Guidance for Pre- and Post-Construction Monitoring to Detect Changes in Marine Bird Distributions and Habitat Use Related to Offshore Wind Development

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

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Disclaimer

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Contents

Part I. Summary

This document was developed by a Specialist Committee convened by the New York Offshore Wind Environmental Technical Working Group (E-TWG) and chaired by a representative from the U.S. Fish and Wildlife Service (USFWS). The goal, developed in consultation with the E-TWG and USFWS staff, was to advance recommendations for the effective detection and characterization of changes in the distributions and habitat use of marine birds in relation to offshore wind (OSW) energy development. Committee members were selected for their knowledge and expertise on marine birds, study design, regional monitoring frameworks, and offshore wind development. The intended audience for these recommendations includes offshore wind energy developers, federal and state agencies that have oversight of marine birds and/or OSW energy activities in the U.S., and others conducting studies of marine birds at offshore wind energy projects.

The Specialist Committee used existing guidance from the Bureau of Ocean Energy Management (BOEM) for site assessment surveys, "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 on 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 (Appendix C), as well as existing relevant power analysis studies to inform recommendations. These recommendations are specifically focused on the following:

- Marine birds and OSW development in the U.S. Atlantic (though, we expect this document to be broadly relevant to OSW development studies in other geographies).
- Studies of changes in movement behavior, distributions and habitat use, namely displacement, attraction, and macro- to meso-scale avoidance. *Micro-scale avoidance and collisions, as well as other types of OSW effects, were not considered here, and additional recommendations should be developed in the future for these other types of studies.*
- Studies intended to detect effects from OSW development, not assess risk or characterize avian resources at the site level prior to construction. Recommendations for site characterization surveys (also known as site assessment surveys) are included in BOEM's current guidelines (BOEM 2020), and in a supplementary document produced by this Committee (Avian Displacement Guidance Committee 2023), that outlines circumstances under which existing data for a project site are sufficient for site characterization purposes.
- Site-specific studies of the effects of individual lease areas. These recommendations are intended to inform project-specific monitoring, because the regulatory framework for OSW development in the U.S. tends to encourage monitoring at this scale. However, many of these recommendations will also be applicable to studies at larger spatial scales.

While there are various potential effects from offshore wind development on marine birds, and all deserve dedicated research recommendations, understanding displacement-related effects from OSW development represents a key research priority. While this should not be the sole focus for project-level studies, when the focus is on displacement, observational surveys represent a key study method. As such, this document outlines various research questions related to changes in distributions, habitat use, and behavior of marine birds and relevant methods at a broad level (Sections 4-8), before diving into detailed recommendations for observational surveys (Sections 9-10). Next steps (Sections 11-12) include the development of detailed recommendations for other methods (e.g., tracking, radar) and effect types (e.g., collisions) to ensure that all types of research at the project-scale are carried out in an effective and scientifically robust manner. Prioritization of regional-scale (multi-project) collaborative studies is also recommended to better detect effects beyond the scale of individual OSW projects.

The deliberative and inclusive process used to develop these recommendations (Appendix A) brought together substantial expertise to reach consensus on the best available science to conduct studies of marine birds at OSW facilities. This Specialist Committee firmly recommends that:

1. **Statistically robust monitoring should be conducted at all lease areas to detect and characterize changes in distributions and habitat use of marine birds** and
2. **The guidance in this document forms the basis for federal guidelines focused on how to conduct pre-and post-construction monitoring to detect changes in marine bird distributions and habitat use at individual OSW facilities in the U.S. Atlantic.**

In addition to this summary (Part I), there are four main parts to this document, including an introductory section (Part II) which details the rationale and purpose for this guidance and define the terminology used throughout (additional terminology is also defined in the glossary in Appendix B). Part III provides general study design recommendations for all types of displacement, avoidance, and attraction studies (summarized in S1 below). Part IV provides detailed recommendations for conducting observational surveys (summarized in S2 below). Part V includes recommendations for future guidance and research (summarized in S3 below). Following the literature cited (Part VI), several appendices provide supporting information (Part VII).

S.1 General Recommendations

General recommendations for conducting studies to detect displacement, attraction, and macro- to meso-scale avoidance include recommendations for the identification of research questions (Section 4), selection of focal taxa (Section 5), choice of appropriate methodologies (Section 6), development of an effective study design (Section 7), and reporting and data transparency (Section 8).

Key Research Questions. Section 4 identifies six key questions to be addressed when examining marine bird displacement, attraction, and avoidance at OSW developments. During study planning, one or more of these questions should be selected to be the focus of study and help direct the choice of focal taxon, study method, and other aspects of the research effort. Section 4 also provides brief guidance on best practices for using site-specific data to inform regional-scale questions.

Selection of Focal Taxa. Section 5 describes how to select focal taxa for studying changes in distributions and habitat use at OSW energy projects to inform study design and data collection even for study methods that can collect information on multiple species simultaneously (e.g., observational surveys). The choice of focal species for understanding displacement, attraction, and avoidance at site-specific scales will depend on a variety of considerations: for example, the research question(s) of interest (Section 4), characteristics of the particular OSW project(s) and location(s) being investigated, and species-specific risk inferred from existing information (Appendix C; Lamb et al. 2024). Data-driven focal species selection may also depend on exposure, sensitivity to effects, population sensitivity, and uncertainty in our understanding of responses. A decision tree is proposed to select focal taxa that will best contribute to a broader understanding of offshore wind effects and inform resource management and other decision making.

Selection of Appropriate Methodologies. Section 6 suggests how to select appropriate methodologies that can detect effects of OSW facilities on birds. This includes a multi-step process to identify appropriate methods for the research question and taxon of interest, and to compare available methods that help identify the most effective approach. Applicable study methods include observational surveys, individual tracking, radar, behavioral observations from fixed points, and use of remote visual imagery.

Development of an Effective Study Design. Section 7 provides guidance on how to design and implement an effective study of changes in marine bird distributions and habitat use at OSW facilities. This includes the definition of clear objectives and the identification of appropriate spatial and temporal scales to estimate acceptable statistical power and effect size. In addition to data collection and analytical methods, study planning should include a focus on data sharing and coordination. A suggested assessment rubric for study plans is provided (Appendix D) to help in the review of proposed methods and guide the selection of project-specific study designs.

Recommendations on Reporting, Data Consistency and Transparency. Section 8 provides recommendations on reporting, including standardization, data sharing, and coordination.

S.2 Detailed Recommendations for Observational Surveys

Observational surveys are a key method for detecting displacement, and therefore this document provides detailed guidance on the use of observational survey methods for pre- and post-construction monitoring. We recommend that separate site assessment and pre-construction surveys to detect effects are conducted (Avian Displacement Guidance Committee 2023), given differences in the objectives of each survey as well as challenges associated with timing under current permitting timelines (Section 9). *Recommendations in Section 10 are therefore specific to conducting observational surveys (e.g., boat-based surveys and digital aerial surveys) to detect effects from OSW development on marine birds.* Additional details, including justification of the summarized recommendations below, can be found in each linked section of the document.

S.2.1 Study Design Recommendations for Surveys

- Study Design – It is recommended that observational surveys to detect effects utilize Before-After-Gradient (BAG) study designs.
- Power analysis – Existing data should be used in site-specific power analyses to inform the choice of spatial and temporal coverage of surveys based on the focal taxa at each site. Surveys should collect data on all species observed, but selection of focal taxa can help to refine the specific survey design. To improve statistical power to detect effects if they occur, focal species should have relatively high exposure and high expected magnitude of response (additional criteria discussed in Section 5). For focal species where potential effect size is unknown, effect size should be estimated conservatively to ensure the study is designed with a higher chance of detecting effects, should they occur.
- Buffer size – In order to have the statistical power to detect effects, should they occur, a buffer zone of 4–20 km should be surveyed around the OSW project footprint with a consistent buffer distance in all directions. Choice of buffer size should be based on species presence and focal species sensitivity to displacement (e.g., predicted displacement distance).

- Survey area – The choice of survey area should be informed by the spatial extent at which changes are predicted to occur, such that the total survey area includes the wind farm footprint, as well as a buffer zone that incorporates the predicted effect distance for focal taxa plus 10%.
- Coordination – For adjacent lease areas, we encourage coordinated survey efforts, to the degree feasible given differences in construction timelines, to maximize efficiency and treat the area as a continuous habitat for marine birds.
- Spatial coverage – We recommend at least 20% spatial coverage of the study area for surveys to detect effects, calculated based on effective strip width for focal species.
- Transects – Transect lines should be a distance apart that is >2 times the effective strip width and placed/oriented such that important environmental gradients are fully represented within sampling designs.
- Temporal scale – For studies to detect effects, 12–16 surveys per year for at least two years pre-construction should be conducted to adequately capture variation in distributions. The duration and frequency of post-construction surveys should depend on the question (e.g., interest in temporal patterns of displacement/habituation; Section 4) and levels of variability in site-level data but should include no less than 3 years of 12–16 surveys per year. Post-construction surveys should be initiated within five years of the completion of pre-construction surveys.
- Seasonal distribution – The distribution of surveys within a particular year should take into consideration seasonal patterns of focal species, as increases in power can be achieved if effort is concentrated in seasons in which species of interest are most abundant (Maclean et al. 2013).

S.2.2 Data Collection, Analysis, and Reporting Recommendations for Surveys

- Consistent methods – Survey methods, including data collection methods, should be consistent across pre- and post-construction surveys so as not to introduce biases (BOEM 2020). Unavoidable changes should be assessed via calibration studies.
- Sampling method – Line transects with distance-sampling methods should be used for boat-based surveys (Buckland et al. 2001; Camphuysen et al. 2004), while strip-transect or grid sampling should be used for digital aerial surveys (BOEM 2020).
- Platform – The same platform should be used for pre- and post-construction surveys, traveling at consistent speeds (boat-based 7–10 knots, digital aerial 185–350 km/hr). For boat-based surveys, an adequate position above sea level is necessary to detect birds within a minimum of 300 m of the trackline for focal taxa, have a clear 90 field of degree view, and be safe and stable. For digital aerial methods, surveys should be flown at a consistent altitude (500 m minimum), with optimal flight height chosen to balance image resolution, disturbance to wildlife, and human safety.
- Surveyor qualifications – Observers/biologists conducting surveys must have documented experience with identifying and counting seabirds (50–100 hours training minimum) and demonstrated ability to rapidly identify seabirds in the region in various conditions.
- Survey conditions – Surveys should be conducted in a sea state of Beaufort 4 or less (depending on survey type), in conditions with enough light to identify birds to species. Survey angle and location should be designed to minimize glare.
- Data collection – Survey data collection should include effort data and information on conditions, as well as observations (see Section 10.4 for full list of data) collected in a standardized way for incorporation in the Northwest Atlantic Seabird Catalog and other repositories. Birds should be identified to species wherever possible (with high confidence), color images should be captured

at adequate resolution (boat: where possible with telephoto lens; digital aerial: minimum 2 cm resolution).

- In-situ environmental data – Careful consideration should be given to the collection of *in situ* environmental and prey data simultaneous with bird observations, continuously or at regular intervals.
- Review of data – Data should be summarized and reviewed by observers for errors (boat) or 20% of data should be independently audited by an expert during detection and identification (digital aerial).
- Data analysis – Development of a clearly defined analysis plan should include specific models and statistical tests, methods to account for biases (e.g., detectability, availability), choice of an appropriate modeling framework, methods to account for spatial and temporal autocorrelation in the data, and a comprehensive identification of covariates.
- Data reporting – Standardized reporting should include information on data collection, spatial and temporal coverage (e.g., % spatial coverage, buffer size, distance between transects, overall survey area, timing of surveys), spatially-explicit density estimates and associated variance by species/taxonomic group, and information on site characteristics (e.g., latitude and longitude, footprint size, number, height, and spacing of turbines, water depth, and distance to shore).
- Public availability – Observational survey datasets from effects studies should be made publicly available as soon as possible (maximum two years following collection, if feasible) via the Northwest Atlantic Seabird Catalog and/or OBIS SEAMAP. This should include the final processed dataset, co-collected environmental covariate data, complete effort data, and comprehensive metadata. Reports and analysis code should also be public and easily accessible.

S.3 Future Directions

Part V (Sections 11-12) provides recommendations for further development and refinement of the guidance in this document, as well as recommendations for additional priority guidance and research. While the recommendations presented in this document represent a key first step in developing standardized methods to accurately and reliably detect macro- to meso-scale changes in marine bird distributions and habitat use at OSW facilities, with an emphasis on observational surveys, further steps will be needed for effective implementation of this guidance at a regional scale. This could include developing specific recommendations for non-observational survey methodologies (which were largely beyond the scope of this document) and improving quantitative analyses that could incorporate different types of data. It will also be important for both OSW developers and regulators to actively pursue coordinated data collection and analysis. This guidance is primarily focused on the individual lease area scale, given the current regulatory framework being applied to OSW projects in the United States. However, broader regional monitoring programs in Europe have typically been much more effective than studies of individual lease areas for detecting change caused by OSW development, due to larger spatiotemporal scales of inference.

Part II. Introduction

1.0 Background and Purpose

Offshore wind (OSW) development is rapidly increasing in the eastern U.S., bringing with it a range of potential effects to bird populations that use the marine environment for foraging, roosting, small- to large-scale movements, and other activities. The potential effects of offshore infrastructure for birds include collision risk (Masden & Cook 2016, Allison et al. 2019), changes in habitat and prey resources (Perrow et al. 2011, Degraer et al. 2020), and behavioral changes that may lead to avoidance (Masden et al. 2009, 2010) or attraction to OSW facilities (Vanermen et al. 2015, Dierschke et al. 2016, Mendel et al. 2019a). For marine birds, changes in offshore habitat use patterns may have the potential to affect individual fitness and, by extension, lead to population-level impacts (Busch et al. 2013).

The Offshore Wind Environmental Technical Working Group (E-TWG) is an independent advisory body to the State of New York with a regional focus on OSW and wildlife issues in the U.S. Atlantic. The E-TWG recognized the need for additional guidance and recommendations for conducting site-level wildlife monitoring at OSW facilities, and with input from biologists at the U.S. Fish and Wildlife Service (USFWS), formed a Committee of subject matter experts (Appendix A) to develop guidance for monitoring changes in marine bird distributions and habitat use at OSW facilities in the U.S. This Committee was chaired by a USFWS biologist with the Migratory Bird Program and includes a range of other expertise from multiple sectors.

Recognizing that there are other potential effects to birds from OSW development (e.g., collisions and micro-avoidance of turbine blades, changes in habitat and prey), this guidance is focused specifically on developing standardized methods to accurately and reliably detect macro- to meso-scale changes (e.g., displacement, attraction, and avoidance) in avian distributions and habitat use at OSW facilities in the U.S. The main objective of this effort is to inform pre- and post-construction monitoring and research approaches for detecting and characterizing displacement, attraction, and macro- to meso-avoidance of marine birds at OSW facilities in U.S. waters. This includes the identification of avoidance and attraction-related research questions and the appropriate methodologies to address those questions (e.g., observational surveys, marine radar, telemetry, and other methods), with a focus on informing study designs for observational boat-based and aerial surveys. The goals of this effort are to:

- Encourage consistency in pre- and post-construction monitoring across projects,
- Facilitate use of site-specific data to address information gaps on the effects of OSW development on birds at regional scales,
- Improve efficiency and thus reduce costs of monitoring,
- Reduce duplicative efforts,
- Ensure the generation of meaningful results, and
- Address knowledge gaps that could inform the broader understanding of potential cumulative impacts from OSW development.

While the focus of this effort is on designing pre- and post-construction monitoring to detect effects, Committee members recognized an immediate need for more detailed guidance to supplement existing BOEM site characterization guidelines (BOEM 2020) for determining when existing avian observational survey data is sufficient for site characterization purposes. This topic is addressed in a separate

Committee document, "Recommendations for Evaluating the Use of Existing Baseline Observational Survey Data in Offshore Wind Site Characterization Processes for the U.S. Atlantic," (Avian Displacement Guidance Committee 2023; hereafter referred to as 'site characterization recommendations'), which is available on the Committee webpage at www.nyetwg.com/avian-displacement-guidance.

1.1 Terminology

A glossary of key terms used throughout this document can be found in Appendix B. **Marine birds**, in the context of this document, 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 scope.

Avoidance is a behavioral response in which birds navigate away from structures at the macro-scale (e.g., the entire footprint of an OSW facility, generally occurring within 3 km of turbines), the meso-scale (e.g., avoidance of individual turbines once they have entered the footprint of an OSW facility, or the micro-scale (e.g., last minute avoidance of turbine blades/structures; Fox & Petersen 2019). **Displacement**, in the context of this document, is defined as the change in distributions and habitat use that occurs as a result of macro-scale avoidance. This involves reduced usage of areas around OSW turbines for activities such as foraging, which causes short- or long-term functional habitat loss and is one of the most regularly observed effects of OSW development on seabirds in Europe. Displacement has been noted for species such as Northern Gannets (*Morus bassanus*), Common Murres (*Uria aalge*), and Red-throated Loons (*Gavia stellata*; Dierschke et al. 2016, Mendel et al. 2019b, Peschko et al. 2020). In this document "displacement" is used to refer to changes in distribution/habitat use, while "avoidance" is generally used to refer to changes in movement behavior.

Some avian species may also be **attracted** (the process by which individuals respond to an object or stimulus by moving towards it) to OSW turbines or other structures due to increased foraging or roosting opportunities, artificial lighting, or other causes (Leopold et al. 2011, Rebke et al. 2019). Changes in distributions and habitat use of marine birds can include avoidance at different spatial scales, displacement, and/or attraction; efforts to **detect and characterize** such changes, as described in this document, include documenting shifts in species' distributions as well as the magnitude, temporal extent, and variability of such changes, the conditions under which these changes occur, and (where possible) the drivers of these changes.

Research is 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 represents a subset of research that includes systematic or repeated data collection.

Site characterization surveys are new observational surveys of an OSW project site implemented prior to construction, generally by the developer, which are designed to collect environmental data for the project site to inform permitting processes, project design, effect minimization measures, and the development of pre- and post-construction monitoring plans. BOEM has existing guidelines for site characterization surveys (BOEM 2020). However, as recognized by the Atlantic Marine Bird Cooperative

Marine Spatial Planning Workgroup[1] and others, these guidelines do not adequately address the collection of data to detect potential effects to marine birds caused by an OSW facility. Effects surveys are generally conducted both pre- and post-construction to compare differences in distributions, abundances, or behaviors between the two time periods. While site characterization methodologies may resemble pre-construction data collection required to assess effects (e.g., for pre- and post-construction comparisons), these surveys may also vary in key ways, such as the geographic scope and duration of monitoring that is required for each purpose.

Additional terminology relevant to identifying focal taxa for research is defined in Sections 5.1-5.2, and terminology specific to study methods is included in Section 6.1, as well as in the document glossary (Appendix B).

2.0 Rationale

Displacement and other changes to avian habitat use, distributions, and movement patterns have been documented at OSW facilities across Europe. The occurrence and degree of displacement, avoidance, and attraction varies in space and time with individual and species-level responses, site-level characteristics, environmental conditions, and other factors (Fox & Petersen 2019). Standardized pre- and post-construction monitoring at individual OSW facilities is important for detecting, quantifying, and contextualizing such changes. Despite existing efforts[2], there is currently no standard guidance in the U.S. that provides specifics for how to best examine effects of OSW facilities, such as displacement, on marine bird species. Before conducting monitoring activities, it is important to identify a clear set of appropriate questions to be answered, as well as the spatiotemporal scales at which to address these questions, to inform the choice of study methodology. Standardized, repeatable, and transparent methods are critical to achieve the statistical power needed to detect effects such as displacement at individual OSW projects, distinguish changes caused by OSW facilities from background/other sources of variation, and aggregate data across projects to improve broader understanding of potential cumulative effects from OSW development.

