GINGR Navigator No. 2

Monitoring Biodiversity at Sea

Discussion paper on advancing standardised biodiversity monitoring for Nature-Positive offshore wind development

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GINGR
Global Initiative for Nature, Grids and Renewables

An introduction to GINGR

The Global Initiative for Nature, Grids and Renewables (GINGR) aims to support the just and sustainable energy transition by providing assessment tools to quantify contributions to Nature- and People-Positive goals. To facilitate this, we intend to develop monitoring and reporting systems that are globally aligned and standardised.

At GINGR, we are developing a comprehensive framework that allows actors within the energy system to report on progress towards biodiversity gains and co-created community benefits in the deployment of wind, solar and electricity grids. The GINGR Framework will support governments, the renewable energy industry, and the financial sector to achieve their energy, climate and biodiversity targets in a timely and socially responsible manner.

Through the efforts of several working groups with active participation from industry, NGOs, and academia, we plan to deliver robust and legitimate guidance and tools that support the final objective of a global standard in monitoring and reporting. Recognising the significant challenges posed by implementation, GINGR will develop a technical assistance hub to provide guidance and support, as well as a repository of best practices and lessons learnt.

The collaborative work on the GINGR Framework will be complemented by a series of publications, *GINGR Navigators*, initially focusing on offshore wind development. Through this series, we aim to provide ready-made solutions for companies, governments, and the financial sector. These activities also have the potential to bring more stakeholders together to share experiences and data, as well as to improve biodiversity monitoring around offshore wind developments.

GINGR is a collaborative initiative of the International Union for Conservation of Nature (IUCN) and the Renewables Grid Initiative (RGI). Find out more on www.gingr.org.

Foreword

As offshore wind development accelerates, it is important to find solutions to ensure that this development has a positive impact on nature and local communities. Offshore wind holds great promise for decarbonising the energy system. However, it also poses unique challenges, particularly concerning its impact on the marine environment. Standardised, comparable, and scientifically rigorous biodiversity monitoring is essential to understand and mitigate these impacts and support the identification of ecosystem restoration measures. It also ensures that offshore wind can claim to contribute to Nature- and People-Positive outcomes.

Consistent and science-based monitoring practices reinforce the principle of dual materiality, applied in corporate sustainability reporting, and are fundamental to supporting public decision-making.

This *GINGR Navigator* is a response to this need. It provides a comprehensive guide to marine biodiversity monitoring to assist project developers, financiers, and policymakers in creating and maintaining Nature-Positive offshore wind projects. This Navigator provides tools for monitoring, evaluating, and adapting measures to protect marine ecosystems. It emphasises the collaborative, cross-disciplinary approaches that are essential for informed decision-making and for achieving both conservation and energy objectives.

This document provides detailed guidance on monitoring methods, key biodiversity indicators, and data-sharing practices. By adhering to these standards, stakeholders in the offshore wind industry can better understand, minimise, and manage their ecological footprint. Through transparent and accessible data, they can also help shape a global standard that promotes consistency, comparability, and continuous improvement across the sector.

By embedding biodiversity at the heart of energy planning, we can advance a future where renewable energy development supports both planetary and human well-being. Together with this paper, we provide a Navigator checklist to support the development of a monitoring plan for offshore wind development. All publications are available at gingr.org.

Contents

© PJ Stephenson. Seas and coasts are subject to a diverse array of human uses and activities.

Acronyms

BRUV	Baited Remote Underwater Video
EC	European Commission
EIA	Environmental Impact Assessment
EMODnet	European Marine Observation and Data Network
EU	European Union
EurOBIS	European Ocean Biodiversity Information System
GBIF	Global Biodiversity Information Facility
HELCOM	Helsinki Commission
ICES	International Council for the Exploration of the Sea
IUCN	International Union for Conservation of Nature
NGO	Non-Governmental Organisation
OBIS	Ocean Biodiversity Information System
OCEaN	Offshore Coalition for Energy and Nature
OSPAR	Commission derived from the Oslo and Paris Conventions on the North-East Atlantic
RGI	Renewables Grid Initiative
SEA	Strategic Environmental Assessment
TSO	Transmission System Operator

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Executive Summary

This document provides biodiversity monitoring guidance for offshore wind energy developments. Four principles should be kept in mind during the development and implementation of monitoring strategies for biodiversity around offshore wind farms.

- Principle 1: Key stakeholders should be engaged in planning and implementing biodiversity monitoring.
- Principle 2: Monitoring methods should be based on the indicators being measured and the questions being asked.
- Principle 3: Invest in and build capacity where it is most needed.
- Principle 4: Data should be shared and made freely and openly accessible to others.

