displacement*	0.5, 3	
Vanermen et al. 2016	Northern Gannet	Boat-based	All	Thornton Bank	BACI	Displacement*	0.5	
Welcker and Nehls 2016	Northern Gannet	Boat-based	All	Alpha Ventus	ACI	Displacement	0.3	
Trinder et al. 2019	Northern Gannet	Digital aerial	B	Beatrice	BACI	Displacement*	2	
Percival 2013	Northern Gannet	Boat-based	All	Thanet	DS-BACI	No Effect*	0, 0.5, 1, 2, 3	
Leopold et al. 2013	Loons	Boat-based	All	Egmond aan Zee	BAG	Displacement*	~4-10	
Mendel 2012	Loons	Visual aerial	NB	Alpha Ventus	BAG	Displacement*	0, 2, 5, 10, 20, 30	2-20[12]
Mendel et al. 2019	Loons	Combined	NB	Multiple	BAG	Displacement*	36[13]	16.5
Petersen and Fox 2007	Loons	Visual aerial	All	Horns Rev 1	BAG	Displacement*	4	
Petersen et al. 2006	Loons	Visual aerial	All	Horns Rev 1	BAG	Displacement*	4	
Petersen et al. 2014	Loons	Visual aerial	All	Horns Rev 2	BAG	Displacement*	10-16	13
Vilela et al. 2021	Loons	Combined	NB	Multiple	ACI	Displacement	0	
Welcker and Nehls 2016	Loons	Boat-based	All	Alpha Ventus	ACI/AG	Displacement	3	2
Gill et al. 2008	Loons	Visual aerial	All	Kentish Flats	BACI	No Effect*	3	
Leopold et al. 2013	Loons	Boat-based	All	Princess Amalia	BAG	No Effect*	~4-10	
Petersen et al. 2006	Loons	Visual aerial	All	Nysted	BAG	No Effect*	4	
Heinanen et al. 2020	Red-throated Loon	Digital aerial	NB	Multiple	BAG	Displacement*	20	10
Percival 2013	Red-throated Loon	Boat-based	All	Thanet	DS-BACI	Displacement*	0, 0.5, 1, 2, 3	0.5
Percival 2014	Red-throated Loon	Boat-based	NB	Kentish Flats	DS-BACI	Displacement*	0, 0.5, 1, 2, 3	
Rehfisch et al. 2016	Red-throated Loon	Combined	NB	Multiple	AG	No Effect	15	

[12] 100% displacement at 2 km from wind farm, significant decrease up to 20 km strata, with significant increase in 30 km strata.
[13] Average buffer distance, variable around different wind farms, with minimum of 19 km and a maximum of 79 km.