This guidance could be used in multiple ways, including being: (1) referenced and/or incorporated into future national OSW-wildlife guidance developed by regulatory agencies, (2) used by OSW developers and their consultants as they develop site-specific monitoring plans, and (3) used by BOEM, states, and other stakeholders in meeting regulatory responsibilities. Site characterization guidance to inform risk assessments already exists (BOEM 2020). The displacement and avoidance-specific guidance for effects studies contained in this document is consistent with, and complements, the existing site characterization survey guidance from BOEM, as well as the site characterization recommendations developed by this Committee (Avian Displacement Guidance Committee 2023) and will be available for BOEM's future use at their discretion. This guidance, which is focused on monitoring at individual OSW facilities, also

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

[2] Relevant efforts include recent site-specific monitoring guidance to investigate the effects of offshore wind development on fishes and invertebrates (ROSA 2021), BOEM offshore wind energy avian survey guidelines for OSW site characterization activities (BOEM 2020), Atlantic Marine Bird Cooperative recommendations to BOEM on these avian survey guidelines, the bird and bat scientific research framework workshop (NYSERDA 2020); a U.S. Fish and Wildlife-led project to develop guidance for deploying Motus telemetry at OSW facilities, and a concurrent E-TWG effort to develop guidance for regional-scale wildlife research and monitoring in relation to OSW development in the eastern U.S.

complements the guidance for regional-scale research and monitoring efforts that was concurrently developed by another E-TWG Specialist Committee (Regional Synthesis Workgroup 2023).

The geographic scope of this effort was the U.S. Atlantic coast. However, recommendations have been developed with the intention of broad applicability to the U.S. Pacific coast, Gulf of Mexico, Atlantic Canada, and other regions of planned OSW development in North America.

3.0 Focus of Guidance

This effort is focused on developing guidance to detect and characterize changes in distributions and habitat use patterns of marine birds in relation to OSW development. These potential changes include avoidance at meso- and macro scales, displacement from habitat use areas as a result of macro-avoidance, and attraction, which may occur during all periods of the annual cycle (breeding, non-breeding, and migration). These effects may be measured using various metrics, such as the distance from the OSW facility at which change occurs, or the abundance or proportion of a population that is affected. An examination of the individual fitness effects of these changes, potential population-level impacts, and management of these effects is beyond the scope of this effort, as are other types of effects (e.g., collisions, micro-avoidance).

While there are various potential effects from OSW development on marine birds, and all deserve dedicated research recommendations, understanding displacement-related effects from OSW development represents a key research priority. While this should not be the sole focus for project-level studies, when the focus is on displacement, observational surveys represent a key study method. As such, this document outlines various research questions related to changes in distributions, habitat use, and behavior of marine birds and relevant methods at a broad level (Part III), before diving into detailed recommendations for observational surveys (Part IV). Next steps (Part V) include the development of detailed recommendations for other methods (e.g., tracking, radar) and effect types (e.g., collisions) to ensure that all types of research at the project-scale is carried out in an effective and scientifically robust manner in consultation with federal agencies.

A main focus of this guidance is to help OSW developers and their contractors to develop an effective study plan for effects studies. Study plans should include the identification of monitoring methods most appropriate to answer research questions at the OSW project scale, including use of radar, telemetry, boat-based and aerial surveys, and other approaches (Largey et al. 2021). As detailed in the conceptual diagram below (Figure 1), the choice of study method(s) should depend, first and foremost, on the selection of research question(s) of interest (Section 4) and one or more focal taxa (Section 5). For methods that are well suited to collect data on multiple taxa simultaneously (e.g., observational surveys), the choice of focal taxa is still important to inform study designs that adequately detect effects.

In addition to the selection of research question(s) and focal taxa, the study plan should also consider the strengths and limitations of potential methods (Section 6). Following the selection of one or more study method, studies should be designed with the statistical power to detect effects (Section 7) and plans for data sharing and transparency should be explicitly incorporated into the study plan prior to beginning data collection (Section 8). Observational surveys are a key method for detecting displacement, and therefore this document also provides detailed guidance on the use of observational survey methods for pre- and post-construction monitoring (Section 10), recognizing that the scientific community would benefit from detailed recommendations for all study methods. The recommendations in this document are intended to be widely applicable across studies conducted at the site-level. However, recognizing that project-level considerations will play a role in study design, any deviations from these recommendations should be carefully considered and justified based on statistically and scientifically robust analysis. Recommendations are additionally provided for future refinement and expansion upon the guidance in this document (Part V). We encourage the development of recommended study protocols similar to Section 10 of this document to inform the use of radar, individual tracking, and other study methods. The focus on detailed recommendations for observational surveys relates to the strengths of this method for characterizing displacement while also collecting community-level information, as demonstrated by the widespread use of this method in Europe (Appendix C; Lamb et al. 2024).

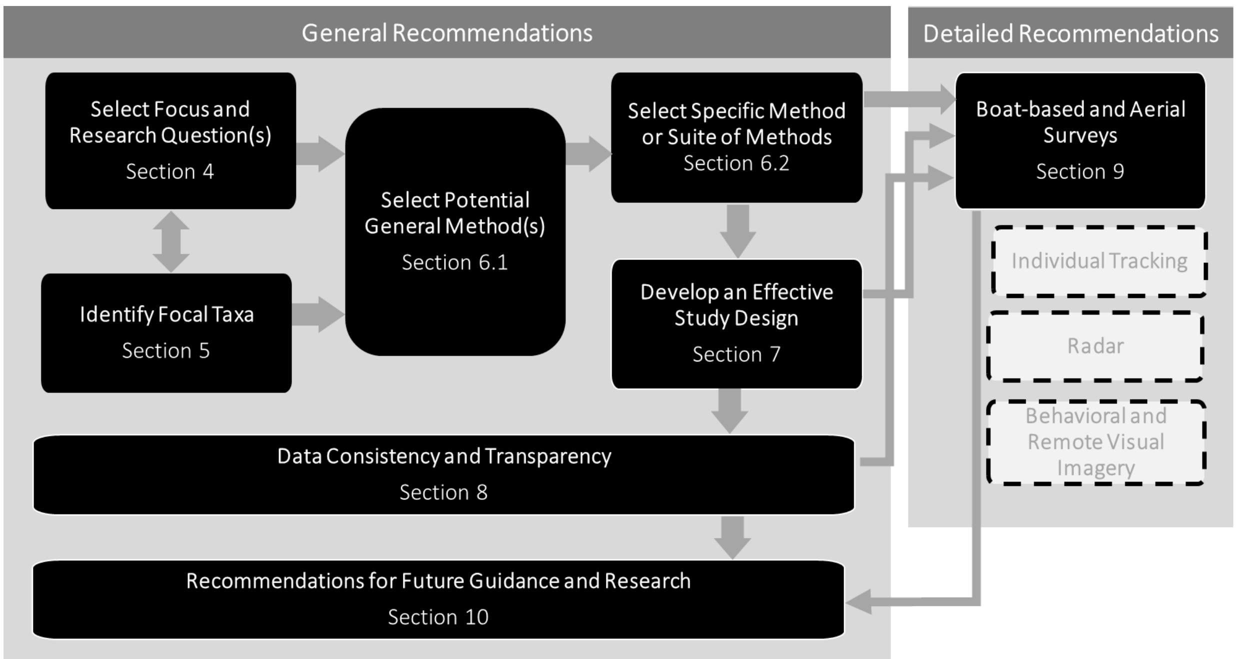

Figure 1. *Conceptual diagram for the main components (black boxes) of this guidance document for the selection of study design options for studies of macro- to meso-scale changes in avian habitat use around offshore wind facilities broadly and detailed recommendations specific to conducting observational surveys (e.g., boat-based and aerial). Detailed recommendations for other methods (grey boxes) are outside of the scope of this effort (see Part V for future guidance recommendations). Processes for each step in this diagram are further detailed in the referenced sections of the text.*

A literature review of existing empirical studies of macro- to meso-scale changes in marine bird distributions and habitat use at OSW facilities (Appendix C) informed the development of the recommendations in this document, particularly those related to spatial and temporal scale of study design as well as consistency of reporting. The literature review analyzed 55 journal articles and monitoring reports from European OSW facilities to document aspects of study design and the type and level of effects identified for suites of marine bird taxa. Results suggest that many factors influence the type and level of response detected, as well as the ability of the study design to have the statistical power to detect effects of OSW development on marine birds. Influencing factors include focal taxa, the pre-construction abundance of focal taxa in the area of interest, aspects of study design (e.g., inclusion of pre-construction data, gradient vs. control-impact design, spatial and temporal scale), site characteristics, and the stage of the annual cycle, among other factors. The literature review can be used to inform the selection of research questions and focal taxa based on the type and magnitude of species-specific responses of previous studies as well as key aspects of study design, including spatial scale. The literature review also highlights challenges associated with aggregating results across studies, particularly when key components of methods, analyses, and results are not comprehensively reported. Gaps identified during the literature review informed recommendations for reporting across methods in this document, as well as specifically for observational surveys.

Part III. General Study Design Recommendations

4.0 Key Research Questions

4.1 Key Research Questions to Examine Displacement, Attraction, and Avoidance

Several key research questions focus on understanding potential displacement, attraction, and macro- to meso-scale avoidance of marine birds at OSW development projects (Table 1). These questions are focused on the scale of the individual OSW facility (e.g., extent of wind facility footprint and immediately adjacent areas), such that a project developer might endeavor to answer them as part of pre- and post-construction monitoring efforts.

These questions about changes in habitat use by marine birds were identified as key questions from previous efforts, including the development of a scientific research framework for understanding offshore wind's effects to birds and bats in the eastern U.S. (Williams et al. 2024) and compilation of research needs and data gaps for offshore wind environmental research in the U.S. Atlantic (Regional Synthesis Workgroup 2023). The choice of research question(s) may inform the selection of focal species (Section 5), or conversely, specific taxa of interest that are known to be present at an offshore wind project site may inform the selection of research question(s). The highest priority research questions at a particular site will vary, and there are several sources of variation that should be considered when identifying which research questions to address, including differences among species, seasons, individuals, ages, sexes, stages of the annual cycle, environmental conditions (such as weather and visibility), and facility operating conditions. It is important to incorporate data collection focused on potential causal mechanisms of responses and variation in these responses, regardless of the specific question of interest, so that site-specific data can be effectively used to inform a regional scale understanding of effects and impacts to marine birds from OSW development.

Table 1. *Potential research questions related to marine bird displacement, attraction, and macro- to meso-scale avoidance of offshore wind energy development that can be addressed at the spatial scale of an individual wind facility. "Type" distinguishes between questions focused on changes in distributions and habitat use (D) and changes in movement behavior such as macro- to meso-scale avoidance (M). Potential study methods are defined in Section 6. Sources of variation to consider when examining these questions (e.g., covariates to include in analysis where possible) include species, season, individual, age, sex, stage of annual cycle, environmental conditions such as weather, and facility operating conditions.*

Research Question	Type	Project Phase
Are changes in distributions and habitat use (e.g., displacement/attraction) of marine birds occurring, and if so, what is the magnitude and distance from the offshore wind facility at which they occur?	D	Pre-construction, Operations
Do the occurrence, magnitude, and distance of changes in habitat use vary temporally (e.g., does habituation occur)?	D	Pre-construction, Construction, Operations
Are there changes in foraging or roosting activities of marine birds in relation to the wind facility?	D	Pre-construction, Operations
Is there nocturnal attraction of marine birds (e.g., to offshore wind-related lighting)?	M	Pre-construction, Construction, Operations
Are macro-scale changes in movement behavior (e.g., macro-avoidance) of marine birds occurring, and if so, at what magnitude and distance from the offshore wind facility does this behavior extend?	M	Pre-construction, Operations
Are meso-scale changes in movement behavior (e.g., meso-avoidance) of marine birds occurring, and if so, at what magnitude and distance from the turbines does this behavior extend?	M	Operations

4.2 Using Site-Specific Data to Inform Regional-Scale Questions

The above questions are relevant to the spatial scale of the individual wind facility. However, site-level research should also contribute to a broader regional understanding of displacement, attraction, and avoidance, and the factors that might contribute to the magnitude of these effects. Many fundamental questions about the effects of OSW on marine birds require data from multiple wind facilities. Understanding the potential for cumulative effects of displacement, for example, requires an understanding of variation in displacement effects in relation to site-specific characteristics and conditions.

Questions such as the following require data from multiple wind facilities, including the reporting of specific OSW project characteristics, and/or require a range of data on populations of interest beyond what can be collected by developers at and around individual wind facilities, and are thus outside the scope of this document:

- How do aspects of OSW areas, such as wind facility size and shape and turbine size and spacing, affect the displacement, attraction, and avoidance behaviors exhibited by marine birds?
- How do these effects vary geographically (in relation to distance to shore, water depth, or other variables)?
- How are displacement, attraction, and avoidance exhibited by marine birds at an OSW influenced by the proximity to, and layout of, other OSW facilities in the region?
- What are the causal mechanisms driving changes in behavior (e.g., changes in prey and oceanographic characteristics)?
- Do displacement, attraction, and avoidance of marine birds at offshore wind developments have population-level effects on fitness via changes in energetics or demography?

For data collected at the individual OSW project scale to be most useful in answering regional-scale questions, as well as informing larger meta-analyses, **studies of individual wind facilities should consistently include key ancillary and covariate data, as well as OSW project data[3], in their analysis and reporting on effects.** Explicitly considering environmental, facility, and individual covariates can also help to inform the interpretation of site-specific results when considered in conjunction with data from other sites. For example, data on number of turbines in a wind facility, distance between turbines, vessel activity, and turbine operational status (e.g., when turbine blades are spinning vs. stationary) can help to inform understanding of whether birds respond differently to wind facilities based on these factors (though some data, such as operational status can be commercially sensitive data, depending on the timescale at which data are summarized). In addition to the ancillary data (age, sex, weather conditions, etc.) discussed above, covariate and site-level data to be consistently reported should include (but not be limited to):

[3] Project data is also available in permitting documentation and should eventually become available via the U.S. Wind Turbine Database (https://eerscmap.usgs.gov/uswtdb/). However, difficulties with accessing such data in the European context, especially for older wind energy projects, suggests the importance of also reporting this type of information alongside environmental monitoring results.

- Location information for the wind facility, including latitude and longitude of the centroid, and distance from shore; and
- Wind facility characteristics, including the number and size of turbines, size of the project footprint, and turbine spacing.

Section 8 provides general data sharing recommendations. Section 10.7 and Appendix C include additional specific details on reporting needs. It is beneficial for the entire industry if data collected at the spatial scale of an individual wind energy facility are also useful at a broader regional scale to inform future monitoring and effects minimization. Regional-scale strategic planning is required to identify priorities, improve coordination, and ensure standardization (Section 12). While this is outside of the scope of this effort, the Regional Wildlife Science Collaborative for Offshore Wind (RWSC; rwsc.org) is working to develop science plans to meet these needs.

5.0 Identifying Focal Taxa

Focal species should inform study design and data collection methods, even for study methods that collect information on multiple species simultaneously (e.g., observational surveys). The choice of focal species for understanding displacement, attraction, and avoidance at site-specific scales will depend on research questions of interest (Section 4), characteristics of the particular wind project(s) and location(s) being investigated, and species-specific risk inferred from existing information (see Appendix C and Lamb et al. 2024 for a summary of findings from existing displacement, attraction, and avoidance studies), along with other considerations. Consultation with federal agencies, as well as coordination with other OSW developers in the region of interest, is important to ensure that selection of focal species at individual projects aligns with regional needs. For observational surveys in particular, information on one or more focal species should be used to inform aspects of survey design, such as spatiotemporal coverage and buffer size, but data should be collected on all species observed. Existing data on these focal species should also be used in power analyses during study design to help ensure that research will adequately detect effects (Section 7). Factors to be considered when choosing focal species include exposure, sensitivity to effects, population sensitivity, and uncertainty in our understanding of responses. Definitions for these terms are described below. These considerations can be implemented in a decision tree (Figure 2) to help select focal taxa for study that will best contribute to a broader understanding of offshore wind effects and inform resource management and other decision making. As explained in Section 4.1, the choice of focal species may inform research questions or vice versa. In addition, the degree to which the answer to the research question for a particular species is being addressed by other researchers and OSW developers, the influence and implications of results, and applicability of results across broader taxa, should be considered. This type of coordination should be facilitated by regional science collaboratives and other mechanisms (Section 12).

We also recognize that species of particular conservation and regulatory interest, such as endangered species, may be considered high priority regardless of the additional considerations and decision tree described below. However, studies of species with low exposure (e.g., due to rarity) are prone to having low statistical power to detect effects. When studying endangered species, extreme care is needed during study design to help ensure adequate sample sizes such that studies will be able to detect effects, should they exist.

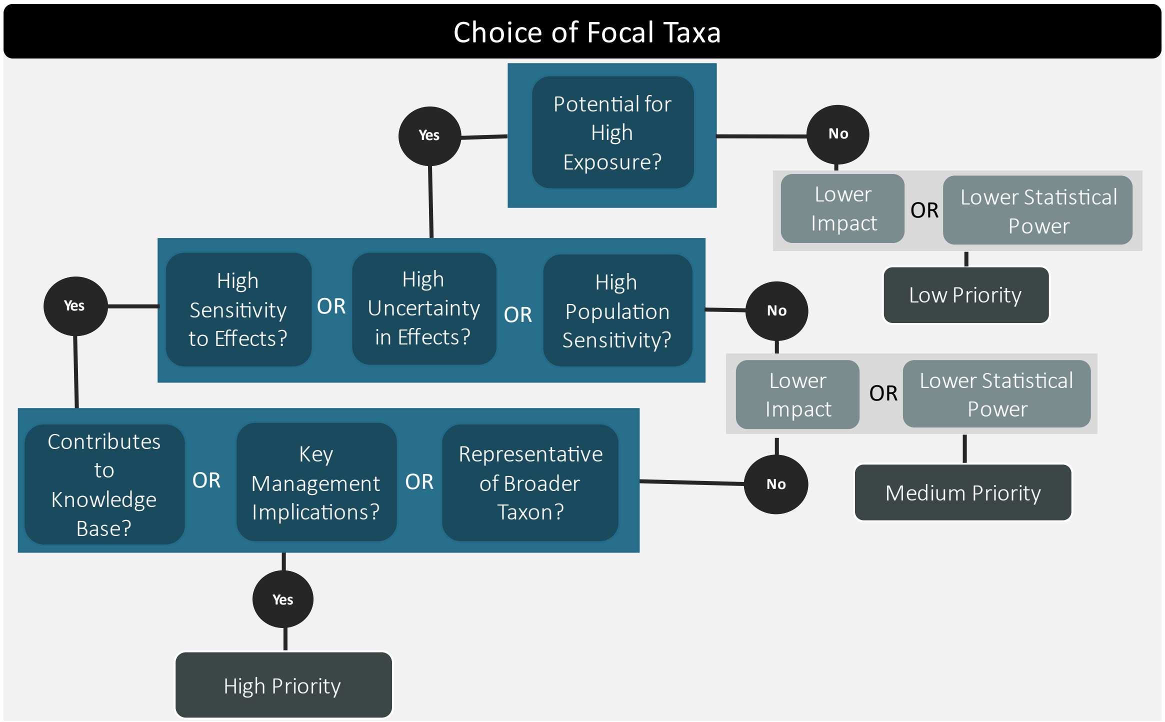

Figure 2. Decision tree to inform the choice of focal species for displacement, attraction, and macro- to meso-scale avoidance studies at offshore wind development sites. Definitions for the terms used in this figure are described below.

5.1 Understanding Exposure

Exposure can be defined as the frequency and duration of contact or co-occurrence between an offshore wind stressor or activity and an environmental receptor (i.e. an individual animal, group, population, or community) that may allow the stressor to act on the receptor in some way (Goodale & Milman 2016). Exposure relates to the abundance, distribution, and behavior of species in the focal geography, which dictate the potential for them to be exposed to offshore wind energy development. In the case of avoidance, displacement, and attraction, the key offshore wind stressor is the presence of offshore wind structures, as well as vessel traffic (Dierschke et al. 2016). Exposure can be assessed in multiple ways but should be informed by existing regional information on the abundance and distribution of species, including modeled seasonal relative abundance of species (Marine-life Data and Analysis Team, or MDAT; Winship et al. 2018), existing survey data for the area of interest from the Northwest Atlantic Seabird Catalog, and available tracking data (such as those archived in Movebank), as well as site-level information collected during the site assessment process and consultation with regional experts. Exposure is a particularly important factor to consider as it is directly related to the statistical power to detect effects.