Key steps required to develop and implement biodiversity monitoring strategies around offshore wind farms are then explained.

- Step 1: Define the scope and the spatial and temporal scales for the monitoring strategy.
- Step 2: Identify target taxa and habitats for monitoring, to focus on those species most impacted by offshore wind development or associated Nature-Positive action.
- Step 3: Develop the key elements of a monitoring plan, which include:
    - Indicators.
    - Methods and data sources.
    - Defining timing and frequency.
    - Roles and responsibilities.
    - Survey design considerations.
    - Minimum monitoring requirements are also explained for marine birds, bats, marine mammals, fish and seabed communities.
- Step 4: Manage, share and analyse data.
- Step 5: Use data.

The guidance ends by discussing key issues to address in the future. There is a need to fill key knowledge gaps and to enhance regional and sectoral collaboration on standardising monitoring protocols and data collection formats to facilitate data sharing and results-based decision-making. Annexes provide links to key resources and tools for biodiversity monitoring, including tools for developing biodiversity indicators and monitoring plans, and data sources of potential use in monitoring; case studies related to monitoring in offshore wind farms; and key references.

Keywords: biodiversity; data; indicators; monitoring.

Introduction

Offshore renewable energy, in particular wind power, is central to global efforts to reduce greenhouse gas emissions and tackle climate change. However, offshore wind farms[1] and their associated submarine power cables and grid infrastructure have potential impacts on biodiversity that need to be quantified and minimised. While the precise environmental footprint of an offshore wind farm will depend on the design or type of technology used (e.g. bottom-fixed versus floating turbines; meshed versus radial grid connections), as well as its location in relation to threatened habitats, bird migration routes, and other natural features, there are several potential impacts on biodiversity. Birds and bats can collide with turbines, habitat loss and degradation can be caused by construction, and there can be adverse effects on wildlife from construction and operation noise, pollution from construction and maintenance vessels, and electromagnetic fields generated by submarine power cables (Gill, 2005; Boehlert & Gill, 2010; Perrow, 2019). If wind farms are placed close together, they can lead to cumulative impacts on biodiversity, multiplying effects as well as compounding other anthropogenic pressures (King et al., 2015; Nogues et al., 2021).

Data are essential for effective maritime spatial planning. In most countries, offshore wind energy operators and transmission system operators (TSOs) are obliged to conduct environmental impact assessments (EIAs) or strategic environmental assessments (SEAs) before developing wind farms and grid infrastructure[2]. These studies usually advocate ongoing biodiversity monitoring through construction and operation to help assess the impacts on nature and the effectiveness of the mitigation measures applied. In addition, as advocated by OCEaN (the Offshore Coalition for Energy and Nature) and RGI (the Renewables Grid Initiative), many offshore energy companies and TSOs are working with governments, researchers, and NGOs to strive for Nature-Positive outcomes, either by applying appropriate nature-inclusive designs or by actively restoring relevant habitats and marine species. Monitoring of these activities and their outcomes is essential to ensure any failures are learned from and successes replicated.

Therefore, it is vital that the marine fauna and flora around offshore wind farms and grids are surveyed during the planning phase of development and that the monitoring of species and the pressures they face is continued during the operational lifetime of the infrastructure, as well as through any repowering and decommissioning phases. However, the methods used to collect data vary between sites and countries and it is often difficult to access available information (Copping et al., 2017; Methratta & Dardick, 2019). The problems faced in collecting data around offshore wind farms are further compounded by the general challenges in monitoring marine biodiversity, including the fact that most species are small and live underwater, and marine

[1] The term offshore wind farm refers to a group of wind turbines placed in the sea to harness offshore wind energy.
[2] In Europe, the assessment of the environmental effects of development are mandated by EU Directive 2011/92/EU: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0092

conditions are often unfavourable to species detection, especially during inclement weather and in high seas. As a result, many actors struggle to acquire the biodiversity data they need.

The aim of this document is to provide biodiversity monitoring guidance for offshore wind development going forward. Where appropriate, other reviews and guidelines on monitoring (e.g., CMP, 2020; Stephenson, 2021; Stephenson & Carbone, 2021) have been taken into account.

Annexes provide additional information of use: links to key tools of use for monitoring in Annex 1; some case studies related to monitoring in offshore wind farms in Annex 2; and key references and resources in Annex 3. A checklist of actions to consider in creating a monitoring plan is published alongside this guidance document.