Source	Focal Species	Study Method	Stage	Site Name	Design	Response	Buffer (km)	Dist (km)
Rexstad and Buckland 2012	Red-throated Loon	Boat-based	All	Kentish Flats	BAG	No Effect	1.5	
Nilsson and Green 2011	Common Eider	Boat-based	NB	Lillgrund	BAG	Displacement	2	
Nilsson and Green 2011	Common Eider	Visual aerial	NB	Lillgrund	BAG	Displacement	2	
Petersen and Fox 2007	Common Eider	Visual aerial	NB	Horns Rev 1	BAG	Displacement*	4	
Petersen et al. 2006	Common Eider	Visual aerial	All	Nysted	BAG	Displacement*	4	
Guillemette et al. 1998	Common Eider	Visual aerial	NB	Tunø Knob	BACI	No Effect*	0	
Petersen et al. 2006	Common Eider	Visual aerial	All	Horns Rev 1	BAG	No Effect*	4	
Petersen and Fox 2007	Common Scoter	Visual aerial	NB	Horns Rev 1	BAG	Attraction*	4	
Leopold et al. 2013	Common Scoter	Boat-based	All	Egmond aan Zee	BAG	Displacement*	~4-10	
Petersen et al. 2006	Common Scoter	Visual aerial	All	Horns Rev 1	BAG	Displacement*	4	
Petersen et al. 2006	Common Scoter	Visual aerial	All	Nysted	BAG	Displacement*	4	
Petersen et al. 2014	Common Scoter	Visual aerial	NB	Horns Rev 2	BAG	Displacement*	10-16	5
PMSS 2006	Common Scoter	Boat-based	All	North Hoyle	BAG	Displacement*	3	
Guillemette et al. 1998	Common Scoter	Visual aerial	NB	Tunø Knob	BACI	No Effect*	0	
Leopold et al. 2013	Common Scoter	Boat-based	All	Princess Amalia	BAG	No Effect*	~4-10	
PMSS 2006	Common Scoter	Visual aerial	NB	North Hoyle	BAG	No Effect*	3	
Nilsson and Green 2011	Long-tailed Duck	Boat-based	NB	Lillgrund	BAG	Displacement	2	
Nilsson and Green 2011	Long-tailed Duck	Visual aerial	NB	Lillgrund	BAG	Displacement	2	
Petersen et al. 2006	Long-tailed Duck	Visual aerial	All	Nysted	BAG	Displacement*	4	
Petersen et al. 2011	Long-tailed Duck	Visual aerial	NB	Nysted	BAG	Displacement*	~10-30	
Petersen et al. 2006	Red-breasted Merganser	Visual aerial	All	Nysted	BAG	Attraction*	4	
Nilsson and Green 2011	Red-breasted Merganser	Boat-based	NB	Lillgrund	BAG	Displacement	2	
Nilsson and Green 2011	Red-breasted Merganser	Visual aerial	NB	Lillgrund	BAG	Displacement	2	

including incidental take (Wong et al. 2018). It seems possible that bird responses to vessel activity, which is heaviest during the construction period, may be driving these patterns.

The only species exhibiting relatively consistent attraction across studies were the Great Cormorant and European Shag (Table C5). Great Cormorants tended to show stronger attraction to offshore wind facilities located farther from shore. They were attracted to facilities farther from shore (6–23 km, n=3 studies), compared to studies that found no effect (7–9 km; n=3 studies), though the buffer area surveyed was often small, particularly for those studies that found no effect. Given that cormorants may use offshore wind turbines as perching and roosting opportunities (Dierschke et al. 2016), perching opportunities may become more attractive at offshore wind projects located farther from shore where fewer natural structures exist.

Null effect studies (e.g., no displacement/attraction detected) included those that found non-significant displacement/attraction effects. In general, null effect studies had lower densities of the focal taxon pre-construction (e.g., low exposure), examined smaller buffer areas (for observational survey studies), and used a before-after-control-impact study design rather than a gradient design. Many of these were telemetry studies that only used data after construction to examine the behavior and habitat use of individuals, with variation in responses at different distances from facilities (Johnston et al. 2022). This suggests that buffer size, study design, and scale of the analysis play an important role in the ability to detect effects of offshore wind energy development on birds. In addition, while most studies used a single study method, Nilsson and Green (2011) compared data from boat-based and visual aerial surveys and found differences in responses of Herring Gulls by survey type. This further exemplifies the importance of careful consideration of study methods, ensuring that all methodological biases are controlled to the extent possible. No clear patterns were found regarding the effectiveness of different study methods for detecting displacement or attraction, likely due to the wide variation in implementation protocols within each study method. For additional recommendations on study design and choice of study method, see Sections 6-7 and (specifically for observational surveys) Section 10.

For observational surveys, we further summarized results by species, survey method, study design, response (including statistical significance), buffer size surveyed, and the distance at which an effect was detected (Table C5). These results exemplify the variation in study designs among studies, and in particular the variation in buffer areas surveyed outside of project footprints. Percent spatial coverage and the ratio of affected area to overall survey area were very infrequently reported, making additional inference around spatial coverage difficult. Despite the high number of observational surveys utilizing variations on the Before-After-Gradient study design, few reported effect distances in addition to effect detection.