5.2 Understanding Sensitivity and Uncertainty

After exposure, the sensitivity of a species or taxon to OSW effects (or our lack of understanding as to whether such a sensitivity exists) could be considered as a second tier of decision-making considerations (Figure 2). Sensitivity can be defined as the properties of an organism or system that influence relative susceptibility to a stressor (Goodale & Stenhouse 2016). This can include sensitivity to OSW stressors, as well as population-level sensitivity to perturbation generally, which together dictate species vulnerability.

Population Sensitivity – Population sensitivity can be defined as 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 OSW development could influence the size of the population. Population sensitivity encompasses species-level information, including conservation status, population size, and the proportion of the population present in the region. Conservation status can be defined at a range of scales, including information from the IUCN Red List, federal and/or state regulatory assessments (e.g., under the Endangered Species Act, Migratory Bird Treaty Act, or state environmental protection laws), and nonregulatory assessments (e.g., Species of Greatest Conservation Need, Birds of Conservation Concern, regional conservation status). This could also take into consideration species that are not currently listed under any of these assessments, but show population declines or are suspected to be impacted in a significant manner by other emerging threats. Species with higher population sensitivity are often considered to be a higher conservation priority for understanding effects of anthropogenic activities, including OSW.

Sensitivity to OSW Stressors –Sensitivity to OSW effects includes the expected response of receptors to OSW stressors at the individual/local scale. Effects may occur inside or outside of the lease area and may carry over to other parts of the annual cycle.

Vulnerability **–** Vulnerability combines 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. Existing avian vulnerability frameworks (e.g., Furness et al. 2013, Robinson Wilmott et al. 2013, Kelsey et al. 2018) provide a model for understanding vulnerability as a combination of site-specific exposure to offshore wind stressors (above) and sensitivity to those stressors, including predicted individual response as well as population sensitivity. Understanding of sensitivity to displacement, attraction, and avoidance effects is informed by studies of behavioral changes at existing offshore wind facilities (primarily in Europe), as well as studies focused on disturbance from boat and/or helicopter traffic and on other industries (primarily offshore oil and gas and land-based wind). An understanding of species-level information, such as habitat flexibility based on diet, is also important for predicting sensitivity.

Existing publicly available literature in relation to marine bird response to OSW development is summarized in Appendix C. The species discussed in this summary represent those for which we have the best understanding of potential effects of OSW structures, recognizing that many factors, including wind facility characteristics, location, stage in the annual cycle, and turbine operational status, may introduce variability in these responses (Lamb et al. 2024). As avoidance and attraction represent opposite responses, we should consider both in relation to sensitivity to response (and indeed, some recent work suggests that both avoidance and attraction behaviors may be occurring within the same populations, or even within the same individuals; Peschko et al. 2021, Johnston et al. 2022). In regard to understanding potential disturbance from boat traffic, a vulnerability index was developed for Northwest European seabirds (Fliessbach et al. 2019), and there is additional literature available to inform our understanding of these effects, with some species, like Red-throated Loons, exhibiting a negative response (Schwemmer *et al*. 2011), while other species, like Northern Gannets, may be attracted to vessels from a considerable distance (10+ km; Bodey et al. 2014).

In general, species with higher suspected sensitivity to OSW effects may be higher priorities for understanding those effects, both from a conservation standpoint (if such effects are expected to potentially reach the point of causing population-level impacts) and from the standpoint of having sufficient power to detect change (since a large effect size will generally increase statistical power, all else being equal).

High Uncertainty in Effects – For some species that have been well studied in other geographies in relation to OSW development, we can get a sense of relative sensitivity to displacement, attraction, and avoidance response (recognizing that these responses may still vary with location and a range of other factors). For other species not present in areas for which OSW responses have been examined to date, we may have a more limited understanding of potential effects. However, recent avian vulnerability assessments for the Atlantic and Pacific U.S. (Robinson Willmott et al. 2013, Kelsey et al. 2018) have attempted to predict vulnerability of avian taxa to displacement (as well as collisions) based on factors such as habitat flexibility, drawing heavily from data on related species where available. There may also be other sources of uncertainty in potential response related to stage in the annual cycle (e.g., non-breeding birds may respond differently than during the breeding season). Thus, in addition to high sensitivity, high uncertainty in that sensitivity by taxon or life history stage may warrant additional research.

5.3. Additional Considerations for Selection of Focal Taxa

There are several additional factors that should be considered when selecting a focal species for study (Figure 2). Species or taxa could be considered as potentially higher priority for study if they are representative of broader taxa, contribute to a regional knowledge base, or have key management implications, as discussed below:

Representative of Broader Taxa – There may be a benefit to focusing on species for which findings may be applicable to a broader taxonomic group. This may be particularly important in cases where the species of interest, due to population sensitivity, is rare (leading to low statistical power to detect effects) or difficult to study (e.g., limited methods available). In these cases, it may be beneficial to consider choice of focal species based on the degree to which a species may adequately represent broader taxa, based on similarities in ecological niche, morphology, and behavior. However, umbrella and surrogate species should be approached with caution, as even closely related species may have substantially different responses to disturbance (Caro et al. 2005, Murphy et al. 2011).

Contribute to a Regional Knowledge Base – It is generally valuable to use a strategic lens for selecting focal species, with coordination among OSW developers funding pre- and post-construction studies, particularly in the same geography, as well as others conducting research in the region. While replication of studies across ecological and project gradients (e.g., different turbine sizes, distances to shore, and other site characteristics) can help inform regional-scale research questions (see Section 4.2), studies should meaningfully contribute to our knowledge base around the effects of OSW development on marine birds, which may at times lead to prioritization of less-studied taxa to broaden our base of knowledge. As a coordinating body, the RWSC has a database of ongoing research for which all site-level studies should be contributing; this database, in addition to participation in RWSC bird and bat subcommittee meetings and requests for subcommittee feedback, can help to inform multiple aspects of the study design process.

Key Management Implications – It is beneficial to consider the degree to which the findings of research would influence future decision making. For example, those species for which there would be a clear nexus for adaptive management may be prioritized as focal species. This may be interrelated with population sensitivity, especially in the U.S. regulatory context, as taxa with higher population sensitivity may also be more heavily protected under federal regulation and thus require more potential management actions. Species with high sensitivity or great uncertainty in effects may also be "high leverage" species for informing the siting and adaptive management of future wind energy projects. In addition, this category may also encompass species with significant cultural and/or indigenous value.

6.0 Choosing Appropriate Methodologies

6.1 Selecting Study Methods

The choice of study method(s) for displacement, attraction, and avoidance studies should depend, first and foremost, on the research question of interest (Section 4) and the focal taxon (Section 5). There are several general methods available to answer the research questions outlined in this document, including:

- Observational surveys involve the counting and identification of wildlife present in or above an area of ocean via direct visual observation by surveyors, collected from either a vessel or aircraft moving through the area in a systematic manner. Observations can occur while surveyors are physically present on the observation platform or by reviewing camera footage acquired from the survey platform.
  Specific Methods: digital aerial surveys, including concurrent use of LiDAR, and boat-based surveys, including use of supplemental technology such as laser rangefinders (Largey et al. 2021; Harwood et al. 2018).
- Individual tracking involves the capture of wild, free-living individuals and the attachment of devices that record coarse or fine-scale locational information, and sometimes behavioral information and/or environmental conditions. Depending on the type of device, information is logged and retained on the device or transmitted to receivers on the ground or via satellites. Ancillary data loggers such as wet-dry sensors, time-depth recorders, and altimeters can also be incorporated into tracking efforts to collect ancillary data and inform interpretation of data.
  Specific methods: GPS, satellite telemetry, automated radio telemetry.
- Radar studies involve the use of electronic instruments with a rotating antenna to emit radio waves, which reflect off nearby objects and generate an image of the surroundings. These include marine radar (horizontally or vertically oriented) that are often used in navigation by ships at sea but can also be used to detect animals in the airspace for several kilometers around the radar unit. 3-D radars may use a combination of S-band and X-band horizonal and vertical radars, depending on the model, to provide 3D images of bird flight trajectories over similar ranges as traditional marine radars. Finally, Next Generation Radar, also known as WSR-88D weather surveillance radar, are land-based S-band units operated by National Weather Service designed to detect precipitation in the atmosphere but also regularly detect "bioscatter," or reflectivity of the electromagnetic energy caused by biological entities in the atmosphere, such as birds, bats, and insects. We also briefly consider systems that include integrated radar and cameras (see remote visual imagery, below).
  Specific methods: marine and 3D radar, including integrated radar/camera systems, and weather surveillance radar.
- Behavioral observations consist of recording of a focal animal's behavioral activity and changes in that activity related to features of its environment (e.g., turbines), noted directly by an observer present in the environment, at repeated intervals or within a specific timeframe and/or study

area (see Rothery et al. 2009, Krijgsveld et al. 2011, as examples).
Specific methods: human observers that may use supporting technology such as spotting scopes, cameras/binoculars, and laser rangefinders.

- Remote visual imagery involves the use of technologies to gather information and/or document activity (e.g., presence, flight behavior, flight patterns) without the presence of human observers. For the purposes of this discussion, we consider this category to include photographic, video, thermographic, and infrared cameras placed on offshore wind infrastructure or vessels, as well as imagery retrieved from satellites.
Specific methods: photographic/video cameras, thermographic and infrared cameras, satellite imagery.

We present detailed guidance for conducting observational surveys in this document. There may not be equally detailed guidance available for other study methods noted above; this need has been identified by the RWSC in their science plan and is also suggested as a next step in Section 12 of this document. Several additional study methods besides those listed above have been used at OSW facilities, such as visual aerial surveys and passive acoustic monitoring. These are not suggested methods for the key questions outlined in this document. Visual aerial surveys are unsafe for human observers, cause disturbance of some bird species, and are not feasible to conduct in the same manner pre- and post-construction, since flights need to be conducted within the altitude of the rotor-swept zone of turbines. Passive acoustics typically have limited geographic range and cannot provide reliable estimates of the number of individuals detected in acoustic data. As a result, this technology is more suited to questions focused on the micro scale, including topics such as species presence. Likewise, many cameras are designed to provide micro-scale information on collisions and micro-avoidance, which are outside the scope of this document. However, some systems can also provide meso-scale or even macro-scale information (in the case of satellite imagery), and these systems are thus included in this document.

In some instances, a focal taxon may be selected before a research question, or vice versa. Regardless, once these decisions have been made, it is often necessary to review the available general study methods for the question and taxon of interest and select one or more methods to pursue. General methods to address each research question have been noted in Table 2.

Selection among study methods should be informed by the taxon of interest. These considerations include the following:

- **Taxonomic breadth** – The degree to which the study focuses on an individual species response versus gauging the response of a larger suite of species or the community. Some methods are better designed at collecting information on multiple species/groups simultaneously (e.g., observational surveys), while others target individuals (e.g., tracking).
- **Activity patterns** – Some methods are limited in their ability to collect quality data during particular time periods and conditions. For example, not all methods can collect information on species at night, so diurnal vs. nocturnal exposure/activity of focal taxa is an important consideration in the selection of methods.
- **Scale of expected response** – The spatial extent of expected response to the OSW facility (based on the literature; see Section 5) will inform the degree to which different methods are suitable. For example, behavioral observations generally occur from a fixed platform with limited spatial range, and thus may be unsuitable for species where macroscale response is expected.

- **Activity type** – How birds are likely using the area (e.g., transit versus foraging), as well as the ecology of foraging (primarily in flight, or spending long periods on the water's surface), will also influence the choice of study methods. Radar, for example, cannot be used to monitor birds at or near sea level (due to wave clutter), and therefore would be a poor choice for species that spend a significant amount of time on the surface.
- **Body size** – Particular methods may be better suited for smaller versus larger-bodied species. Some methods may have limitations relating to the ability to detect or identify small-bodied species at the desired distance away from the observation platform. Body size also affects the capacity of tracking methods to answer some types of questions, due to limitations on what types of tags can be deployed.

These considerations should be used to further narrow the suite of potential methods for the research question of interest (Figure 3) to identify one or more general methods to pursue.

Table 2. *Potential pre- and post-construction study methods for examining key displacement, attraction, and macro/meso-scale avoidance questions for marine birds at offshore wind facilities. Additional details on each general type of study method are described below. Definitions of terms, including avoidance and displacement, are included in Section 1.1 and in the document glossary (Appendix B).*

Research Question	Potential Methods
Are changes in distributions and habitat use (e.g., displacement/attraction) of marine birds occurring, and if so, what is the magnitude and distance from the offshore wind facility at which they occur?	• Observational Surveys • Individual Tracking
Does the occurrence, magnitude, and distance of habitat change vary temporally (e.g., does habituation occur)?	• Observational Surveys • Individual Tracking
Are there changes in foraging or roosting activities of marine birds in relation to the wind facility?	• Observational Surveys • Individual Tracking • Behavioral Observations
Is there nocturnal attraction of marine birds (e.g., to offshore wind-related lighting)?	• Remote Visual Imagery • Individual Tracking • Radar
Are macro-scale changes in movement behavior (e.g., macro-avoidance) of marine birds occurring, and if so, at what magnitude and distance from the offshore wind facility does this behavior extend?	• Individual Tracking • Remote Visual Imagery • Radar
Are meso-scale changes in movement behavior (e.g., meso-avoidance) of marine birds occurring, and if so, at what magnitude and distance from the turbines does this behavior extend?	• Individual Tracking • Behavioral Observations • Radar • Remote Visual Imagery

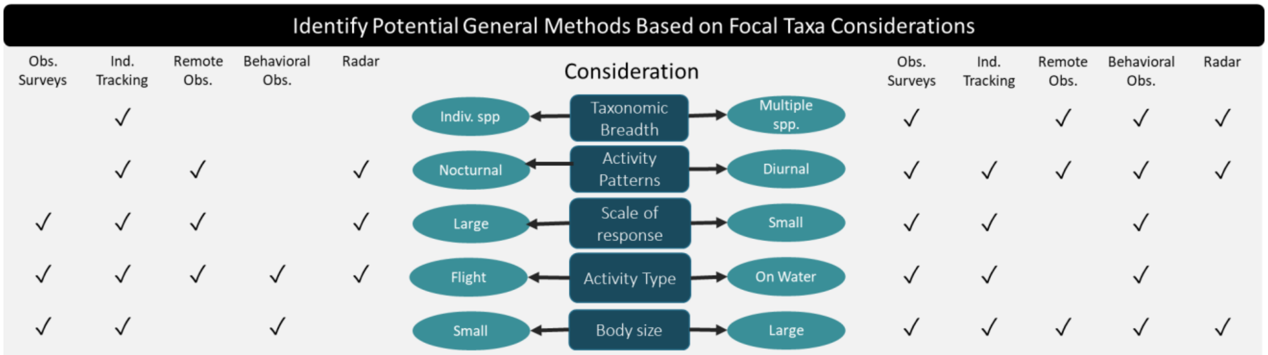

Figure 3. Taxa-related considerations that inform the selection of general study methods (in combination with the choice of research question, as described in Table 2.

In addition to the influence of research question (Table 2) and considerations based on focal taxa (Section 5; Figure 3), the selection of overall study method(s) may also be influenced by the following:

- Collection of Ancillary/Covariate Data – Some methods lend themselves to collection of specific types of ancillary data, such as physiological data (e.g., tracking) or prey sampling (e.g., observational surveys). Ancillary data collection should be considered depending upon the specific taxa, research hypotheses of interest, and the degree to which site-level data could contribute to larger-scale research questions.
- Sampling Bias – There are multiple aspects of sampling bias that should be considered when choosing among methods. These relate to:
    - Detectability (e.g., differences in the ability to detect species based on platform, environmental/weather conditions, or other factors),
    - Availability (e.g., the degree to which birds are available to be sampled), which can relate to the speed of information collection, knowledge of behavior, and other considerations,
    - Ease of species identification and associated limitations, and
    - Representativeness (e.g., the degree to which the sample is representative of the broader population) which relates to sample size/statistical power concerns, the degree to which data are collected at the group level (e.g., surveys) or individual level (e.g., tracking), and whether the study method allows for information to be collected on species absence as well as presence.
- Spatial and Temporal Scale – Some methods collect "snapshots" of data in time, while others collect longitudinal information, and the preferred option will vary depending upon the question of interest. Likewise, methods vary in their spatial coverage and locational accuracy depending on design, platform availability, and other factors.
- Environmental Conditions – Some methods may be limited by weather or other environmental conditions in ways that may hinder their ability to answer particular questions. For example, surveys are restricted to lower sea states, compared with tracking which collects information regardless of conditions.
- Logistics and Feasibility – There are many logistical challenges to be considered in the choice of method for offshore study of marine birds. These include, but are not limited to, platform availability (which is important for methods such as radar, behavioral observations, and some types of remote imagery), deployment of data collection devices (tracking, radar, camera

systems), feasibility of data collection at different stages of the annual cycle (for example, there may be differences in accessibility or capture feasibility for breeding vs. nonbreeding periods), and logistics related to information transfer (applicable to all methods to greater or lesser degrees). Additional constraints include cost and health and safety considerations, which will likely be dependent upon individual study designs and those conducting the research. Given this variation, these are difficult to categorize at this broad methodological level but are touched on briefly for various methods in Section 6.2.

- **Invasiveness** – As always with wildlife research, it is recommended that the least invasive option be used that is available to answer the study question (e.g., implanted transmitters may be needed to answer some research questions whereas less invasive tagging techniques such as bands may be sufficient to answer others).

These considerations are discussed below (Table 3) for each of the five general methods categories (observational surveys, individual tracking, radar, behavioral observations, and remote visual imagery). Strengths and limitations of specific methods (e.g., GPS tracking) are further discussed in Section 6.2.

Table 3. *Key considerations when choosing among the five major categories of study methods for examining displacement, attraction, and macro- and meso-scale avoidance of marine birds at offshore wind energy development projects. Considerations and methods categories are described in text (this section). Additional strengths and limitations of specific methods can be found in Section 6.2*.