Principles for Enhancing Monitoring of Nature Around Offshore Wind Energy

As described in the RGI report on offshore monitoring needs in Europe (Stephenson, 2021), a more integrated approach to biodiversity monitoring needs to be developed for the sector, using multiple, harmonised systems and tools to monitor multiple species and pressures concurrently. While precise survey and monitoring needs and methods used at a given site will depend on environmental conditions and legal frameworks, the use of a more standardised approach across the sector, with at least some common indicators and common monitoring methods used at each site, will greatly help to compare sites, aggregate data, and study cumulative impacts, as well facilitating results-based decision-making.

Based on lessons learned, four principles should be kept in mind during the development and implementation of monitoring strategies for biodiversity around offshore wind farms.

Principle 1: Key stakeholders should be engaged in planning and implementing biodiversity monitoring

Involving key stakeholders is a key factor in the development, implementation and monitoring of biodiversity strategies across sectors (IFC, 2012; CMP, 2020; Stephenson & Carbone, 2021). The stakeholders involved in the development of a given offshore wind site (government departments, companies, TSOs, contractors, NGOs, scientists) should work together from the outset on designing and implementing biodiversity monitoring plans. Ideally this should be in the context of a national monitoring programme for offshore wind energy.

Principle 2: Monitoring methods should be based on the indicator being measured and the questions being asked

The development of indicators needs to follow best practices to ensure they are feasible, consistent and relevant to a specific wind energy impact on a specific taxon or habitat. Wherever possible, indicators common across offshore wind farms need to be used to help facilitate data aggregation. Methods should be chosen primarily due to their relevance to the indicators being measured and the monitoring questions they are being used to answer. While in some cases they will also be influenced by company policies, the available budget and capacity to implement them, or national standards or legal requirements, they should be harmonised as much as possible between sites.

Principle 3: Invest in and build capacity where it is most needed

Collecting and using biodiversity data requires the mobilisation of relevant technical capacity and expertise across the key stakeholders, from energy companies and wind industry organisations and TSOs to academic institutions, NGOs and consultancies.

Principle 4: Data should be shared and made freely and openly accessible to others

There is a need for improved co-ordination and collaboration at national, regional and global levels to improve data collection and sharing in the context of offshore wind development in particular and maritime spatial planning in general (e.g. Stephenson, 2021; OCEaN, 2022a). Free and open access data sharing under the Creative Commons open-source Attribution 4.0 International[3] should be mandatory in permitting and auctioning processes as it will help contribute to biodiversity monitoring and research efforts and enhance transparency. Learning and sharing lessons will also help improve the impact of Nature-Positive initiatives.

© PJ Stephenson. Sea ducks such as the common eider (Somateria mollissima) are considered to be at high risk from offshore windd evelopments and are a priority for further research according to BirdLife International.

[3] https://creativecommons.org/licenses/by/4.0/deed.en

Key Steps to Develop and Implement Biodiversity Monitoring Strategies

Step 1: Define the scope and the spatial and temporal scales for the monitoring strategy.

The scope of the monitoring strategy should be devised around the key questions that need answering. For most offshore wind farms these questions will include:

- Which marine species and habitats occur in the area before and after construction?
- Are there any seabird or seal colonies in the area that might be foraging or breeding at the site?
- What is the distribution and abundance of the species that are present? (e.g. How abundant are the fish populations and how diverse in terms of size and community composition?)
- Is the site used by migratory birds? Which ones and in which periods of the year?
- Are there any protected areas present that need to be safeguarded?
- How severe are the threats to marine life? For example, what is the level of noise? What is the distribution and abundance of invasive alien species?
- Does the distribution and abundance of species change as a result of wind farm construction, operation, repowering or decommissioning or the laying of sub-sea cables?
- Is there evidence of behavioural traits that place birds at risk (such as flying at rotor blade height or foraging near farms)?
- Are mitigation measures and Nature-Positive actions impacting the fauna and flora?

Monitoring strategies may have a thematic scope (e.g., focused on certain pressures or Nature-Positive responses), taxonomic scope (e.g., fish, marine mammals) or geographic scope (e.g., a given wind farm, national waters, a sea basin), or some combination of all three. However, an integrated strategy covering all main taxa and habitats is encouraged.

The spatial scale of monitoring tends to be the offshore wind farm and a suitable buffer zone (Annex 2 - Case Study 1) although, depending on the actors and the goal, it may be national or sea basin level, especially if cumulative impacts are being investigated. Principles used in International Finance Corporation Performance Standard 6 (IFC, 2012) should be considered as they include for the marine environment Project Area of Influence, seascape, Ecologically Appropriate Area of Analysis, and processes and functions for wide-ranging species (Cousins & Pittman, 2021), all of which are pertinent for offshore wind. Note, too, that Habitats Regulation Assessments and European

Protected Species Licensing processes also require data beyond the development's site boundaries, meaning that any data from the site-specific surveys must be supplemented with additional information (Thompson et al., 2014).