Inconsistency in analysis and reporting complicated the summarization of data (see recommendations below), particularly as the choice of effect size metric was highly variable among studies and often lacked reporting of associated uncertainty, and buffers were implemented in different ways depending on the study design (e.g., some Before-After-Control-Impact studies included a buffer in the affected area in comparison with a control, while others did not). Thus, caution should be taken in using summary data from any individual study in the above tables to inform the design of future studies.

C.3.2 Macro- and Meso-Avoidance

Macro- and meso-scale avoidance studies primarily used radar and visual observations or GPS telemetry, with many studies conducted during migration periods, particularly for waterfowl. The majority of findings focused on macro-avoidance and a few studies examined both macro- and meso-avoidance. Macro-avoidance detection varied by species, study design, and method (Table C6). Sources of variation were similar to those discussed above in relation to displacement/attraction studies. For example, macro-avoidance varied by life history stage for some species, including Great Cormorant, but not gulls or Common Scoter (Rothery et al. 2009).

Table C5. *Evidence of macro-avoidance of offshore wind facilities by taxon and species, including the percent of studies that found evidence of macro-avoidance, the study design (BAI=Before-After-Impact, ACI=After Control-Impact, BAG=Before-After-Gradient, BACI=Before-After-Control-Impact), and the study method (radar, GPS tracking, visual observations) for studies that found macro-avoidance and those that found no response.*

Taxa Group	Focal Species	Total Studies (n)	Studies Finding Macro-Avoidance			Studies Finding No Effect		
			% of Studies	Study Design	Method	% of Studies	Study Design	Method
Cormorants	Great Cormorant	4	25%	BAI	Visual Obs.	75%	BAI, ACI	Visual Obs.
Gannets	Northern Gannet	10	90%	ACI	GPS, Visual Obs., Radar	10%	BAI	Visual Obs.
Gulls	Black-legged Kittiwake	4	50%	ACI	Radar	50%	BAI, ACI	Visual Obs.
	Great Black-backed Gull	3	33%	ACI	Radar	67%	BAI, ACI	Visual Obs.
	Herring Gull	3	33%	ACI	Radar	67%	BAI, ACI	Visual Obs.
	Lesser Black-backed Gull	4	50%	ACI	GPS, Radar	50%	ACI	Visual Obs., GPS
	Little Gull	2	50%	ACI	Visual Obs.	50%	ACI	Visual Obs.
	Gull spp.	4	100%	ACI	Visual Obs., Radar	-	-	-
Terns	Sandwich Tern	4	20%	BACI	Visual Obs.	80%	ACI, BAI	Visual Obs.
	Tern spp.	3	100%	ACI	Visual Obs., Radar	-	-	-
Waterfowl	Common Eider	7	71%	ACI, AG, BAG, BACI	Visual Obs., Radar	29%	BAI	Visual Obs.
	Common Scoter	6	67%	ACI	Visual Obs., Radar	33%	BAI	Visual Obs.
	Dark-bellied Brent Goose	1	100%	ACI	Visual Obs.	-	-	-
	Pink-footed Goose	1	100%	ACI	Radar	-	-	-
All	Marine birds	6	83%	ACI, BACI	Radar	17%	ACI	Radar

Site characteristics may also play a role. For example, two studies of Little Gull with similar methods and study designs showed variable results, with one study finding evidence of macro-avoidance (Blew et al. 2008) while the other found no evidence (Krijgsveld et al. 2011). While distance to shore and footprint size were similar across wind facilities examined, the number of turbines (and thus density of turbine placement) varied, with macro-avoidance at an 80-turbine project contrasting with no evidence of avoidance at a 36-turbine project. However, the sample sizes available to make this type of inference are currently quite limited.

The choice of study method may also influence a study's ability to detect avian avoidance; many of the null effect results came from visual observation studies (n=9), while radar studies (n=13) tended to detect effects. For example, in the case of Black-legged Kittiwakes, studies using radar found evidence of macro-avoidance (Skov et al. 2012a, Skov et al. 2018) while those that found no response used visual observations (Rothery et al. 2009). Variation in the scale of inference of these methods (e.g., radar has a farther range) may help explain the discrepancy in these results. In addition, many of the avoidance studies collected data only after construction using a control-impact approach. Pre-construction data likely play a key role in understanding species avoidance of facilities.