Methods Considerations	Observational Surveys	Individual Tracking	Radar	Behavioral Observations	Remote Visual Imagery
Collection of Ancillary/ Covariate Data	-Can record behavioral information (particularly boat surveys) and flight heights -Can collect environmental data including SST, salinity, and prey data simultaneously (boat surveys)	-Can provide detailed information on movement behavior -Must infer behavior from movement patterns (unless ancillary data loggers are used) -Can collect information on body condition and diet (e.g., morphometrics, tissue samples, feces) at time of capture and/or recapture -Can integrate sensor types (e.g., temperature, pressure, accelerometer, magnetometer, energetics)	-Can provide flight behavior data such as flight height and speed (depending on the radar unit)	-Can record behavioral information such as foraging, roosting, interactions among individuals -May allow for ad-hoc collection of diet information (e.g., feces, pellets)	-Some types of systems may record temperature -Satellite imagery can also provide environmental covariate data, though potentially at different spatiotemporal resolutions than animal observations
Sampling Bias	-Difficulty in detecting small/dark species and distinguishing among visually similar species -Availability bias for species that dive -Provides both presence and absence information	-Limitations regarding capture and deployment feasibility for some species, age/sex classes, etc. (see below) -Typically small sample sizes and few capture locations, which may affect representativeness of sample -Data points represent only presence information.	-No species/taxa identification (unless paired with another method) -Target discrimination can be difficult -Detectability varies with body size and wavelength, as well as weather and interference from other objects -Cannot sample animals at/near sea level	-Observation range is limited by multiple factors including optic quality, vantage point location, height above water, weather -Difficult to observe avoidance behaviors at multiple spatial scales from the same position (e.g., would require positioning outside of the wind facility to observe macro-avoidance)	-Taxonomic classification to species may be difficult, with a tradeoff between field of view and image resolution, as well as poor resolution for most nighttime camera options -Difficulty in detecting small/dark species and distinguishing among visually similar species -Typically small sampling volume (for camera systems)

Methods Considerations	Observational Surveys	Individual Tracking	Radar	Behavioral Observations	Remote Visual Imagery
Spatial and Temporal Coverage	-Provides a snapshot of information during daytime only -Spatial coverage dictated by survey design -Post-construction coverage may be affected by turbine locations/height, depending on survey method	-Provides longitudinal data (repeated observations over time) -Spatial coverage may be unpredictable -Necessary temporal resolution will be question-dependent (e.g., attraction to lighting requires finer resolution than displacement) and may not be possible for all taxa or questions of interest	-Spatial coverage limited to range around platform locations but good coverage at the scale of <10 km (for marine radar; Gauthreaux & Belser 2003) and dozens of km for weather radar -Can record continuously regardless of time of day -Not suitable for micro-scale monitoring of movements due to interference from turbines	-Provides a snapshot of information during daytime only -Spatial coverage limited by number of observers and platform locations	-Spatial coverage is limited by platform locations and tradeoff with image resolution (for camera systems) -High temporal coverage may be possible
Environmental Conditions	-Limited to good weather conditions -Glare, sea state, and observer visual acuity impact accuracy, though variable	-Generally not affected by environmental conditions	-Clutter and backscatter from the water surface, turbines, and other major landscape features -Some models can operate in bad weather, but performance decreases with rain/snowfall	-Limited to good weather conditions	-Can monitor across a range of conditions in some cases, but typically limited to clear weather conditions -Cloud cover blocks satellite views
Logistics and Feasibility	-Appropriate survey platform for wildlife viewing that meets industry health and safety standards	-Limitations regarding tag weight and body size and capture feasibility (e.g., by age class, sex, timing in annual cycle) -Difficulty in capture/recapture during particular times of year/locations -Can be challenging to predict whether tagged individuals will use area of interest - Many species do not retain tags across multiple years as they are lost during molt. So, it may be difficult to obtain data from the full annual cycle	-Requires stable platform free from obstruction and may require gyro-stabilization, as well as power supply (for marine and 3D radars) -Some systems lack remote data transfer -Generally high level of post-processing	-Access to platforms in or near the wind facility may be challenging due to health and safety regulations, operator guidelines, access limitations, etc.	-Requires stable platform and power supply (for camera systems) -Some systems lack remote data transfer -Generally high level of post-processing
Invasiveness	-Some disturbance from boats; typically, little or none from digital aerial surveys so long as flight heights >~500m are maintained (see Section 10.4)	-Handling of birds during capture, potential disturbance at breeding sites -Potential for tag effects	-Non-invasive for animals	-Non-invasive for animals	-Non-invasive for animals

6.2 Considerations for Specific Methods

Once the general method(s) has been selected (e.g., individual tracking), specific methods within those broad categories must be considered for research (e.g., GPS vs. automated radio telemetry). This section details additional strengths, limitations, and additional considerations for each specific method. Cost and health and safety are highly dependent upon individual study designs and must be addressed on a per-project basis; as such, are not explicitly addressed in the below tables as a strength or limitation but noted in some cases in the "other considerations" sections. For examples of studies using each of these study methods, see Appendix C.

6.2.1 Observational Surveys

Strengths and limitations of digital aerial and boat-based observational surveys are detailed below. As mentioned in Section 6.1, we do not recommend the use of visual aerial surveys.

<table>
<tr><th colspan="2">BOAT-BASED SURVEYS</th></tr>
<tr><td>Strengths:</td><td>Limitations:</td></tr>
<tr><td>• Longer survey window. Better than aerial surveys at detecting episodic events (such as migration flights) that require a longer survey period.
• Covariate data. Allow collection of contemporaneous environmental covariate data (e.g., water sampling, proxies for fish abundance, real-time bathymetric data, species composition of forage fish schools, eDNA, multibeam side scan sonar, etc.) to accompany avian observations.
• Other local data. Can collect local-scale data such as foraging behavior, foraging hotspots, etc.
• Image collection. Produce an archive of data, assuming a long-lens camera is used (requires an extra observer).
• Species identification. Observers on boats may be able to detect and identify smaller species than aerial surveys. Diving birds are assumed to be more likely detected than via aerial surveys due to slower speed.
• Speed of accessing data. Observational data from vessels is generally available more quickly than digital aerial survey results.
• Strip Width. For highly detectable species, effective survey strip width centered on track line is larger from a boat than from a plane.
• Assessment of biases. Multiple observers easily incorporated to include an assessment of detection biases.</td><td>• Double counting. The longer time scale of the surveys may lead to higher instances of double-counting individuals, which violates analytical assumptions.
• Flight height. Assessments of bird flight height from shipboard observers can be highly inaccurate as well as uncertain. Can use a laser rangefinder to help improve accuracy but requires a dedicated extra observer.
• Weather-dependent. Poor conditions lead to more cancellations than digital aerial surveys, which can lead to increased permitting/consenting risk if projects require a certain number of surveys in specific time periods.
• Platform effects. More likely to cause platform effects on animal movements (including both avoidance and attraction) than aerial surveys, especially if a fishing boat is used as the survey platform.
• Lack of QA/QC post-survey. Cannot be validated after the event to assess reliability of counts and species identified (though species ID can be verified for a subset of animals if long-lens camera is used).
• Avoiding hazards. May be unable to follow same survey design pre- and post-construction.
• Coverage. Effective strip width for smaller/darker species and species on the water can be quite narrow and varies with weather conditions (e.g., sea state).</td></tr>
<tr><td colspan="2">Other Considerations: Not as economical as digital aerial surveys for covering large areas located far offshore. More man-hours at sea compared with digital aerial surveys.</td></tr>
</table>

<table>
<tr><th colspan="2">DIGITAL AERIAL SURVEYS</th></tr>
<tr><th>Strengths:</th><th>Limitations:</th></tr>
<tr><td>Covering large areas far offshore. Survey planes fly higher and faster than visual aerial surveys and are much faster than boat surveys, thus particularly well suited for surveying larger areas located farther offshore.
Survey Speed. The rapid survey flight speed captures a quick snapshot of bird distributions, reducing any risk of double counting.
Survey Altitude. The high flight altitude reduces disturbance to birds at the surface.
Flight height data. Estimated flight heights can be calculated, though there is uncertainty around estimates depending on method, and may require additional data collection (e.g., use of LiDAR).
Image collection. An archive of data is produced for future reference, allowing robust quality assurance and quality control (QA/QC) procedures.
Location accuracy. Geospatial accuracy of individuals captured in the data as compared with estimated from human-observer estimates of distance and angle.
Avoiding hazards. Digital aerial surveys are typically conducted at a high enough altitude to be flown safely over turbines (though this may require refinements of cameras and camera configurations as turbines get taller).</td><td>Availability and behavior. Due to the rapid survey speed, the availability of diving birds to be detected may be lower, and the opportunity to gather behavioral data is reduced compared to boat-based surveys.
Substantial data review time. Substantial imagery review time is required to locate and identify animals. There have been several attempts to develop automated detection and identification algorithms, but there has been limited success for most species to date due to challenges associated with repeatability across surveys. Deep learning neural networks, for example, while effective for a single survey, have been less successfully applied across surveys and conditions. USFWS and BOEM are currently exploring digital approaches and deep learning algorithms.</td></tr>
<tr><td colspan="2">Other Considerations: Not as economical as boat surveys for covering smaller areas closer to shore. Fewer man-hours at sea compared with boat-based surveys. For safety reasons, need to fly all surveys at >152 m (500 ft) above highest point of planned or existing offshore structures.</td></tr>
</table>

6.2.2 Individual Tracking

Tracking methods have varying accuracy and precision in their location estimates. In this context, **precision** describes the dispersion of calculated positions if the device is stationary (e.g., how much uncertainty there is in the estimated location of the tagged animal), while **accuracy** is a measure of conformity between estimated and true positions (e.g., how close the estimated position is to the true position of the animal; Garrido-Carretero et al. 2023). Key tracking methods include automated radio telemetry, GPS telemetry, and satellite telemetry. Archival geolocators are also used in avian distribution studies; they are not recommended as the primary tracking technology for displacement, attraction, and avoidance studies of marine birds due to their lower spatial accuracy and precision, but they can provide auxiliary behavioral information when used in conjunction with other tag types (e.g., wet-dry sensor can inform estimates of dive activity). There are a variety of movement modeling approaches that can be used to estimate locations and habitat use areas from tracking data, as well as to differentiate behaviors (e.g., foraging vs. migrating; Baldwin et al. 2018, Gulka et al. 2023, Green et al. 2023).

GPS TELEMETRY	
Strengths:	Limitations:
• **Flexibility**. Wide variety of tags and associated capabilities (i.e., power management, data collection regimes) available. In some cases, remote download either to a base station or via GSM network is available such that data can be transferred remotely. • **Spatial coverage**. Can provide unbiased location information. • **Flight height**. Can provide good-quality flight height data, although the accuracy of altitude estimates varies and can impact tag weight and battery life. Uncertainty in estimates also relates to the temporal resolution of GPS fixes (Schaub et al 2023). Add-on pressure sensor can improve altitude estimates but requires pressure measurements for calibration and adds to tag weight. • **Flight speeds.** If sampling is frequent enough, can estimate or instantaneously measure (e.g., Fijn and Gyemisi 2018) flight speeds. • **Other behavior**. Can often differentiate between general behavior types (e.g., flying vs roosting) based on movement patterns, and can refine estimates with addition of ancillary data (e.g., from TDRs or wet-dry sensors). • **Lower location error than satellite telemetry.** Generally higher precision and accuracy than satellite and radio telemetry, generally <25m (Acacio et al. 2022, Lui et al. 2018), allowing for fine-scale estimation of movement and habitat use. Accuracy and precision increase with fix rate (Acacio et al. 2022).	• **Weight.** Many GPS units are heavy enough that they cannot be safely carried by smaller marine bird species. • **Recapture**. While larger tags do not require the recapture of the tagged individual to access data, smaller tags either do, or require remote download via a nearby base station, both of which limit the tags' utility in the non-breeding season. Smaller GPS units with remote download capabilities are currently in development but are still limited in what species can carry them and/or can only log data for a limited number of point locations. • **Temporal coverage**. Due to tag attachment limitations, may be difficult to get data from a full annual cycle or across multiple years. • **Tradeoffs between resolution of location information and auxiliary data and battery life**. The finer the resolution of information collected, the greater the required battery power. Some tags have solar panels allowing for additional data collection, but many are limited in the total number of locations tags can collect. • **Sample size**. Cost per tag may limit sample sizes.
Other Considerations: More expensive per tag than automated radio telemetry. The use of GSM cell network for data transfer requires that data transmission costs for the life of the tags need to be budgeted for during project development.	

AUTOMATED RADIO TELEMETRY	
Strengths:	Limitations:
• **Weight**. Automated radio transmitters are one of the only options for offshore tracking of small-bodied species. • **Sample sizes**. Automated radio transmitters are relatively inexpensive as compared to other tag types, allowing for large sample sizes. • **Collaborative network**. The Motus Wildlife Tracking System is centralized to share data among users, and guidance on the offshore deployment of receiver stations exists (Loring et al. 2023a).	• **Spatial coverage**. Limited by the network of receiving towers. Expansion of telemetry stations on offshore wind energy infrastructure (e.g., turbines, buoys) would help improve offshore coverage and could allow for development of a regional-scale monitoring network in the offshore environment. • **Temporal coverage**. Due to tag attachment limitations, may be difficult to get data from a full annual cycle or across multiple years. • **Three-dimensional location estimation**. Tags do not provide actual location estimates, though modeling efforts via triangulation of detections from multiple antennas/receivers is ongoing (Loring et al. 2023b). More precise estimates may require integration with pressure sensors or accelerometers. • **Frequency**. Two different radio frequencies are used and not all stations can detect both. • **Logistics/safety restrictions**. Gaining access to offshore wind energy infrastructure for station deployment and maintenance is challenging due to cost, safety, and access limitations.
Other Considerations: Monthly data fees must be paid by owners of receiving stations if the stations are equipped with remote connectivity. Tags are relatively inexpensive compared to other telemetry approaches (though this does not include the cost of receiving stations).	

SATELLITE TELEMETRY	
Strengths:	Limitations:
• **No recapture**. Tagged individuals do not have to be recaptured to access data, as data are transferred in real-time via the Argos system. • **Flexibility**. Wide variety of tags and associated capabilities. • **Spatial coverage**. Can provide unbiased location information at fair spatial resolutions. • **Flight speed and behavior**. If sampling is frequent enough, can estimate flight speeds and/or differentiate between general behavior types (e.g., flying vs roosting) based on movement patterns.	• **Tag size**. Satellite tags require a battery source and are therefore larger and heavier than other tag types, so limited to large-bodied species, and may require surgical implantation in some species. • **Temporal coverage**. Due to tag attachment limitations, may be difficult to get data from a full annual cycle or across multiple years. • **Increased location error compared to GPS telemetry**. Spatial accuracy and precision not suitable to investigate at finer scale than macro-avoidance. Error varies depending on number of satellites involved among other factors, but generally have a precision of >250 m at best (range of field tests: 500m-15 km; Boyd and Brightsmith 2013, Irvine et al. 2020). • **Tradeoffs between resolution of location information and auxiliary data and battery life**. The finer the temporal resolution of information collected, the greater the required battery power. Some tags have solar panels allowing for additional data collection, but many are limited in the total number of locations tags can collect.
Other Considerations: More expensive per tag than automated radio telemetry. The use of satellite telemetry services (such as the Argos system) requires that data transmission costs for the life of the tags need to be budgeted for during project development.	

6.2.3 Radar

There are multiple types of radar that can be used in studies of marine birds at OSW facilities (see review in Nicholls et al. 2022 for specific technologies). In general, these include (1) marine (surveillance) radar, typically used by vessels for marine navigation that can also be used to map the trajectories of individuals or flocks of birds, (2) three-dimensional (3D) radar systems, which generally integrate multiple marine radar units in horizontal and vertical planes, and (3) weather surveillance radar systems that can assess and map biomass in the atmosphere. Generally, radar used to monitor birds must use either X-band (3 cm) or S-band (10 cm) wavelengths to detect objects in the atmosphere; the different wavelengths affect the radar's ability to detect different size objects (e.g., there is a greater chance of missing objects that are smaller than the radar's wavelength) as well as affecting sensitivity to clutter (e.g., precipitation and other moisture in the atmosphere). One of the key limitations of radar systems is the inability to identify species; as such, integrating radar with use of visual observers (Skov et al. 2018) or camera systems (which combine a marine radar or 3D radar unit with a camera system to inform species identifications) are increasingly being used at offshore wind facilities (see Tjørnløv et al. 2023 for example of integrated radar/camera system). Due to generally similar strengths and limitations, marine and 3D radars are discussed jointly below.

<table>
<tr><th colspan="2">MARINE AND 3D RADAR</th></tr>
<tr><td>Strengths:</td><td>Limitations:</td></tr>
<tr><td>

Coverage. Relatively large-scale coverage as compared to some other study methods (multiple km).
Movement data. Can provide data on passage rates, flight speed, and flight direction, as well as macro- to meso-avoidance (e.g., Leemans et al. 2022).
Altitude data. Good altitudinal distribution data if a vertical unit or 3D radar is used.
Effective in low visibility. Can monitor avian activity during hours of darkness, as well as in some periods of low visibility (e.g., light mist, fog), so close to 24-hr data collection is possible.
Effective at lower altitudes. Can survey lower altitudes than weather radar.

</td><td>

Coverage. Lower spatial coverage compared to weather surveillance radar (generally <10 km).
Species identification. Cannot provide species identification or taxa-level identification without addition of supplemental technology or visual observers.
Appropriate platform. Requires a stable platform, free of obstructions, for detector deployment, and may require gyro stabilization offshore, which can be expensive.
Only suitable for studying birds in flight. Susceptible to clutter from water, turbines, and other landscape features that prevent detection of birds, including birds at or near the water's surface.
Weather. Limited detection during rain; more clutter issues in high seas.
Abundance estimation. Target discrimination can be difficult (sometimes cannot differentiate between individual birds and flocks of small birds).
Lack of remote data download. Many systems lack the ability to send data remotely, meaning issues may go a long time without being noticed. Additionally, accessing the system for manual data download is expensive and potentially dangerous.
Weatherization. Challenges with maintaining equipment in offshore environment.

Logistics/safety restrictions. Gaining access to platforms for device deployment and maintenance in or near the wind facility can be challenging due to cost, safety, operator guidelines, access, etc.
</td></tr>
<tr><td colspan="2">Other Considerations: Systems can be expensive to deploy. These radars can be integrated with camera systems, which are discussed in Section 6.2.4, below.</td></tr>
</table>

WEATHER SURVEILLANCE RADAR	
Strengths:	Limitations:
• **Coverage**. Large-scale coverage. • **Flight height data**. Can provide flight height data within the detection cone of the radar. • **More effective in precipitation**. Performs better than marine radar in poor weather conditions.	• **Spatial coverage**. Limited by existing network of weather radars and therefore may not overlap with some offshore study areas. Additionally, detection range increases in altitude with distance from the radar, meaning that the monitored airspace at many offshore wind lease areas is above rotor-swept height. • **Target discrimination**. Target discrimination is generally not possible, so radar provides a measure of biomass in the airspace rather than allowing tracking of individual birds or flocks.
Other Considerations: Data are collected by the federal government and can be accessed without an up-front cost.	

6.2.4 Behavioral and Remote Visual Imagery

Behavioral observations from fixed platforms and remote visual imagery, while different methods, have similar limitations and therefore have been combined for the purposes of comparing strengths and limitations. Remote visual imagery methods include photography/video, thermographic, and satellite imagery.

OBSERVERS ON PLATFORMS	
Strengths:	Limitations:
• **Availability, affordability, portability**. The use of optics (binoculars, spotting-scopes) allows for a relatively cheap, site-specific, and fast means to collect fine-scale data. • **Fine-scale behavior/movement data**. Useful for observing behaviors such as foraging, roosting, and inter- and intra-specific interactions within OSW project footprints. In certain cases, may allow for ad-hoc collection of diet data, such as pellets/feces present on platforms. • **Good species identification**.	• **Limited range**. Observation range is limited by factors including optic quality, weather, and height above water. Unless positioned on the outside edge of the OSW facility, it can be hard to observe avoidance behaviors. • **Weather-dependent**. Poor conditions lead to cancellations, which can lead to increased permitting/consenting risk if projects require a certain effort in specific time periods. • **Logistics/safety restrictions**. Gaining access to observation platforms in or near the wind facility can be challenging due to cost, safety, operator guidelines, access, etc.
Other Considerations: Possible health and safety concerns for human observers on offshore platforms.	

SATELLITE IMAGERY	
Strengths:	Limitations:
• **Detection**. Used to detect whales, and resolution sufficient to detect larger birds on the water and in aggregations in staging areas.	• **Species Identification**. Resolution not adequate for identifying many species. Limited utility for smaller, darker species with inferior detectability. • **Substantial data review time**. Possible high level of post-processing of datasets. • **Weather condition limitations**. Not usable in low visibility conditions with cloud cover.
Other Considerations: Government agencies can utilize the WorldView-3 and -4 platforms at no cost. Does not require man-hours offshore.	

VISUAL PHOTOGRAPHY / VIDEO	
Strengths:	Limitations:
• **Fine-scale monitoring**. Useful for examining meso-scale interactions with turbines as well as providing flight behavior data (i.e., flight patterns, flight height). • **Collision detection**. Not relevant to the scope of this document, but one of the only available technologies that can be deployed long term to detect micro-avoidance behaviors and collisions with turbine blades. • **Species identification**. Provides detailed imagery of individual birds.	• **Logistics/platform restrictions**. Photo/video systems require a stable platform and power source for device deployment. • **Tradeoff between field of view and image resolution**. Species identification can be difficult for smaller birds farther from the camera; to achieve better resolution, the field of view must become so narrow that only a small fraction of airspace is monitored, causing low sample sizes. • **Lack of remote data download**. Many systems lack the ability to send data remotely, meaning issues may go a long time without being noticed. Additionally, accessing the system for manual data download is expensive and potentially dangerous. • **Substantial data review time**. Possible high level of post-processing of datasets. • **Weatherization**. Challenges with maintaining equipment in offshore environment. • **Weather condition dependent**. Challenges in low-visibility conditions. • **Logistics/safety restrictions**. Gaining access to wind facility platforms for device deployment and maintenance can be challenging due to cost, safety, operator guidelines, access, etc.
Other Considerations: These systems can be integrated with marine and 3D radar units, which are discussed in Section 6.2.3, above. Minimal man-hours offshore as compared with observers on platforms.	