National monitoring policies and standards usually suggest monthly surveys continuous across contiguous seasons for at least 2-3 years before consent and up to 5 years after, then phased down and restarted prior to decommissioning. Since many species change location throughout the year (birds, for example, may have different breeding, passage and wintering areas), monitoring must consider temporal change (RSPB, 2012). Hemery (2020) noted that some authors recommend that monitoring studies last more than three years to enable accurate measurement of extreme and subtle changes (Wilding et al., 2017), if not six to eight years to cover the recovery timeframe of some cable sites (Kraus & Carter, 2018; Taormina et al., 2018). However, at least some indicators may be best monitored throughout the operational life of the wind farm, especially if the results of Nature-Positive actions are being measured.

Step 2: Identify target taxa and habitats for monitoring, to focus on those species most impacted by offshore wind development or associated Nature-Positive action

Although national regulations will dictate precisely what taxa and pressures are monitored, there should be a concerted approach to focus on those species most impacted by offshore wind farms, namely marine birds, seals, small cetaceans and the benthic fauna and flora (infauna and epifauna) (Bennun et al., 2021; Danovaro et al., 2024).

Monitoring needs to be adapted depending on the phase of wind farm development to take account of the different impacts on different taxa. For example, surveys at the planning stage rely more on data on the presence of threatened or sensitive species and habitats; the construction phase has bigger impact on habitats, mammals and fish; operating wind farms have bigger impacts on birds. The decommissioning phase is still relatively new and less well understood. Service vessels will operate throughout the phases of wind farm development and will need to monitor mammal observations constantly to avoid collisions.

Therefore, monitoring across all stages of development should focus on measuring regularly the abundance, distribution and behaviour of marine birds and marine mammals. The benthic and demersal habitats and species should be more of a focus in planning and then measured every few years. Pre-consent surveys will need to factor in relevant national legislation and expectations for EIAs or SEAs but should include an assessment of fish and benthic invertebrates, and the proximity to, and extent of, priority habitats and protected areas, such as Natura 2000 sites.

Step 3: Develop the key elements of a monitoring plan

A monitoring plan will need to consider national or regional strategies, policies and legal frameworks. For example, given the strategies and agreements in place in Europe, wherever possible the monitoring of marine biodiversity and the pressures it faces around offshore wind and grid development should factor in and prioritise:

- species and habitats listed as important by EU directives such as the Habitats Directive and the Birds Directive
- regional species priorities identified in the regional seas action plans, such as those for the Baltic Sea and North Sea;
- actions to minimise pressures, especially noise, pollution and invasive alien species;
- the sharing of data with EU-supported databases like EMODnet (see Annex 1.2), as well as national databases.

3a Indicators

Indicators should measure a change in biodiversity state (e.g., species abundance; habitat cover) or a change in the pressure on biodiversity (e.g., number of invasive alien species; level of noise; level of pollution; number of bird strikes). Some indicators will also be required to measure changes in activities that cause or mitigate pressures (e.g., number of incidents of shutdown-on-demand, area of mussel beds restored, painting of blades in black or red). Such a state-pressure-response framework helps identify relationships and correlations between inter-related indicators and show change along a theory of change. If the indicators used are common across different sites or monitoring strategies, it helps facilitate comparisons and data aggregation (Stephenson & Carbone, 2021).

Key state indicators for offshore wind revolve around species occurrence, diversity, abundance or relative abundance, habitat extent, and proximity to and use of the offshore wind area. Key pressure indicators focus on noise, pollution and invasive alien species. Response indicators (sensu Stephenson & Carbone, 2021) will also be needed to answer questions such as what tools have been applied to mitigate impacts or what Nature-Positive actions have been taken. Whatever the methods used to collect data, the same unit of measurement needs to be used for each indicator at each site. Some of these indicators have already been aggregated and compared between sites, such as the study of abundance trends in fish (Methratta & Dardick, 2019; Annex 2 - Case Study 2).

As a rule, indicators should be:

- scientifically credible (e.g., using methods that have been peer-reviewed in the scientific literature);
- feasible and cost-effective to apply (i.e., data can be collected either directly or through others using identified methods);

- measurable (in quantitative or qualitative terms);
- precise (defined the same way by everyone who uses them);
- consistent (always measuring the same thing);
- understandable (everyone who is concerned by the results can interpret what they mean);
- relevant to a specific offshore wind energy impact on specific species groups or habitat types or to a specific Nature-Positive intervention;
- sensitive to changes in the state of biodiversity or the pressures placed upon it.