Of the few studies that examined meso-avoidance, all found some evidence of this response. Skov et al. (2018) documented meso-avoidance in Northern Gannet, Black-Legged Kittiwake, Great-Black-backed Gull, Herring Gull, and Lesser Black-backed Gull, and additional studies showed similar findings for Lesser Black-backed Gull (Thaxter et al. 2018, Vanermen et al. 2020a) Sandwich Tern (Perrow et al. 2015), and Common Eider (Tulp et al. 1999). The only species that displayed no evidence of meso-avoidance was Pink-footed Goose (Plonczkier and Simms 2012). Studies used various methods including radar, GPS, visual observations, and camera tracking systems. Because of the scale of meso-avoidance (i.e., avoidance of wind turbines within the project footprint), studies of this response are contingent upon the birds entering the wind facility. As such, species that show high levels of displacement and macro-avoidance are unlikely to be studied in this context.

C.4 Discussion

The available literature was highly variable in quality, which made synthesis challenging. In particular, gray literature reports of monitoring activities at individual wind facilities were in some cases opaque and lacking in essential details, indications of a need for greater scientific rigor and peer review. Common challenges encountered during the literature review included:

- Long and convoluted reports with extraneous detail and poor descriptions of methods and results.
- Lack of key details on study methods, study area, and wind project site characteristics. In many cases the level of detail did not provide enough information for the study to be replicable, and in some cases, it was difficult to tell how and where the study was even conducted.
- High levels of variation in study design and analysis within the general categories of before-after and control-impact vs. gradient designs, making it difficult to adequately characterize studies. For example, in the case of control-impact study designs, the inclusion of buffers combined with the effect area in comparison with control areas was highly variable, as were the number of controls used and the distance between controls and project footprints. In the case of gradient study designs, the use of distances bands in analysis was inconsistent, among other sources of variation.

- Substantial variation in how buffer zones were implemented, particularly for studies using observational surveys. Many Before-After Gradient studies used variable buffer zones, whereby the distance included in the zone differed on each side of the wind facility. In the case of Before-After-Control-Impact studies, the definition of the "impact" site also varied substantially, with inclusion of different size buffer zones (or no buffer zones) alongside the project footprint.
- Inconsistent use and reporting of quantitative analytical methods and statistical tests.
- Other inconsistent and sometimes poor-quality reporting of results; for example, a quantitative measure of change (such as degree/magnitude of change or distance at which effects were observed) was not always included in reports and it could be very difficult to extract key findings. In addition, associated effect size uncertainty was often not reported.

Given these challenges, we recommend the following for study design that studies of displacement, attraction, and macro- to meso-scale avoidance of offshore wind facilities by marine birds:

- Collect data following best practices, existing guidelines, and established protocols for effectiveness and efficiency.
- Collect data before and after wind facility construction, as well as during construction for species that may be affected by construction activities (e.g., vessels).
- Utilize gradient study designs without separate control areas. It can be quite difficult to select a representative control area in the marine environment (Methratta 2021). Additionally, some studies in our dataset (particularly earlier studies) selected inappropriate control locations in proximity to the wind facility, such that bird behavior in these areas could have still been affected by the offshore wind development.
- Use consistent data collection methods over space and time (to the degree possible) to avoid introducing methodological biases into study design.
- Incorporate data collection on behaviors (such as perching, foraging, etc.) to help understand potential habitat-related drivers of changes in habitat use.
- Carefully consider the spatial and temporal scale of the proposed study, including consideration of 1) the research question, 2) existing knowledge of focal taxa's scale of response, 3) statistical power, and 4) sources of variation (see below).
- Consider sources of spatial and temporal variation in responses, including life history stage, site characteristics, and other anthropogenic factors that may influence movement and habitat use. Incorporate these variables into study design and analysis when possible, and at minimum, clearly report these data such that future synthetic reviews and meta-analyses can explore their effect on bird behavior.
- Include quality assurance and quality control to minimize inaccuracies in the data and subsequent results.