THERMOGRAPHIC PHOTGRAPHY/VIDEO	
Strengths:	Limitations:
• **Effective in low visibility**. Can monitor avian activity during periods of low visibility/complete darkness. • **Collision detection**. Not relevant to the scope of this document, but one of the only available technologies that can be deployed long term to detect micro-avoidance and collisions with turbine blades.	• **Limited range**. Thermal imaging cameras typically have a short range, limiting effectiveness. • **Species identification**. Lack of clear imaging/ color as well as poorer resolution than visual camera systems, making species identification difficult. • **Logistics/platform restrictions**. Requires a stable platform and power source for device deployment. • **Lack of remote data download**. Many systems lack the ability to send data remotely, meaning issues may go a long time without being noticed. Additionally, accessing the system for manual data download is expensive and potentially dangerous. • **Substantial data review time**. Possible high level of post-processing of datasets. • **Weatherization**. Challenges with maintaining equipment in offshore environment. • **Weather condition limitations**. Challenges in low visibility conditions. • **Logistics/safety restrictions**. Gaining access to wind facility platforms for device deployment and maintenance can be challenging due to cost, safety, operator guidelines, access, etc.
Other Considerations: Integrated photographic and thermographic systems can help to address the respective limitations of both types of systems. These systems can also be integrated with marine and 3D radar units, which are discussed in Section 6.2.3, above. Minimal man-hours offshore as compared with observers on platforms.	

6.3 Summary: Choosing Appropriate Methods

The above process of selecting a research question, focal taxon or taxa, general study method, and specific study method is summarized in Figure 4. Aspects of Figure 4 may be cross-walked to relevant portions of Sections 4-7 of this guidance document.

Additional discussion of study design choices for examining the key research questions relating to displacement, attraction, and avoidance are examined below specifically for observational surveys. This includes recommendations on study protocols, sampling design, and effect quantification considerations where appropriate. We know of no similar guidance for using the other general study methods (tracking, radar, behavioral observations, and remote visual imagery) to assess OSW effects on marine birds. However, several recent reviews (Dierschke et al. 2016, Cook et al. 2018, Largey et al. 2021) provide guidance on appropriate study methods and may be useful references. Additionally, many of the below recommendations on data consistency, reporting, and data transparency are broadly applicable to all study methods discussed in this guidance.

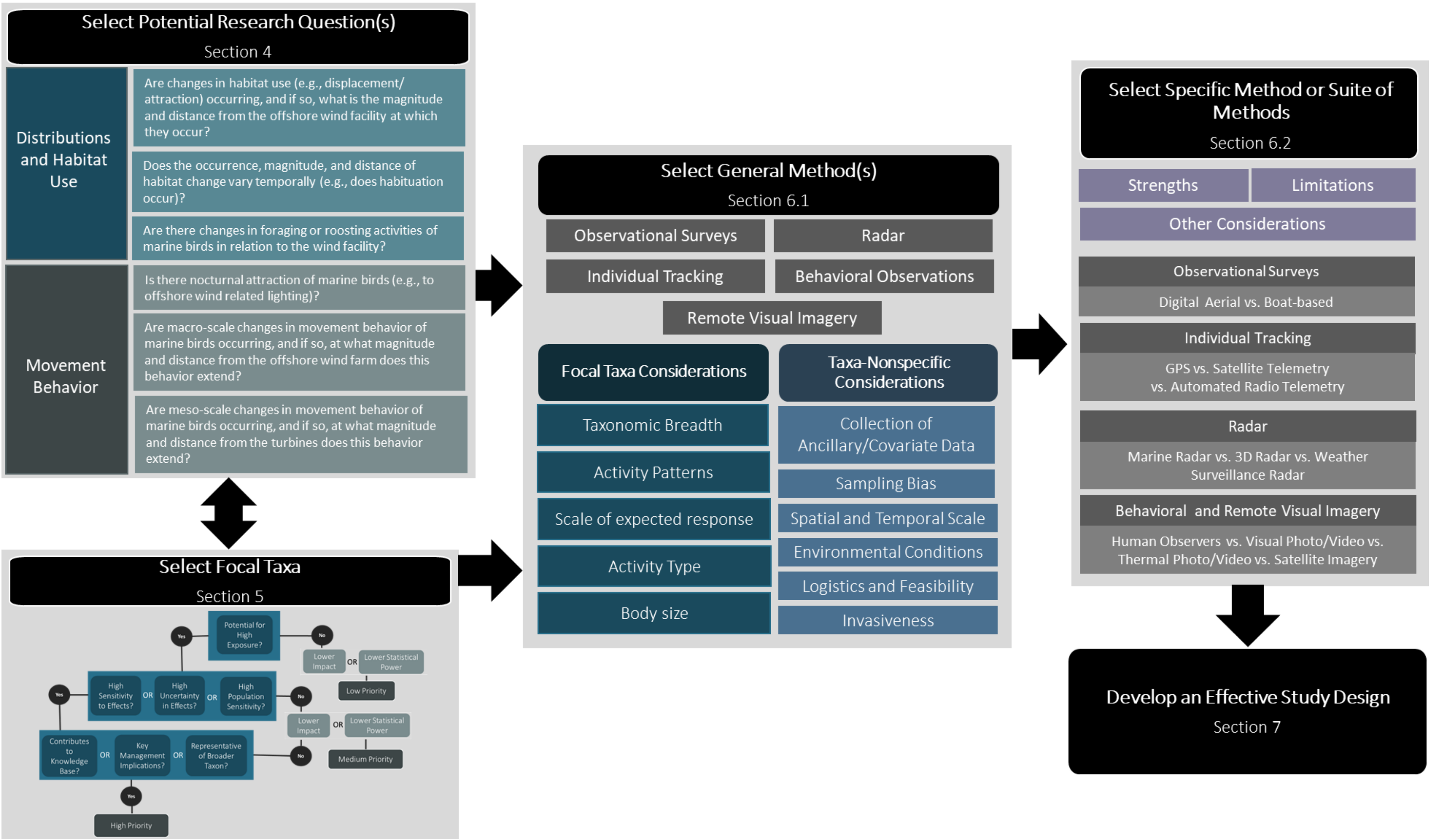

Figure 4. *Detailed decision tree that walks through the process of selecting a research question, focal taxa, and study method. Additional details are provided in Sections 4.0-6.2, above.*

7.0 Developing an Effective Study Design

Once research questions, focal taxa, and methods have been identified, further study design choices should focus strongly on maximizing statistical power to answer the study questions. **A study plan should be developed for all pre- and post-construction monitoring of marine birds that clearly articulates: (1) the study objectives, research questions, focal taxa, and testable hypotheses, (2) a study design, including data collection methods, sample sizes, and analytical approaches, informed by power analyses, and (3) data sharing and coordination plans**. There are existing regional resources that provide high-level recommendations for study plan development (Regional Synthesis Workgroup 2023, ROSA 2021, Mackenzie et al. 2013), and further relevant guidance may become available through RWSC and other relevant efforts in the coming years. **Study plans should be developed and assessed in consultation with subject matter experts (building on existing efforts where possible) and in coordination with other OSW developers conducting similar monitoring in the region of interest (see Section 12 for further recommendations on coordination of research activities). A rubric for assessing study plans can be found in Appendix D.**

These recommendations are intended to apply broadly across research questions identified in Section 4, with more detailed recommendations specific to observational surveys in Section 10.

7.1 Study Objectives

A study plan should be developed that clearly articulates the objectives and intended outcomes, including selection of clear research questions (see Section 4), focal taxa (see Section 5) and identification of how resulting knowledge will improve our understanding and decision-making. Testable hypotheses should be developed based on existing conceptual frameworks of potential effects from OSW development on marine birds (see NYSERDA 2020, Williams et al. 2024), and include supporting documentation from published literature and reports (see Appendix C).

7.2 Study Design

7.2.1 Statistical Power and Effect Size

We recommend that the study design process should (1) evaluate whether expected data types and sample sizes are sufficient to detect a reasonable level of observable effect, and (2) ensure that planned data collection can most effectively address the articulated research questions and/or hypotheses (Regional Synthesis Workgroup 2023). While aspects of study design should be reassessed throughout the life of a study, effectiveness of a proposed study design (including the proposed sample sizes) should be evaluated during planning using the metric of statistical power, which can estimate the probability of detecting an expected effect at a particular significance level. Maslen et al. (2023) outlines the main steps of a power analysis:

1) *Specify analytical approaches and testing procedures*. Analytical approaches should capture key properties of the data that are expected to be collected, including sample sizes (e.g., number of observations) based on best available information from the location of interest (e.g., site assessment data), or at minimum from the literature. Statistical testing procedures should be based on questions, hypotheses and data.
2) *Decide on a measure and value of effect size that is ecologically meaningful*. The choice of metric for effect size should be informed by the specific study question and the ecological system or population of interest (Osenberg et al. 1997). In many types of power analyses,

effect sizes must also be selected (i.e., the expected percent decrease in density within an OSW project footprint following construction of the facility). We recommend selecting a range of reasonable effect sizes from existing literature, to assess the influence of this value on statistical power. Using existing data to the degree possible, the choice of effect size value should take into consideration taxonomy, sources of variability including temporal (e.g., seasonal, annual, and longer-term fluctuations) and spatial variability (ROSA 2021), and the biological relevance of the selected value (Osenberg et al. 1997). These factors are discussed in detail in the following sections on spatiotemporal scale considerations, data collection, and data analysis.

3) *Estimate power, either analytically or using a simulation approach* (e.g., generating data under the assumed observation process, then applying the analytical approach and testing procedure to each simulated dataset and recording the proportion of times the null hypothesis is rejected). This estimation should also carefully consider the effects on decision making that may result from both Type I error (e.g., detecting an effect when there is none) and Type II error (e.g., not detecting an effect when there is one; Leirness & Kinlan 2018, Fairweather 1991). Given the uncertainty of potential effects from OSW development, as well as the conservation status of many marine bird taxa, a precautionary approach is generally recommended for the conservation and management of ecological populations (in which researchers strive to minimize errors of omission, or Type II error; Hoenig & Heisey 2001).

Note that, while we use the language of frequentist statistics to discuss aspects of power and error, this should not be interpreted as an endorsement of frequentist methods; in many cases, Bayesian approaches may be better suited to effects studies (additional recommendations on analysis are included in "Data Analysis," below).

Statistical power generally increases with increasing sample size, increasing effect size (e.g., the magnitude of expected change/response), and decreasing variability (Cohen 2013). Thus, we recommend the following:

- **We encourage the choice of focal species with relatively high potential exposure (Section 5).** Studies of species that are uncommon or lower in abundance at a site will likely result in a large number of zeroes in the data and/or low sample sizes, which negatively affect statistical power (Vanermen et al. 2015b; LaPeña et al. 2011). While this should not preclude the study of species that are lower in abundance at a site relative to other species or locations, it is important to recognize that focusing on lower-abundance species will typically require additional sampling effort (within or across study methods) and/or coordinated efforts at a larger spatial scale (e.g., meta-analysis across projects) to achieve adequate statistical power.
- **Selection of focal species with expected greater magnitude of response will increase the chance of detecting that response if it occurs (Section 5).** Small effect sizes may be difficult to detect even with high intensity data collection (Donovan & Caneco 2020; Leirness & Kinlan 2018). **For species where potential effect size is unknown, effect size should be treated conservatively (e.g., smaller magnitude of response, higher uncertainty) such that the study is designed with a greater chance of detecting effects, should they occur.**
- Study design should include explicit consideration of, and measurement to control for, potential sources of variation **that may affect the detection of effects and level of response, and/or**

interpretation of results. Statistical power is greatly affected by the level of variation in the system (Vanermen et al. 2015b). As such, understanding and accounting for as many sources of variability as possible, particularly environmental and biologically relevant variability, is key for increasing statistical power (Maclean et al. 2013, Vanermen et al. 2015b). In particular, this should include data that may influence and help control for sources of variation, including: (1) environmental conditions (e.g., oceanographic conditions, weather) collected simultaneously with response data, when possible, (2) biological parameters (e.g., body condition, age, sex), (3) external factors (e.g., OSW facility/site characteristics, other anthropogenic factors), and (4) seasonality or other sources of predictable spatiotemporal variation (e.g., study designs should ensure sufficient sample sizes specific to the season in which effects are expected to occur).

7.2.2 Spatial and Temporal Scale

The spatial and temporal scale of the study can influence statistical power (Maclean et al. 2013). Thus, studies should be designed with appropriate spatial and temporal scales for the question(s) of interest. We strongly recommend that existing data (e.g., site assessment data) and available literature are used to inform power analyses regarding choices related to spatial and temporal scale during study design (Mackenzie et al. 2013). While existing data can inform these decisions, consideration should be given to potential changes and uncertainty over space and time in datasets, and testing various scenarios within a power analysis framework can help identify and clarify the influence of different study design decisions on statistical power. Specifically, we recommend that:

- The spatial extent of the study should be chosen based on the spatial scale of the question and available knowledge of response distance for focal taxa. The spatial scale of the question relates to the focus on displacement and macro-avoidance (large scale), or meso-avoidance (smaller scale) and should also incorporate knowledge of potential response distances from existing studies (see Appendix C and Lamb et al. 2024). It should be noted, however, that while it is important to focus data collection on the scale perceived to be most relevant, this should not be at the expense of overlooking potential responses at other spatial scales (Cook et al. 2018).
- The spatial scale of the study, including overall spatial extent and spatial coverage (i.e., percent of the study area surveyed) should include consideration of statistical power. Understanding how spatial scale affects statistical power is important, as it can influence both effect sizes and the amount of uncertainty. Too large or too small of an overall study footprint can decrease statistical power, and as such the spatial scale used should be equivalent to that at which responses are anticipated to occur (Maclean et al. 2013). In the case of observational surveys, increasing spatial coverage may increase power. For example, LaPeña et al. (2011) found that a three-fold increase in spatial coverage increased statistical power from 0.55 to 0.84. As such, using power analyses to inform decisions of spatial scale is of the utmost importance.
- Ensure that the temporal scale of the study (e.g., duration and frequency) captures potential scales of response based on best available knowledge and associated uncertainty. This is particularly important for studies directly interested in temporal variation in responses (e.g., habituation), which will require data collection across longer temporal scales, but is relevant for all studies in which there is expected to be potential seasonal variation in responses. Given high levels of variation in marine systems, a conservative approach should be taken (e.g., longer overall temporal scale of study; extending the sampling data collection period) and should be reassessed if additional data becomes available.

- Careful consideration should be given to the temporal scale of the study (including frequency of sampling) in relation to timing in the annual cycle for focal taxa, as this can greatly influence behavioral response. Many seabirds are spatially constrained as central place foragers during the breeding season, and thus, responses to OSW development may be different during breeding than during non-breeding periods (Peschko et al. 2020). This is also particularly important for studies directly examining behaviors such as foraging and roosting.
- The overall duration of the study should include data collected both before and after construction of the wind facility (where possible) to effectively examine changes in responses of individuals or populations. This may not be possible for all study questions, particularly those related to avoidance and attraction, where some methods may be constrained by the presence of platforms offshore during the pre-construction period. Post-construction surveys should be initiated within five years of the completion of pre-construction surveys in order to ensure that all effects surveys (two years of pre-construction surveys and 3 years of post-construction surveys) can be completed within a ten-year period. Given that marine systems are highly variable, this serves to minimize the chance of non-OSW variables (e.g., decadal shifts in marine ecosystems due to climate change) influencing distributions and abundance in ways that could be conflated with OSW effects (Kinlan et al. 2012, Morse et al. 2017, Friedland et al. 2019, 2020a, b). In order to complete two years of pre-construction effects surveys, developers and regulators should coordinate to ensure the surveys are initiated >2 years prior to construction.

7.2.3 Data Collection Methods

- **Data collection methods should follow** best practices, existing guidelines, and established protocols (when available) for effective and efficient data collection, such as those developed by BOEM (2020), and other regional science entities, such as the RWSC. For surveys, see recommendations in Section 10 of this document.
- **Use consistent data collection methods over space and time (to the degree possible) to a**void introducing methodological biases into study design. These biases are often unnecessary and left unaccounted for in studies and can lead to additional uncertainty. If substantial changes occur in methodology (e.g., switching survey platforms; Section 10), calibration and/or exploration of the effect of these changes may be needed to understand their potential impact on results.
- Data collection processes should include quality assurance and quality control. Quality assurance (QA) represents a set of steps taken to minimize inaccuracies in the data produced, while quality control (QC) occurs following data collection to test whether the quality of the data meets necessary requirements determined by the end user (Campbell et al. 2013). These processes will vary by data type but should follow existing protocols and best practices.

7.2.4 Data Analysis

A clearly defined analysis plan, based on the study's objectives, should be articulated prior to beginning data collection. This should include specific modeling and statistical approaches and tests anticipated to be used. The development of an analysis plan should include the following considerations:

- **Accounting for biases** – Depending on the method, many different types of biases may be introduced during data collection and should be controlled to the degree possible. For example, detectability, availability, and misidentification biases are present in observational survey data. In the case of detectability (e.g., differences in how likely birds are to be detected by observers, related to distance, conditions, etc.), distance sampling data can be used to model species-level distance functions (Buckland et al. 2001) that can be used to correct density and abundance estimates during analysis of boat survey data. Availability bias (i.e., the degree to which birds are available to be observed), which is particularly relevant for diving species, can be considered in analysis of survey data by using information from the literature (Laake et al. 1997, Borchers et al. 2013). Other study methods introduce other sources of bias, such as population sampling bias (Soanes et al. 2013) and capture location bias (Hays et al. 2020) that likewise must be considered during both study design and data analysis. In cases where analytical methods are not available to account for biases, the influence of these biases on results should be carefully explored.

- Choosing the appropriate modeling framework – For any given research question, there are likely multiple modeling approaches, all of which have strengths and limitations for a specific study. The most appropriate modeling framework for the taxon, question, and location of interest should be carefully considered. Data type, sample size, the data distribution, and other data and study characteristics will help dictate the best potential options for modeling frameworks. Comparisons between modeling approaches may also be needed during analysis to identify the best choice for a given study.
- Accounting for autocorrelation – Spatial and temporal autocorrelation is common in ecological data, whereby observations tend to be more similar at some geographic distances and time differences than expected by chance. This can violate statistical assumptions in common modeling frameworks. Autocorrelation can be an issue across different data types, including observational surveys and individual tracking, and there are many methods to account for the effects of autocorrelation (reviewed in Keitt et al. 2002, Dormann et al. 2007).
- Selecting appropriate model complexity – Identification of models of the appropriate complexity is crucial, as models that are too simple can be biased or inaccurate, while overfitted models that are too complex will perform poorly in predicting to areas without data (Mackenzie et al. 2013). Appropriate model complexity can be assessed using model selection and assessments of model fit. Model selection criteria (e.g., Akaike Information Criterion values) can be used to determine the best fit model across potential covariates and balance the predictive quality of the model with parsimony (Maclean et al. 2009). However, these techniques are not always useful when the study is focused on maximizing predictive accuracy. In these cases, model fit must be assessed using robust methods like k-fold cross validation (e.g., leave-one-out approaches) with careful consideration of the predictors included in the model (Diniz 2022).
- Comprehensive identification of covariates – As discussed above, variation has a large influence on statistical power. The inclusion of covariates can help control for variability in response to the underlying environment that is not attributable to OSW development. In particular, it is important that (1) the spatial resolution of covariates is appropriate for the spatial scale of the study and predicted response (i.e., if the expected response/variation is predicted at the scale of a few kilometers, aim to have spatial covariates at that or finer spatial resolutions), (2) candidate variables are not too similar (collinear) such that they cause model instability (which can be assessed via correlations or variance inflation factors; Mackenzie et al. 2013), and (3) a spatial term be considered for inclusion in the model as a proxy for unmeasured covariates. Such a spatial term (generally related to latitude and longitude) can be applied as a global smooth or via spatially adaptive methods, both of which should be trialed and considered in model selection (Mackenzie et al. 2013). Some analyses may benefit from a multi-scale approach to the resolution

of covariates if a species may respond to different covariates at different spatiotemporal scales (McGarigal et al. 2016).

- **Assessment of model performance** – It is important to assess the degree to which model assumptions are reasonable and associated results are defensible (Mackenzie et al. 2013). While evaluation will depend on the model type, assessment must include an examination of the relationship between observed and fitted values from the model.
- **Consideration of synergies and collaboration opportunities** – It is important to consider the collection of community-level data (where feasible, depending on the method, and while also having focal species), as well as the potential to collect information to inform and support regional and community-level assessments that may not directly be used in the study (e.g., tissue sampling during telemetry deployment).

7.3 Data Sharing and Coordination

Study plans should include a clearly delineated process and timeline for sharing study results, including with federal and state agencies, collaborators, and the broader public. This includes publication of scientific papers and reports, as well as raw dataset(s) following QA/QC procedures (Regional Synthesis Workgroup 2023) and associated metadata. Data sharing and coordination are essential components of a study plan to (1) ensure that results are disseminated effectively, (2) reduce potential duplication of effort, and (3) ensure that data can be used to help answer regional-scale research questions. This topic is addressed in further detail in Section 8.

8.0 Data Consistency and Transparency Recommendations

Collection of avian data in relation to offshore wind energy projects should be standardized and conducted in as transparent a manner as possible. Detailed recommendations for the content and format of observational survey data are included in Section 10, but regardless of study method, this expectation for data consistency and transparency includes:

- Coordination with regulatory agencies such as BOEM and USFWS throughout the study design and implementation process to ensure adequacy, timeliness, and scientific robustness.
- Communication and coordination with others collecting similar data to help ensure consistency, as well as with regional entities including the Regional Wildlife Science Collaborative to ensure that data collection can support regional research. Ideally this should occur on a national and even international scale, but at minimum, coordination should occur among those working within the same ocean basin. If there are no publicly available protocols for a specific study type, then development of a project-specific protocol should (1) incorporate expert support to inform study plans, and (2) include publication or dissemination of the final protocol, so that others can reference it and use it for future studies.
- Implementing formal data sharing agreements among data funders, operators, and those analyzing results, if applicable (NYSERDA 2021), to ensure that expectations and intellectual property rights among collaborators are clearly defined at the outset, and that all data that are not commercially sensitive are made available to the public in a timely manner.
- **Standardized public reporting,** including information on data collection methods, spatial and temporal coverage, effect size, uncertainty, and analytical assumptions, as well as sharing of analytical code (when relevant). Sufficient information should be provided so that the study could be repeated from the description. This will also facilitate integration of data into future meta-

analyses and other regional assessments. Key aspects of reporting should be tailored to the data type and study, but should, at minimum, include the following:

- **Study design information**, including sample size, spatial and temporal scale, response variables, and analytical approaches.
- **Results**, including effect sizes and associated uncertainty and parameter estimates for all statistical tests (even non-significant ones).
- **Potential sources of variation**, including information on site characteristics (e.g., latitude and longitude, size of the OSW project footprint, distance between turbines, number of turbines, water depth, and distance to shore).

- Making data publicly available as soon as possible, but within a maximum of two years following collection, if feasible. This includes public access to raw dataset(s) (following QA/QC processes), co-collected environmental covariate data (where relevant), effort data (where relevant), comprehensive metadata (NYSERDA 2021), and code used to conduct final analyses. Prior to data collection, a study plan should be developed that includes a plan to (1) collect, manage, and store data in an appropriate format for seamless integration into a public database (where available), and (2) deliver the data to the publicly available repository or otherwise make the data publicly available. The release of datasets may occur in multiple stages (e.g., initial release to federal agencies vs. fully public datasets) but should occur in a transparent and clearly defined process.
  - For multi-year data collection, subsets of data should be released as they are finalized to ensure that the data can be incorporated in a timely way into broader efforts.
  - Sharing of data summaries or derived data products, such as density maps, is also important (see below) but does not replace making full datasets publicly available to facilitate re-analysis of data, assessments of cumulative impacts, and incorporation of data into future regional analyses. Sharing data with research collaborators likewise does not replace making full datasets publicly available.
  - Recommended databases for housing different wildlife data types are discussed in a recent NYSERDA (2021) report, "Wildlife Data Standardization and Sharing: Environmental Data Transparency for New York State Offshore Wind Energy." Specific suggestions for observational survey data are further discussed in Section 10.
  - Appropriate metadata standards, such as the International Organization for Standardization (ISO) standards finalized in 2003 and endorsed by the Federal Geographic Data Committee[4], should be followed for development of comprehensive metadata for both spatial and non-spatial data types (NYSERDA 2021).
  - Reports, analyses, and journal publications (below) can continue to be pursued after public release of the underlying data. Contracts and data-sharing agreements with researchers and subcontractors should make this expectation explicit prior to the initiation of data collection.
- Contributing derived analytical products to data portals, such as the Northeast and Mid-Atlantic Ocean Data Portals. Summary products, such as maps and modelled estimates of abundance, occupancy, or habitat use, can aid in user interpretation (NYSERDA 2021).
- Publishing study results in primary literature to facilitate scientific review of study methods and results and provide even greater transparency (NYSERDA 2021).

[4] Federal Geographic Data Committee FGDC; https://www.fgdc.gov/metadata/iso-standards

Part IV. Recommendations for Boat-based and Aerial Surveys

As indicated in Section 6, observational surveys are best suited to answer the following types of effects questions:

- Are changes in habitat use (e.g., displacement/attraction) of marine birds occurring, and if so, what is the magnitude and distance from the OSW facility at which it occurs?
- Does the occurrence, magnitude, and distance of changes in habitat use vary temporally (e.g., does habituation occur)?
- Are there changes in foraging or roosting activity of marine birds in relation to the OSW facility?

In contrast, observational surveys are not well suited to answer effects questions related to individual movements. Surveys to detect effects from OSW facilities are typically focused at the spatial scale of a single OSW project, with a "buffer area" around the project footprint (except in cases where effects of neighboring wind facilities are studied with a single survey effort). Such surveys are typically conducted both prior to and following OSW construction and must be designed to have adequate statistical power to detect responses. The recommendations below build from existing BOEM avian survey guidelines (BOEM 2020; references where relevant) but have been expanded upon to focus specifically on surveys to answer the above types of research questions. The recommendations in this section are intended to be widely applicable across effect studies conducted at the site-level using observational surveys. However, recognizing that project-level considerations will play a role in study design, deviations from these recommendations should be carefully considered and justified based on statistically and scientifically robust analysis in consultation with federal agencies.

9.0 Connection Between Site Assessment Surveys and Pre-Construction Surveys to Detect Effects

Before OSW facilities are built, observational surveys are conducted for several purposes, including (1) to inform the siting of wind energy areas, (2) for site characterization to inform permitting processes and monitoring plans, and (3) to pair with post-construction surveys to detect effects of OSW development ("effects surveys"; above). Government-funded offshore surveys to inform siting are often regional in spatial scale, and thus may lack the fine-scale spatial resolution to adequately detect effects at the project scale. Both site characterization surveys and effects surveys occur at a finer spatial scale, focused in and around an OSW facility. **The primary focus of this effort is to provide recommendations for conducting surveys to detect effects from OSW development on marine birds, including surveys conducted both pre- and post-construction**. However, it is important to consider the degree to which surveys conducted at an OSW project site prior to construction may inform site characterization efforts as well as the assessment of OSW effects.

The primary question that site characterization surveys should be designed to answer is: What are exposure levels for different species/taxa at the project site and how does exposure vary spatiotemporally? With this exposure information, the following questions can then be explored to inform risk assessments and project design: (1) Do existing vulnerability data suggest any of these species could be at high risk from OSW development given considerations of population status and sensitivity to effects (see Section 5 for definitions)? And, if so, (2) Where should avoidance and minimization efforts be focused, based on the greatest potential effects to different species across the annual cycle?

In some locations, existing survey data for a site can be used in place of new site characterization surveys (see Avian Displacement Guidance Committee 2023) for additional guidance on when new site characterization surveys are needed). The existing BOEM avian survey guidelines (2020) are explicitly focused on recommendations for conducting site characterization surveys, and the methods recommended therein are thus inadequate for effects studies focused on understanding changes in distribution and abundance patterns due to the presence of OSW facilities[5]. This issue is further discussed by this Committee in the site characterization recommendations (Avian Displacement Guidance Committee 2023).

Given that both site characterization surveys and pre-construction effects surveys occur prior to construction of a wind facility, it is theoretically possible that the two types of surveys could be combined into a single survey effort prior to OSW construction. However, pre-construction surveys have stricter study design limitations than site characterization surveys, to ensure they have sufficient power to detect change (see Section 9), and post-construction surveys should be initiated within five years of the completion of pre-construction surveys, to minimize the chance of non-OSW variables (e.g., decadal shifts in marine ecosystems due to climate change) influencing distributions and abundance in ways that could be conflated with OSW effects (Kinlan et al. 2012). It is unlikely that post-construction surveys could be initiated within five years of the completion of site characterization surveys (which should be conducted prior to development of a Construction and Operations Plan), particularly given the length of current permitting and construction timelines. As such, in cases where there are insufficient preexisting survey data for a proposed OSW location for site characterization purposes, and additional data are needed to characterize the site, we recommend that separate site assessment and pre-construction surveys to detect effects are conducted (Avian Displacement Guidance Committee 2023), given differences in the objectives of each survey as well as challenges associated with timing under current permitting timelines. Site assessment data (either pre-existing or collected during site characterization surveys for the project) on species presence and abundance at the site should be used to inform the choice of focal taxa and the design of effects surveys.

10.0 Survey Design and Methodology Recommendations

Surveys can be used for many different types of research questions, but the recommendations below are focused on effectively quantifying effects of displacement and attraction from OSW energy development (see Section 6). If the intent is for observational surveys to serve multiple objectives, careful consideration is needed to ensure that all objectives are met effectively. Some of the below recommendations apply broadly to observational surveys. Others may be specific to boat-based or digital aerial surveys or may be specific to certain focal taxa, as indicated.

10.1 Define Clear Study Goals

Given that observational surveys can be used for multiple purposes, it is important to define clear study goals and research questions (Section 7.1). In addition to defining research questions (Section 4), it is also important to define focal species (Section 5). While one of the strengths of observational surveys is the ability to simultaneously collect data across a range of taxa, key aspects of study design and methodology (e.g., choice of buffer size) rely on the choice of focal species. As such, existing data from the area (either from previous site characterization surveys, or other data sources such as tracking data and incidental observations), should be used to define the full list of species likely to be found in the area, and then

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

categorized into “high”, “medium”, and “low” priority species (Section 5). The goal should then be to design surveys to adequately answer research questions for the high priority species with careful consideration of the amount of existing data available to inform the design and the level of likely exposure and sensitivity to effects of these focal taxa, as these considerations will be key in refining study methods.

10.2 Use of Gradient Study Design

It is recommended that observational surveys to detect effects utilize Before-After-Gradient (BAG) study designs (Cook et al. 2018). Effect studies using observational surveys in Europe have used various study designs, including Before-After-Control-Impact (BACI), Stratified BACI, After-Control-Impact (ACI), and Before-After-Gradient (BAG) designs (see Appendix C for summary). BACI designs sample a treatment site (e.g., the OSW facility) and a control site away from the facility before and after “intervention” (e.g., when the OSW project is built) and statistically compare across locations and time periods (Green 1979). Stratified BACI and ACI are variations on this design whereby the impact area is stratified into concentric areas for comparison with the control, or a comparison only occurs after impact, respectively. While study designs involving a control are commonly used in the study of effects from OSW development (Methratta 2021), there are challenges associated with these designs whereby it is difficult, if not impossible, to choose adequate control sites (Vanermen et al. 2015b). In contrast, a BAG design includes data collection at relative distances from the OSW facility both pre- and post-construction (Ellis and Schneider 1997). Combining the before-after sampling design with distance-based methods is a powerful approach that accounts for both spatial and temporal variation in response (Methratta 2021). While often more powerful than BACI-type designs, the spatial and temporal scale of BAG designs must still be carefully selected (Section 10.3).

10.3 Assessment of Spatial and Temporal Coverage

Before-After-Gradient survey designs require that surveys be conducted in the entirety of the wind facility, plus a buffer area of some distance outside of the project footprint. Appropriate survey design must consider the necessary size of this buffer zone and the proportion of the “survey area” (the wind facility plus buffer area) that is covered by survey effort, as well as the ratio of the “effect area” (e.g., the wind facility footprint) to the full survey area. All three of these aspects interact to affect statistical power and therefore should be carefully considered. In addition to spatial coverage, the temporal scale of surveys, both in terms of the length of the overall data collection period pre- and post-construction, and frequency of surveys throughout the period, require careful consideration. Below, we provide general recommendations on aspects of spatial and temporal coverage based on existing knowledge, but **strongly recommend that existing data are used in site-specific power analyses to inform the choice of spatial and temporal coverage of surveys based on the focal taxa at each site**. There are various tools, such as the R package MRSeaPower (Scott-Hayward et al. 2014) that can aid in this type of analysis.

It is important to note that regardless of choice of spatial and temporal coverage, zero inflation (e.g., as dictated by species abundance and distribution) and effect size (e.g., the magnitude of change in these distributions due to the presence of the OSW facility) play important roles in determining a study’s statistical power to detect an effect if the effect exists. Surveys of species that are uncommon or lower in abundance at a site will have large numbers of zeroes in the data, which has a strong negative effect on statistical power (Vanermen et al. 2015b; LaPeña et al. 2011). **As such, we encourage the choice of focal species with relatively high exposure** (Section 5). Similarly, small changes in abundance (e.g., 10%) are difficult to detect even with high intensity survey effort (Donovan & Caneco 2020; Leirness & Kinlan 2018), so **selection of focal species with expected greater magnitude of response will increase the chance of detecting that response if it occurs** (Section 5). **For species where potential effect size is unknown, effect size should be estimated conservatively to ensure the study is designed with a higher chance of detecting effects, should they occur.**

10.3.1 Buffer Size and Ratio of Effect: Overall Area

While we can draw from European studies regarding potential species-specific displacement and attraction distances, there have been relatively few well-designed studies to date. There is a high level of variation in effects among species and studies in the existing literature, and the degree to which results are applicable to U.S. populations and ecosystems is unknown. However, for species where there is evidence of displacement in Europe (e.g., auks, loons, gannets, sea ducks), populations were displaced anywhere between 500 m and 16.5 km (see Appendix C and Lamb et al. 2024).

- **We recommend a buffer zone of 4–20 km be surveyed around the OSW project footprint with a consistent buffer distance in all directions. The choice of buffer size should be based on the suite of species present in the area, selection of specific focal species (Section 5), and their known or suspected sensitivity to displacement (based on** best available knowledge from the literature). For example, if primarily focused on species such as auks, a 4–6 km buffer would likely suffice, whereas if species with high displacement distances (e.g., loons, sea ducks) are focal species of the survey, a larger buffer (10+ km) is needed (NatureScot 2023). See Appendix C and Lamb et al. 2024 for current literature on displacement distances. In cases where sensitivity is unknown, a precautionary approach (e.g., larger buffer) should be used. If data are also intended to contribute to regional understanding of distributions, not capturing the areas where birds are displaced to introduces additional bias into overall density estimates.
- The choice of buffer size should be informed by 1) power analyses of existing data, 2) abundance of focal species at the site, as an increase in species abundance helps to reduce skewness of the distribution and in turn increases statistical power (LaPeña et al. 2011), and 3) ratio of effect area to overall area surveyed. A reduced ratio (e.g., increased area surveyed outside of the effect area), with density of observations held constant, decreases variance and reduces spatial autocorrelation, thereby increasing statistical power (LaPeña et al. 2010). As a rule of thumb, the choice of survey area should be informed by the spatial extent at which changes are predicted to occur, such that the total survey area includes the wind farm footprint, as well as a buffer zone that incorporates the predicted effect distance for focal taxa plus 10%.
- For adjacent lease areas, we encourage coordinated survey efforts, to the degree feasible given differences in construction timelines, to maximize efficiency and treat the area as a continuous habitat for marine birds. Such coordination should be supported by regulators and by regional groups, such as the Regional Wildlife Science Collaborative.

As data from the U.S. Atlantic become available from initial offshore wind project studies, the recommended buffer size should be revisited to confirm that studies to detect displacement effects are designed to have adequate statistical power and are incorporating updated information on effect distances for species in the region.

10.3.2 Spatial Coverage

The percentage of the total survey area that is covered by the survey is calculated as sampled area/total survey area) *100. The **effective strip width** is calculated differently for boat-based and digital aerial surveys. For data collected by digital aerial surveys, the assumption is that image reviewers detect every target within the surveyed area and estimate seabird relative abundance by dividing the number of individuals sighted by the area of ocean surface surveyed (Hyrenbach et al. 2007). For strip transects, the effective strip width is a single value representing the sum of the digital aerial survey cameras' width of coverage at sea level, while accounting for the actual (rather than planned) altitude of the aircraft. For boat-based surveys, **line transects** utilize distance sampling methods to handle imperfections of the observation process such as decaying detectability with increasing distance from the observer (Buckland et al. 2001), the overall detectability at zero distance (Buckland et al. 2001) and the effect of environmental conditions on detectability (Marques and Buckland 2003). The effective strip width with line transect methodology varies by species, as detectability of those species varies with distance from the observer. Distance (u) from the transect line where the number of animals detected beyond u are equal to the number that are missed within u. This value estimates the effective area of the survey and can be used to correct density estimates or estimates of survey coverage (Buckland et al. 2001). From both a logistical feasibility and statistical analysis standpoint there may be tradeoffs between buffer size and percent spatial coverage as these are interacting spatial factors in study design.

- Generally, **we recommend at least 20% spatial coverage of the survey area for surveys to detect effects in order to achieve adequate statistical power**, as is common in European OSW studies (Harker et al. 2022, HiDef 2021), has been achieved in some U.S. Atlantic regional studies (Mid Atlantic Baseline Studies; Williams et al. 2015). However, power analyses with existing data should be used to inform this choice, taking into consideration both the abundance and spatial distribution of focal species. In general, increasing spatial coverage leads to an increase in power due to improved ability to estimate means and reduced variance (e.g., reducing transect spacing from 3 km to 1 km increased power from 0.55 to 0.84 in La Pena et al. 2011). While there may be instances where a study can achieve adequate statistical power to detect change with 10% or less spatial coverage, this is likely only true for abundant and consistently distributed species with high effect size (>20% change; Donovan & Caneco 2020). If focal species are rare (e.g., low exposure, high population sensitivity) or highly aggregated in space, additional spatial coverage beyond 20% may be required to achieve adequate statistical power.
- **Percent spatial coverage for boat-based line transects should be calculated based on effective strip width for focal species**. If the study is focused on detecting effects across multiple species, the minimum effective strip width across focal taxa can be used to calculate percent spatial coverage based on previous detection probability curves (ideally weighted from existing data in the region or, if none are available, from the literature). If there is a single focal species, the detection probability curve of that species should be used.
- For smaller areas, 20% spatial coverage may be difficult to achieve while ensuring that sampling units are independent (e.g., avoiding double-counting issues). Generally, **transect lines should be a distance apart that is >2 times the effective strip width** (Buckland et al. 2001; Jackson & Whitfield 2011). If focal species are known to be influenced by vessel activity, then boat-based survey transects should also be spaced >2 times the distance at which this behavioral effect is known to occur.
- **Stratified sampling:** Transects should be placed/oriented such that important environmental gradients are fully represented within sampling designs (e.g., water depth, benthic complexity, etc.).