Additional recommendations for study design can be found in Section 7 of the main document as well as Section 10 (specific to observational surveys).

We recommend that studies of displacement, attraction, and macro- to meso-scale avoidance of offshore wind facilities by marine birds consistently report the following:

- Methodological details of study design, such that the study could be easily replicated. This should include, but is not limited to, 1) study design (e.g., BAG, BACI etc.), 2) field study method (e.g., survey platform and make/model, data collection methods, etc.) 3) data type or metric being assessed, 4) spatial and temporal scale of the study, including buffer sizes, number and timing of surveys, survey effort, percent spatial coverage, etc., and 5) sample sizes.

- Analysis approach, including effect size metric, type of uncertainty, statistical tests, modeling frameworks, and other details such that the analysis is replicable.
- Statistical test results and effect size and associated uncertainty.
- Potential sources of variation, including site characteristics (e.g., distance from shore, footprint size, number of turbines, turbine height, turbine spacing, and water depth).

Additional reporting recommendations can be found in Section 8 (all methods) and Section 10 (observational surveys). In addition to reporting key information, making data publicly available in a timely manner with comprehensive metadata, contributing analytical products to data portals, and publishing results in the primary literature (and at minimum making grey literature publicly available at a stable web link), all are necessary to ensure that site-specific study data can be used to improve our understanding of effects to marine birds from offshore wind development at the regional scale and help us to further refine recommendations for the design of future studies.

C.4.1 Next Steps

In addition to the summary presented here, members of the Specialist Committee and support staff have used the database of studies developed during this effort to conduct a quantitative meta-analysis of studies that used observational survey methods (Lamb et al. 2024). This meta-analysis further informs understanding of displacement/attraction responses by taxon, as well as informing recommendations for survey methodology and reporting standards. Other next steps are outlined in Part V of the main document.

Appendix D. Assessment Rubric for Study Plans

There are many factors that may be used to assess a proposed study plan. The following example rubric (not comprehensive) can be used for the assessment of proposed study plans for conducting OSW project-level research and monitoring related to displacement, attraction, and avoidance of marine birds from OSW development. Assessments should be conducted by subject matter experts with careful consideration of study objectives, study design, and data sharing and coordination.

Evaluation Criteria	0	1	2	3	4	N/A
STUDY OBJECTIVES						
Clearly identified and discusses research focus/purpose						
Succinct, clear, relevant research questions identified						
Hypotheses are testable and clearly grounded in previous research/theoretically relevant literature						
Focal taxa clearly identified and justified based on exposure, sensitivity, uncertainty, and other key factors						
STUDY DESIGN						
Choice of general methods adequate to answer research questions based on key considerations (e.g., focal taxa considerations, biases, logistics)						
Choice of specific study method supported and justified based on strengths and limitations						
Sample sizes clearly defined and justified based on power analyses						
Power analysis includes selection of effect sizes and associated uncertainty based on existing information						
Consideration was given to the selection of power (i.e., Type II error) and Type 1 error rates and relevance for decision making						
Spatial and temporal scale of study defined based on scale of the question and predicted response based on best available knowledge.						
Includes consideration of potential sources of variation, including environmental covariate data and other factors that may affect the detection of effects, level of response, and/or interpretation of results						
Includes data collection before and after wind facility construction						
Data collection methods follow best practices, existing guidelines, and established protocols, or detail plans for developing project-specific protocols with expert input						
Methodological biases are minimized and/or addressed						
Process for quality assurance and quality control clearly delineated and adequate						
Clearly defined analysis plan including appropriate modeling framework and statistical tests, considerations of biases, autocorrelation, sources of variation, model complexity and performance						
DATA SHARING AND COORDINATION						
Process and timeline for publicly sharing study results delineated						
Plans for publication of results in peer-reviewed scientific literature						
Plans for making raw data publicly available within a maximum of two years						
Plans to contribute derived analytical products to data portals						
Communication and coordination with other developers and stakeholders outlined in plan						