The financial cost of increasing coverage versus the scientific and management value of additional data likely varies based on factors including species exposure levels and effect size. Additional research is needed to refine the 20% coverage recommendation outlined above (see Section 11 for additional details). In the case of digital aerial surveys, it may be possible to collect data at a higher spatial coverage, analyze a subset of the data initially, and then use detection rates and other metrics from the initial dataset to determine if additional data need to be analyzed in order to reliably detect change if it occurs.

10.3.3 Temporal Resolution

In addition to spatial scale considerations, the temporal resolution of surveys requires careful consideration to ensure that surveys are statistically independent while capturing adequate variability in the abundance and distribution of marine birds over time. Previous analyses using data from the Northwest Atlantic Seabird Catalog found that surveys conducted 3+ days apart can be considered independent (Kinlan et al. 2012). However, this should be balanced with consideration of spacing to capture seasonal variability (AMBC 2021).

- For studies to detect effects, **12–16 surveys per year for at least two years pre-construction should be conducted to adequately capture variation in distributions** (Kinlan et al. 2012). Two years of monthly surveys are currently recommended in the BOEM avian survey guidelines (BOEM 2020). In addition, pre-construction surveys need to commence early enough (minimum of two years) to allow for completion prior to the start of construction. There should be no more than five years between pre-construction data collection and the first post-construction data collection to avoid introduction of additional sources of variation.
- **The duration and frequency of post-construction surveys should depend on the question (e.g., interest in temporal patterns of displacement/habituation) and levels of variability in site-level data but should include no less than 3 years of 12–16 surveys per year** (Percival 2013). Particularly for low abundance species and/or those with low effect sizes, additional surveys may be needed to achieve sufficient statistical power (Vanermen et al. 2015b). Studies focused on temporal patterns/habituation should aim to survey periodically throughout the lifespan of the project.
- **The distribution of surveys within a particular year should take into consideration seasonal patterns of focal species**, as increases in power can be achieved if effort is concentrated in seasons in which species of interest are most abundant (Maclean *et al*. 2013).

10.4 Data Collection Methods

In addition to the above survey design topics, there are several other key considerations to obtain high-quality data from surveys. Some of these are applicable across multiple types of observational survey, while others are specific to boat-based or digital aerial surveys. Conducting surveys in the same way pre- and post-construction is not always possible, but care should be taken to make post-construction surveys as similar as possible to pre-construction surveys to allow for strong comparison of the two datasets. Generally, **to the degree possible, survey methods, including data collection methods, should be consistent across pre- and post-construction surveys so as not to introduce biases relating to changes in survey methods that are unnecessary or unaccounted for (BOEM 2020).** Upgrades in survey capabilities (i.e., new camera systems for digital aerial surveys) should still be pursued for integration into survey designs post-construction, if they are available, especially if they provide significant improvements in data quality or safety. **If** substantial aspects of the study design or survey methods change between survey periods, however, calibration studies must be conducted to understand the effect of these changes on detection rates, identification rates, and the behavior of the animals being surveyed, to inform viable approaches for data analysis (Matthiopoulos et al. 2022).

10.4.1 Sampling Method

Sampling methods should be used that allow for correction of potential biases and follow established methods. Specific characteristics of survey platforms are discussed in "Platform height and other characteristics," below.

Boat-based surveys: As noted in the BOEM avian survey guidelines (2020), line transects with distance-sampling methods should be used for boat-based surveys (Buckland et al. 2001; Camphuysen et al. 2004; Ballance and Force 2016). The observer should search within a 90-degree bow to beam arc either to port or starboard of the track line (ideally the side with the best visibility) to detect individuals prior to their response to the survey platform (Buckland et al. 2001). Individual birds and groups of birds should in turn be identified with an estimate of distance and bearing along with behavior (see "Data Collection," below). Before surveys, observers should calibrate distance estimates using a laser rangefinder on inanimate objects (e.g., buoys; BOEM 2020). Observers should aim to detect and record all birds with no *a priori* truncation of distance (Buckland et al. 2001; Camphuysen et al. 2004; Ballance and Force 2016; Bolduc and Fifield 2017). While data analysts may need to truncate the maximum distance to optimize model fit, it is best to leave them with the decision of how to implement that with continuous distance estimates. If this is infeasible due to unusual survey constraints or exceptionally high bird densities, we recommend ignoring the collection of distance data, as the detection process can be assumed from the recorded data in other locations in some situations (Goyert et al. 2016).

If expected detection rates or study design do not allow for a true line transect approach, predefining distance bands (e.g., 0–100m, 100–200m, etc.) and assignment of birds to each band during observation can be an acceptable alternative approach. However, distance bands must be carefully selected *a priori* and must be useful to all the study species of interest. Regardless of whether line transects or distance bands are used, boat-based surveys conducted pre- and post-construction to evaluate changes in marine bird distributions must address fundamental requirements to 1) use a standardized, replicable sampling protocol, 2) allow for extension of inference from the sampled population to a clearly delineated biological population, and 3) adjust for detectability bias that arises from distance, movement, environmental covariates, and other relevant factors.

Digital aerial surveys: follow existing guidelines (BOEM 2020) to use strip-transect or grid sampling methods. Either of these methods may be used in a model-based analysis (e.g., before-after-gradient design). Continuous strip transects, such as digital video or abutting digital still imagery, may better capture sampling gradients, but may have high variance due to autocorrelated distributions of aggregated (e.g., flocking or schooling) species. Grid samples, often used with digital still photography, may better handle aggregated species by reducing autocorrelation, but are generally more expensive per unit of observation data.

10.4.2 Consistency in Survey Platform

If possible, the same platform (e.g., the specific boat or plane as well as camera setup for digital aerial surveys) should be used for pre- and post-construction surveys to control for detection differences that may be caused by different platforms. If a different platform is used for pre- and post-construction surveys, the potential biases caused in the resulting dataset due to variation in size, platform height and field of view, etc. must be explicitly addressed in the study plan and data analysis (Section 7) or via targeted calibration studies (see Munson et al. 2010 and Matthiopoulos et al. 2022).

10.4.3 Platform Speed

- **Boat-based surveys: A speed of 7–10 knots is recommended for boat-based marine bird surveys**. Platforms moving <4 knots (7.4 km/h) or >19 knots (235.2 km/h) are not appropriate for collecting marine bird survey data (Gjerdrum et al. 2012). The existing BOEM guidelines for site characterization surveys recommend 10 knots (BOEM 2020).
- Digital aerial surveys: follow existing guidelines and fly surveys between 220–350 km/hr (ground speed; BOEM 2020). Speed should not be significantly varied between surveys, or within surveys (less than+/-10% fluctuation), during periods when imagery is being collected for analysis.

10.4.4 Platform Height and Other Characteristics

The choice of survey platform, and specific location from which observations are conducted/images are recorded, can have a large influence on the quality of resulting data. For boat-based surveys, in general, observers should be located high above the water's surface in a location with a wide forward field of view. Larger boats can also conduct surveys safely in a wider range of weather conditions. However, vessel availability is also a consideration; if a slightly smaller vessel will be more readily available for surveys when there is a weather window, which might be preferable to a larger vessel that has more limited availability for surveys. In addition, a vantage point that is too high can negatively influence detection for some species. Surveyors should also consider safety and observation efficacy when selecting a survey platform on the vessel. The location of survey observers on the vessel should be:

- At a position above sea level that enables detectability within a minimum of 300 m of the trackline for focal taxa, ideally ~10 m (range: 5–25 m; Camphuysen et al. 2004). A vantage point that is too high or low can negatively influence the detection of some birds, particularly small, dark birds near the water's surface. Positions within a couple meters above sea level (e.g., small recreational boats) can limit the depth of field for distance estimation, such that farther distances (e.g., > 100m) are indistinguishable. Taller platforms (e.g., > 5m above sea level) are recommended to better distinguish farther distances but may require careful selection of observation points to prevent the ship breadth from blocking the view alongside the vessel.
- Have a clear (>90 degree) field of view to the front and side of the vessel.
- Be a safe location from which to conduct surveys (e.g., without having to hold onto railings or other infrastructure).
- Be a stable location from which to conduct surveys (e.g., a crow's nest or similar platform that tilts back and forth with wave action is generally not going to be an effective location from which to conduct surveys).

For digital aerial surveys, there is a key tradeoff between flight height of the plane (i.e., higher flights increase crew safety, make it easier to conduct surveys using the same methods pre- and post-construction, and reduce wildlife disturbance caused by the plane) and image resolution (i.e., higher flights may result in lower image resolution and fewer birds identified to species).

- For digital aerial surveys, surveys should ideally be flown at the same altitude pre- and post-construction, but at minimum should have consistent image resolution between these survey periods to provide the most comparable data between these two periods (see data collection section below for additional recommendations on image resolution). The optimal flight height for a given situation will be a balance between (1) obtaining the necessary image resolution (see data collection section below), and (2) flying at heights that eliminate disturbance to wildlife (500 m minimum; AMBC 2021[6]) and allow safe flying above turbine rotors. However, flight height may evolve as camera resolution and technology improves (e.g., by the time post-construction surveys are flown for a project, it may be possible to fly higher while retaining the same image resolution as pre-construction surveys). Given current Federal Aviation Administration guidelines, for safety reasons, planes will likely be required to fly at least 500 feet above the upper edge of the rotor-swept zone (14 CFR 91.119).

- In many cases, exact turbine height will not be known at the time that pre-construction surveys are flown. In this situation, the most conservative estimate of turbine height should be used (e.g., higher end of the design envelope identified in the Construction and Operations Plan) to identify a safe flight height for surveys.

10.4.5 Surveyor Qualifications

The value of data is directly related to its quality, which depends on the capabilities of the surveyors as well as the quality of training provided (Environment and Climate Change Canada 2020). Current BOEM avian survey guidelines recommend the use of "qualified biologists specializing in seabirds" for surveys (BOEM 2020), but how qualification is determined is not clearly defined. In the UK, commercial and volunteer boat-based surveyors are assessed by accredited instructors on five key standards – bird identification, visual acuity, application of methods, recording stamina, and navigation (Lewis & Dunn 2020). Based on these standards and the Eastern Canada Seabirds at Sea standardized protocol for pelagic seabird surveys, we recommend the following:

- **Observers/biologists conducting boat-based surveys or identifying images from digital aerial surveys must have documented experience observing and counting seabirds with a good understanding of seabird behavior and ecology. Experience includes at least 50–100 hours of training with qualified observers/biologists** (Environment and Climate Change Canada 2020, Jackson & Whitfield 2011).
- **Observers/biologists should have demonstrated ability to rapidly identify seabirds at sea/from images in the region in all plumages, in various lighting conditions, under reduced visibility, and in rough sea conditions.**

10.4.6 Survey Conditions

The weather conditions (e.g., visibility, sea state, glare) during which surveys can be conducted should be defined based on human safety considerations as well as quality of data collection. Conditions can significantly impact detection rates, leading to biases in resulting data. An improved understanding of the relationship between survey conditions and species detection and identification could aid in developing a correction to allow for a broader range of conditions to be acceptable for conducting surveys. Unless there are data available with which to correct detection probabilities based on differing conditions, and

[6] From the AMBC 2021 letter to BOEM: "Published studies suggest that digital aerial surveys should be flown above 460 m, preferably a minimum altitude of 500 m, to avoid disturbance (Thaxter et al. 2016), but operators have reported minimal disturbance or flushing of target species during surveys conducted at 415 m. More empirical support is needed to determine the ideal minimum survey altitude, and whether it should range depending on environmental conditions."

these differing conditions remain safe for those conducting the surveys, we recommend that surveys are conducted in the following weather conditions:

- **Boat-based surveys: In general, surveys should be conducted at no higher sea state than Beaufort 4 and with >1 km visibility** (with the exception of large research vessels specifically designed for survey work that can remain safe and provide a stable viewing platform in conditions up to sea state 5–6). **As much as possible, transect orientation and observer orientation during surveys should be designed to minimize glare-related effects on detections (BOEM 2020).** Following existing BOEM guidelines (2020), surveys should commence when there is enough light to identify birds to species. Boat size and platform height, and conditions in which surveys were conducted, should always be noted in metadata such that these variables can be included in future data analyses.
- **Digital aerial surveys: Surveys generally should be conducted at no higher than Beaufort 4 (BOEM 2020).** Higher sea conditions may lead to both safety concerns and the potential to miss smaller species depending on the region and species present. Glare, likewise, can affect species detection and identification. **Prior to initiating surveys, transect orientation should be designed to minimize glare (while also designing surveys to cover important environmental gradients).** Additionally, when conducting surveys, the angle and height of the sun should be carefully considered when assessing survey conditions for glare, and cameras that can be rotated (e.g., away from the sun) are an effective way to avoid glare. **Light conditions should be adequate for species identification in imagery (BOEM 2020).** Flight altitude and speed, and conditions in which surveys were conducted (such as sea state and glare), should always be noted in metadata to inform future data analyses.

10.4.7 Data Collection

Data collection on each survey should encompass information on survey conditions, timing, level of effort, and bird observations. The general information collected during surveys should be consistent with existing guidelines (BOEM 2020, Normandeau 2012).

- **Survey data collection should include effort data and information on weather conditions at the scale of the transect segment, where a new transect segment is defined by a change in any one of the conditions listed below. Effort/conditions data should include, at minimum:**
  - Full time-location track information, including the start and end date and time
  - GPS track of transect with associated time of each position
  - Sampling method (e.g., line transect, strip transect, grid sampling)
  - Sea state (boat-based surveys)
  - Visibility
  - Glare (digital aerial)
  - Observer ID
  - Altitude of plane (digital aerial) or height above sea level of observer (boat-based)
- **Data collected for each observation should include, at minimum:**
  - Date and time
  - Location (latitude and longitude)
  - Species identification
  - Number of individuals in group

- Behavior (such as flying, on water, foraging)
- Distance and angle (with certain short-term exceptions based on conditions; see above)
- Non-bird objects/events that could influence distributions (e.g., fishing vessels, debris, sea turtles, fish, and marine mammal observations). If the observer can collect data on other animals observed during surveys, they should do so consistently. If data on non-bird animals is only collected during portions of the survey, or for certain non-avian taxa, this effort-related information should be included with the observation data. Unless systematically recorded, these observations should be treated as opportunistic.

- **Data collected for each observation should also, where possible, include:**
  - Bird flight direction
  - Flight height, collected using the best available science. In the case of boat-based surveys, ornithodolites/laser rangefinders paired with inclinometers should be used to the degree possible for flight height estimation of all individuals, due to lesser accuracy of purely visual flight height estimates from vessels (Largey et al. 2021). At minimum, such systems should be used for calibration and training of observers (Harwood et al. 2018). If binning flight height data, categories should be carefully considered (based on project's proposed rotor swept zone) and consistent across observers, surveys, and studies. For example, AMAPPS[7] surveys use 0–10 m, 10–25 m, 25–50 m, 50–100 m, 100–200 m, >200 m bins. For digital aerial surveys, recent advances in LiDAR and digital aerial imaging also offer the potential to collect estimates of the altitude of birds in flight (Cook et al. 2018, Humphries et al. 2023) and should be used whenever possible. Biases associated with the chosen method for estimating flight height should be carefully considered and explicitly stated in study design and reporting.
- **Birds should be identified to species whenever possible (but only when confidence in identification is high); if this cannot be done, then birds should be identified to lowest distinguishable taxonomic group, as recommended in the BOEM guidelines (BOEM 2020)**. While confidence in identification is subjective, a common set of identification criteria should be used by all observers.
- For digital aerial surveys, color images should be collected with a ground spatial resolution of 2 cm or finer. Image resolution is a key factor influencing species identification for digital aerial surveys and should be somewhat dependent on species of interest. The recommendation to use 2 cm resolution or finer is applicable regardless of survey intent, finer resolution may be obtained to allow for distinction among similar small-bodied species of particular interest (e.g., auks, terns). For boat-based surveys, color images using a digital camera with telephoto lens should be collected, where possible, of birds, with a particular focus on (1) rare species and (2) species that are difficult to distinguish (e.g., tern species).
- **Survey data should be collected and recorded in a standardized way that can seamlessly be incorporated into the Northwest Atlantic Seabird Catalog and other data repositories**. To improve data standardization and workflow, boat-based surveys should collect data using a survey application, such as SeaScribe (Gilbert et al. 2016) or Sealog (Swingley et al. 2023).
- **Careful consideration should be given to the collection of *in situ* environmental and prey data simultaneous with bird observations, continuously or at regular intervals (e.g., hourly or per**

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[7] Atlantic Marine Assessment Program for Protected Species: https://www.fisheries.noaa.gov/new-england-mid-atlantic/population-assessments/atlantic-marine-assessment-program-protected

transect) to inform data modeling and mechanisms of potential effects from OSW development on marine bird habitat use, abundance, and distribution**.** Environmental data could include weather conditions for each observation, water temperature and salinity (for boat-based surveys), and prey information including hydroacoustic surveys of fish biomass (for boat-based surveys) or the location and size of fish shoals identified in images from digital aerial surveys (Goetsch et al. 2023).

10.5 Review of Data

Data collected on each survey should be reviewed for quality control purposes.

- **Boat-based surveys: data should be summarized and reviewed by one or more of the observers for obviously erroneous information**, with a particular focus on species and counts to ascertain incorrect information was not recorded (for example, the standard 4-letter species code is ROST for Roseate Tern and ROYT for Royal Tern). Preliminary data review should be carried out as soon as possible (within 48 hours of survey completion) to prevent any potential errors being overlooked. Any unidentified individuals for which images were taken should be identified from the photographs, if possible.
- **Digital aerial surveys:** following the BOEM avian survey guidelines, **qualified biologists specializing in seabirds should assess images, and at least 20% of images should be independently audited by an expert during both the detection and identification stages of the review process** (see Buckland et al. 2012).

10.6 Data Analysis

The current BOEM avian survey guidelines (2020) provide useful guidance for analysis regardless of whether surveys are intended to inform site assessment or to assess effects of OSW on marine bird distributions. **The development of a clearly defined analysis plan (See Section 7) should include specific models and statistical tests along with the following considerations specific to surveys:**

- **Accounting for biases**: Following existing BOEM avian survey guidelines, for line transect sampling from boats, distance sampling data should be used to model species-level distance functions (see Buckland et al. 2001) to correct density and abundance estimates. Analyses should use formulations of distance models that allow for inclusion of covariates (observer, sea state, etc.). While detectability is assumed to be constant across the captured area for digital aerial surveys, species-level and condition-dependent detectability should be considered, as appropriate. Availability bias is an additional important consideration, perhaps particularly for digital aerial surveys that move much faster than boat surveys and therefore may have a higher availability bias for some diving species (e.g., Winiarski et al. 2014). Data on activity budgets from tracking studies (existing or future) may be required to adequately characterize species-level availability biases to allow for corrections. In addition, accounting for uncertainty in species identification can be achieved using various analytical methods, including multiple simulation approaches (see Johnston et al. 2014 for details on approaches).
- **Choosing the appropriate modeling framework**: There are multiple modeling approaches that provide methods to examine displacement and attraction effects for gradient study designs comparing pre-construction and post-construction distributions, including generalized linear mixed models (GLMM), generalized additive mixed models (GAMMs), Poisson point processes,

and Complex Regional Spatial Smoother models (CreSS). All have strengths and limitations given data and research questions, but in an analysis comparing analytical methods for offshore renewable energy surveys, CreSS performed better than GAMMs at assessing whether effects were present and at identifying spatially explicit differences (Mackenzie et al. 2013). Comparisons between spatial modeling approaches will be needed during analysis to identify the best choice for a given study.

- **Accounting for autocorrelation.** Spatial and temporal autocorrelation is highly likely to be present in observational survey datasets and should be adequately accounted for in study design and/or analysis. Observations collected close together in space and time may be more similar than those collected further apart, resulting in autocorrelation among count data. If similarities are not accounted for in analysis, it can lead to an underestimation of uncertainty and thus an overestimate of effect size. Correlograms or variograms, for example calculating Moran's I, may be used to test for spatial and temporal autocorrelation in the data and the residuals of a model. Autocorrelation may be minimized through the use of design-based studies (e.g., grid sampling) or model-based analyses. For example, inclusion of autocorrelated predictors in models may remove some of this non-independence, in which case model tests should indicate no residual autocorrelation. Where predictors do not sufficiently account for such autocorrelation, other methods, such as conditional auto-regressive (CAR) models or Generalized Estimating Equation (GEE; Hardin & Hilbe 2002) can be used to account for this type of autocorrelation.
- **Comprehensive identification of covariates helps ensure successful model selection** as these covariates help control for variability in response to the underlying environment (e.g., changes in distributions/abundance) that is not attributable to OSW development. The choice of covariates will vary depending on research questions, focal taxa, biological relevance, and data availability.
    - **Potential covariates should include, to the extent available, environmental variables (e.g., bathymetric features, flow dynamics) as well as existing anthropogenic pressures (e.g., vessel traffic)** based on existing information about the biological relevance and influence of these variables on abundance/distribution of focal taxa (Mackenzie et al. 2013).
    - **To describe effects across small spatial scales (10s of km), a relatively high spatial resolution of covariates is most appropriate (e.g., at the resolution of turbine spacing or higher).**

10.7 Data Reporting

Standardized reporting should include information on data collection methods (including boat size and platform height), spatial and temporal coverage, effect size, uncertainty, and assumptions, such that survey data can be integrated into future meta-analyses and other assessments (Section 8). For observational surveys in particular, key aspects of reporting include the following:

- **Report study design information including spatial and temporal coverage of surveys** (% spatial coverage, distance between transects, buffer size/area, overall survey area in km^2, timing of surveys).
- **Following existing BOEM avian survey guidelines (BOEM 2020), provide spatially explicit density estimates and associated variance (95% confidence intervals) by species/taxonomic groups in map and tabular formats**. Uncertainty about estimated parameters is crucial when drawing conclusions from a model. 95% confidence intervals can be used as best- and worst-case

scenarios, as well as provide key information about uncertainty of effects for future meta-analyses.

- **Provide information on site characteristics** including latitude and longitude, OSW project footprint size, distance between turbines, number of turbines, height of turbines, minimum and maximum water depth, and minimum and maximum distance to shore.
- **Make observation datasets publicly available** via the Northwest Atlantic Seabird Catalog and/or OBIS-SEAMAP (BOEM 2020, NYSERDA 2021). This should include final processed dataset(s) (following QA/QC), co-collected environmental covariate data, complete effort data, and comprehensive metadata (NYSERDA 2021). Until a suitable database or archive for digital aerial survey imagery is developed, projects should aim to at least make clipped 'snag' images available publicly online via searchable websites. Full images, image metadata, and image annotations (e.g., observation data associated with each frame) should be archived for the life of the OSW wind project, and in such a manner that they can be easily made available on request of federal and state regulatory agencies for machine-learning applications or other purposes. For guidance on formatting requirements and archiving of digital aerial imagery, contact Kyle Landolt at klandolt@usgs.gov at the Upper Midwest Environmental Science Center.
- Make data publicly available as soon as possible, but within a maximum of two years following collection, if feasible. For multi-year data collection, subsets of data should be released as they are finalized to ensure that the data can be incorporated in a timely way into broader efforts.

Additional recommendations for data transparency and reporting are discussed in Section 8, above.

Part V. Recommendations for Future Guidance and Research

While the recommendations presented in this document represent a key first step in developing standardized methods to accurately and reliably detect macro- to meso-scale changes in marine bird distributions and habitat use at OSW facilities, further steps will be needed for effective implementation of this guidance at a regional scale. Additional guidance development efforts and quantitative analyses could also serve to strengthen and build on these recommendations. As such, the Specialist Committee recommends several activities following the publication of this document.

11.0 Next Steps for Guidance

- **Review the recommendations presented in this document to develop formal federal guidelines for OSW energy developers**. BOEM and USFWS should develop guidelines focused on how to conduct pre-and post-construction monitoring to detect changes in marine bird distributions and habitat use. **Statistically robust monitoring should be conducted at all lease areas to detect and characterize changes in distributions and habitat use** (see Section 7 for additional discussion of how to develop statistically robust study plans).
- **Support additional analyses to address unresolved study design questions for surveys**. BOEM and USFWS should support additional quantitative analyses to inform key areas of uncertainty in the recommendations for at-sea surveys (Section 9). It will be important to provide more detailed and scientifically supported guidance to developers and other stakeholders regarding how various factors affect detection of OSW-related displacement, attraction, and avoidance, and how best to estimate these spatiotemporal changes. The literature review and meta-analysis conducted as part of Phase 1 of this Committee's work, which assessed displacement distance and other metrics from existing studies of marine bird distributions at OSW facilities (Appendix C), were limited by small sample sizes and inadequate reporting in the available studies from Europe. Additional analyses could help to quantify unresolved questions on survey design by using existing raw survey data and simulation-based approaches to inform the development of more detailed recommendations for boat-based and aerial survey methods (e.g., Lapeña et al. 2010, MacLean et al. 2013, Vanermen et al. 2015b). This Committee recommends additional quantitative analyses include the following steps:
    - Access finalized observational survey datasets on marine bird species distributions and variability in habitat use from the Northwest Atlantic Seabird Catalog and other databases as appropriate.
    - Use data compiled for the Phase 1 meta-analysis to inform study questions and analytical approaches. The degree of displacement and attraction that occurs at OSW facilities appears to vary in space and time in conjunction with individual and species-level responses, facility characteristics, and environmental conditions. In particular, we recommend the use of these existing data (and associated uncertainty) to refine key study design recommendations related to:
        - Species/taxon of interest. From initial analysis, this seems to be one of the most significant factors determining whether an effect is detected (Appendix C; Lamb et al. 2024).

        - Survey frequency and duration (e.g., number of surveys per year and in total, focusing in part on number of years of post-construction data (following preliminary results in Appendix C as well as results from Lamb et al. 2024)
        - Size of survey area (e.g., extent of buffer area to survey outside of the project footprint)
        - % ground coverage of surveys required to detect change for different species/taxa
        - Characteristics of survey platforms best suited to answer specific questions.
        - Additional data streams to explain potential sources of variation in response, such as operational status.
    - Implement power analyses on the above datasets to inform recommendations for species of interest, for example, using simulation-based approaches. Combining existing data on species distributions with simulated survey efforts will promote more informed U.S.-based recommendations on survey extent and other characteristics. This work has already been initiated as part of Project WOW[8] and could be expanded to develop a regional study design framework for observational surveys, similar to a recently published framework for marine mammal passive acoustic monitoring in relation to OSW (van Parijs et al. 2021).
    - Update the recommendations in this document based on findings from the quantitative simulation study.
- **Formulate more detailed recommendations for non-survey methods identified in this document (e.g., individual tracking, radar, remote visual imagery) for assessing avoidance/attraction.** Detailed recommendations for incorporating additional methods into understanding displacement will improve the quality and standardization of studies across projects.
- **Form an expert working group or technical review panel (potentially through the RWSC) to further refine survey-based guidance and undertake recommendations in this document** (e.g., key unresolved questions, standard protocols, power analyses, and monitoring measures) and facilitate planning and coordination of surveys aimed at understanding displacement at multiple scales. Among other issues, such a Committee could help to develop a recommended joint protocol for surveys conducted at adjoining lease areas (e.g., with overlapping buffer zones) in order to understand cumulative displacement impacts (see Section 12, below). This group should be made up of experts in designing and conducting observational surveys and have broad representation across OSW-wildlife sectors.

12.0 Additional Guidance, Frameworks, and Research Needs

- **Develop approaches for conducting surveys or other monitoring efforts at multi-project scales.** For OSW facilities in proximity (such as adjoining lease areas), research and monitoring efforts focused on a single project will be inefficient, involve challenging logistics, and be less effective at detecting change, due to activities in each project area that may be affecting marine bird distributions in additive or synergistic ways. Ideally, developer-funded surveys in such situations should be coordinated and conducted at a larger multi-project or regional scale to collectively assess changes in marine bird habitat use and distributions from all OSW projects in the vicinity.

[8] More information on Project WOW: https://offshorewind.env.duke.edu/

This type of coordination may be challenging, particularly given differing permitting and construction timelines across projects. However, a lack of coordination can increase the expense of surveys for individual OSW developers and hinder the ability of both OSW developers and regulators to detect effects of offshore wind energy using pre- and post-construction surveys. The Committee recommends that BOEM and USFWS:

- Encourage OSW developers to contribute to a common fund or research effort, perhaps coordinated via the RWSC, to fund regional-scale surveys in lieu of surveys conducted on a site-by-site basis. This approach could be even more effective than standardizing studies on a site-by-site basis for producing high-quality, consistent data to reduce uncertainty and inform understanding of effects, while also increasing cost efficiency.
- Prioritize the designation of one or more people with appropriate expertise to coordinate the implementation of the recommendations in this document. Most likely this person would be a federal agency biologist, possibly working in coordination with the RWSC bird and bat subcommittee. Regardless, this position must have sufficient regulatory support and authority to support the design and coordination of studies, data sharing, and other key aspects to ensure the quality, standardization, and availability of data and findings from site-level effects research.

- **Develop standardized approaches and recommendations for conducting power analyses and analytical approaches to inform study design and reporting.** As described in Sections 7 and 9), power analyses are key to informing study design choices, and estimating the anticipated variability of the data represents an important step of this process. Given the pitfalls of using insufficient/inaccurate data to inform power analyses, and the potential conflicts of interest associated with such an important/consequential analysis, it is important to develop a standardized or centralized approach to power analyses for study design purposes to ensure that they are used consistently, correctly, and in a scientifically robust manner. Additional guidance on the analytical approaches that should be used for study design power analysis as well as data analysis could also be beneficial to improve consistency across projects.
- **Formulate recommendations for studies of other types of OSW effects on marine birds.** While changes in marine bird habitat use and distributions are important to study and understand, other types of effects, including collisions, are also important, particularly as they may affect a wider range of taxa, including nocturnal migrants. Recommendations focused on other types of OSW effects studies should include the identification of effective approaches for assessing micro-scale avoidance, collisions, and habitat alteration (including changes in distribution and abundance of prey species). In some cases, this may require agencies to also develop standardized validation/acceptance approaches for new technologies. BOEM or USFWS could choose to develop research and monitoring guidelines directly or could participate in an effort like the current Specialist Committee (through the E-TWG, the RWSC, or another venue) to obtain specialized expertise in shaping the development of federal guidelines. This could help to form comprehensive guidelines for all avian monitoring at offshore wind facilities.
- **Develop species distribution modeling frameworks that integrate data from different sources (e.g., surveys, tracking, colony data, environmental covariates) to inform risk assessments and improve understanding of potential cumulative and population-level impacts**.
  - Currently, surveys and tracking data are largely considered independently when conducting risk assessments for marine birds. Integration of these data types into a single

spatiotemporal framework for risk assessment would better utilize existing data, fill data gaps, and improve the overall quality of risk assessments. However, given the different spatiotemporal scales at which surveys and tracking operate, such integration would require substantial quantitative expertise and method development. There is a current study[9] funded through the Offshore Renewables Joint Industry Programme (ORJIP) for Offshore Wind that is beginning to tackle this issue; further work should build on the ORJIP effort.

    - Better integration of colony data (e.g., productivity, adult survival) with survey data would be useful both for understanding spatial patterns of habitat use during the breeding season and for understanding how changes in distribution and habitat use in relation to OSW development may affect fitness and survival, thus, drive population level change. In the U.S. Atlantic, we recommend starting with a dedicated effort to QA/QC a federal seabird colony dataset and use it in an analysis of breeding seabird foraging ranges.

- **Conduct studies to better understand the mechanisms of behavioral change, as well as the potential for population-level impacts from resulting attraction and avoidance.** This guidance focuses on detecting and characterizing displacement, attraction, and avoidance but does not address the mechanisms and potential impacts of these effects on populations and ecosystems. Further study is needed to 1) understand causal mechanisms (e.g., what aspect of OSW turbines or wind farms birds are responding to when they avoid or are attracted, and why), and 2) determine the fitness consequences, if any, of these behavioral changes, and the potential for resulting population-level impacts.

The end goals of all these surveys and analyses are to be able to (1) assess the impacts to fitness of cumulative changes in habitat use in response to OSW development, and (2) minimize and mitigate changes in fitness, if they exist. While these objectives are beyond the scope of this guidance, successful implementation of the recommendations in this document will be an important step towards achieving these goals for the OSW industry in the U.S. Atlantic. Existing effects data are from a very different set of ecosystems than the U.S. Atlantic, and it is important to assess whether changes in distribution and habitat use at U.S. wind facilities are consistent with those observed at European OSW facilities, as well as adding additional datasets to the global knowledge base on this issue.

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[9] ORJIP for Offshore Wind: Integration of tracking and at-sea survey data (InTaS) www.carbontrust.com/news-and-insights/tenders/orjip-for-offshore-wind-integration-of-tracking-and-at-sea-survey-data-intas

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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.

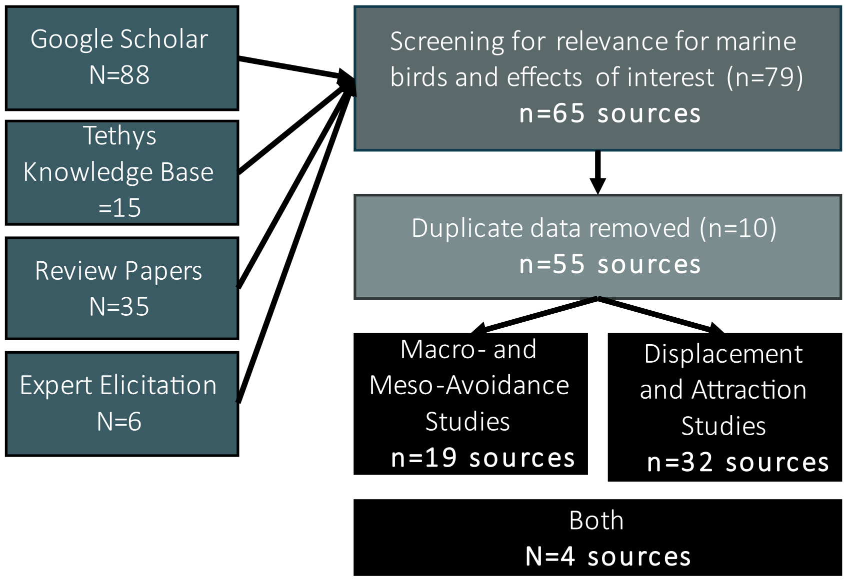

Figure C1. *Process for collation of sources for literature review on displacement, attraction, and macro- to meso-scale avoidance of marine birds at offshore wind facilities.*

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

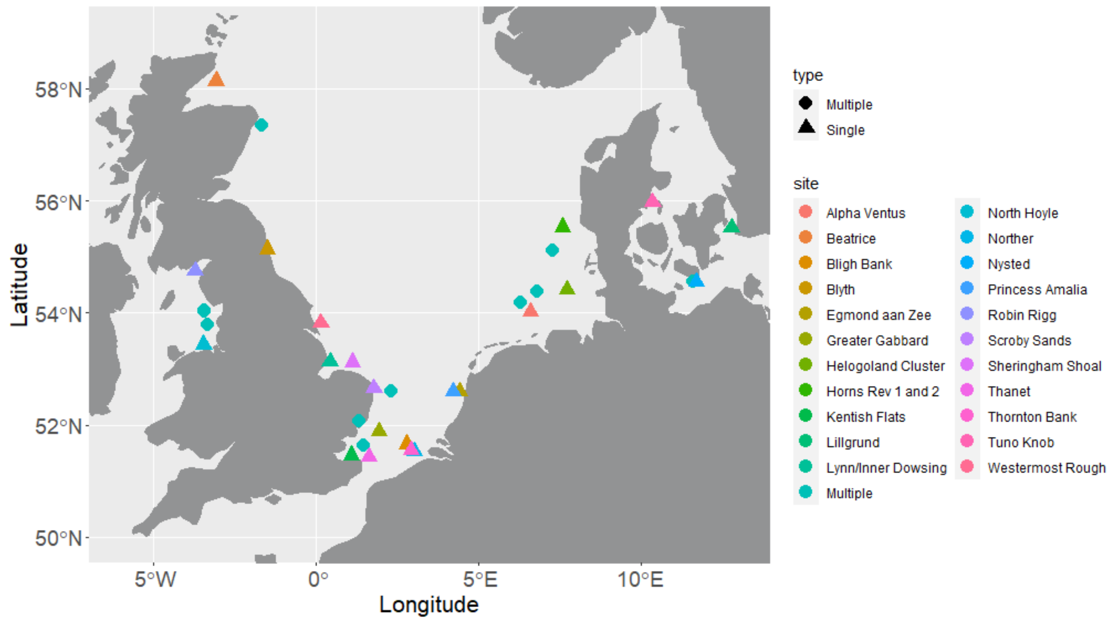

Figure C2. *Locations of studies included in the literature review of displacement, attraction, and macro- to meso-scale avoidance of marine birds to offshore wind facilities. Colors indicate studies at different offshore wind development facilities, including individual projects (triangles), or across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

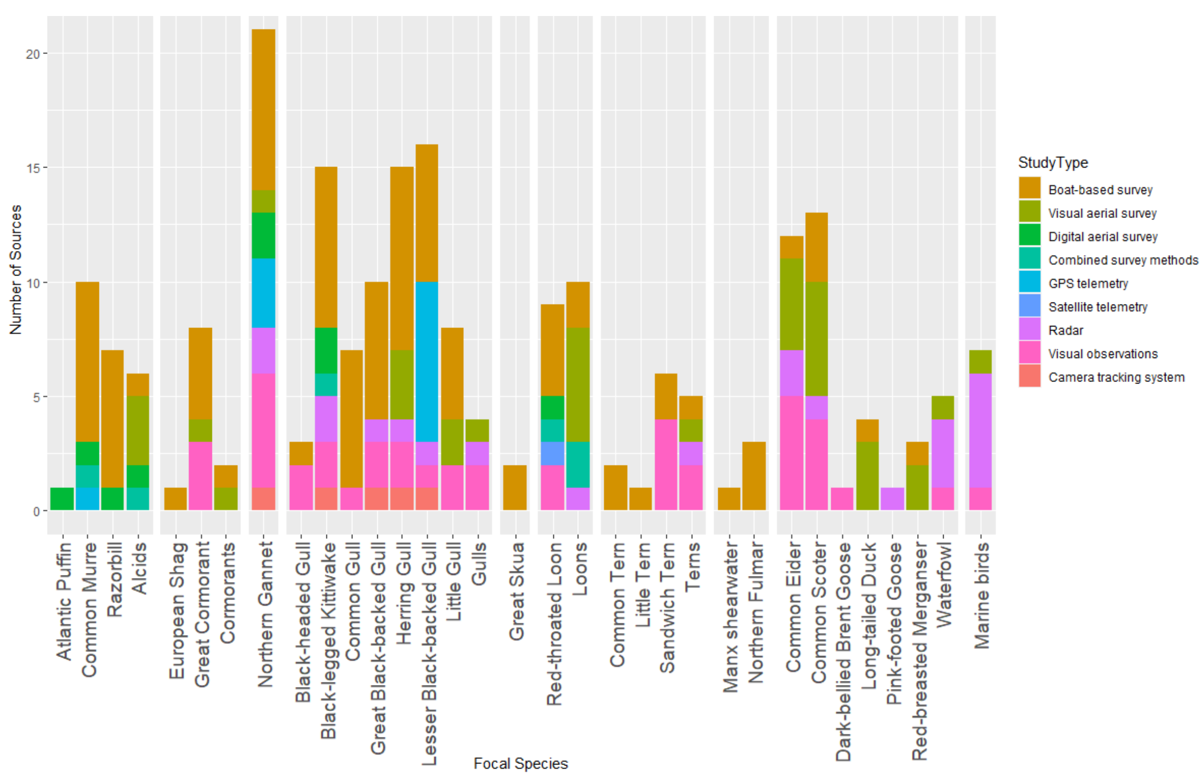

Figure C3. *Number of sources by marine bird species and study method. Individual sources may have examined effects on multiple marine bird species or groups or utilized multiple study methods.*

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						