3b Methods and data sources

"*Consistent and continuous environmental monitoring should be applied in order to assess the results of mitigation measures, nature-inclusive designs and restoration projects*" and "*be the basis of adaptive management*" (ENTSO-E, 2024). Stephenson & Carbone (2021) note that monitoring methods should be accurate (with minimal error), reliable (consistently repeatable with minimal variation in results), cost-effective, feasible to use, appropriate (in this case, ensuring they answer specific questions and are statistically meaningful) and precise enough to measure the change monitored and to signal any relevant thresholds identified.

Wherever possible, methods used should follow established standardised protocols to ensure harmonised approaches and to follow best practices for ensuring robust sampling design, statistical power (see below) and consistent replication of methods. Some flexibility is needed and in choosing the most appropriate method and protocol for a given case, a range of factors must be considered including the relevant taxa impacted and the remoteness of the site.

Choice of method should involve weighing up the various pros and cons of the options available (as summarised in Stephenson, 2021). Cost is always a key factor to consider. If resources are limited, extra care must be taken in choosing methods. Note that some methods that appear to save time and money may have hidden costs. For example, sensors such as cameras and acoustic recording devices may collect data more quickly than human observers, but upfront equipment costs and the extensive data processing and analysis time and expertise required may mean they are not as economical overall. In the planning stage of the monitoring strategy, all potential elements need to be costed to help inform the final choice of tool.

Based on current needs and practices, the methods most likely to be used across offshore wind farms include digital aerial surveys, passive acoustic monitoring, underwater video surveys and grab sampling. Digital camera footage from aerial or underwater surveys and acoustic recordings has the advantage of providing a permanent and verifiable record of detections, which is especially useful given the long timeframe of offshore wind site monitoring (Thompson et al., 2014; Williamson et al., 2016). If new technologies are used for monitoring, different software applications or artificial intelligence systems may be able to help with data processing or analysis (Ditria et al., 2022).

While there are some methodological differences for monitoring different taxa, many rely on similar vehicles or sensors. If deployed at the same time, it would maximise cost efficiencies (e.g., in boat or aircraft hire; observer salaries). Therefore, options to integrate surveys to monitor multiple taxa concurrently should always be explored. This is already happening for marine mammals and birds which can be monitored with the same digital aerial survey and the same vessel transect by different observers, for example with European Seabirds at Sea surveys (Macleod et al., 2011). However, if different methods are used on the same platform, "*it is important that surveys for birds and marine mammals are conducted by specific staff trained for that purpose and that the two surveys are conducted simultaneously but separately with no interference between them*" (Macleod et al., 2011).

Therefore, an integrated approach should be adopted to biodiversity monitoring around offshore wind farms, using harmonised methods to address the key indicators across multiple taxa. This is in line with other recommendations that encourage the complementary use of multiple methods and tools in an integrated approach (e.g., Kunz et al., 2007; Walls et al., 2009; BSH, 2013; Molis et al., 2019; Smith et al., 2020; Annex 2 - Case Study 3).

While every offshore wind energy operator will need to monitor biodiversity around wind farms, experience from conservation projects (e.g., Stephenson et al., 2015) demonstrates that in situ data can often be complemented by data from other sources. A suite of national, regional and global data sources is available that may prove useful in some cases (see Annex 1).

3c Defining timing and frequency

The timing and frequency of data collection will be dependent on the questions being asked, the indicators chosen and the taxa concerned. National guidelines in Europe generally recommend monthly surveys before and after construction. However, it may not always be practical or cost-effective to conduct surveys monthly, especially for more remote offshore sites. Stephenson (2021) suggests that, while some data may need to be collected monthly in some sites, in others it may prove more effective and efficient to conduct more intense and more widespread surveys less often during periods with maximum detection power. It should also be noted that monthly surveys over several years may prove costly, as well as causing added risk, such as having to conduct surveys in high seas or extreme weather.

The key is to ensure monitoring is applied for long enough to see long-term change in the metrics, as well as to cover the changes caused by the offshore wind development or Nature-Positive actions. Generally, response indicators will be measured more frequently than pressure indicators, and pressure indicators will be measured more frequently than state indicators. Note that for a rare species it is more efficient to survey more sampling units less intensively, while for a common species fewer sampling units should be surveyed more intensively (MacKenzie & Royle, 2005).

3d Roles and responsibilities

The individuals or organisation(s) responsible for collecting data for each indicator need to be explicitly described in the monitoring strategy. If a national offshore wind energy monitoring programme is in place, roles should be harmonised with that. Consultation and collaboration need to be extensive from the beginning of the planning phase and include all key stakeholders, including the universities and consultants who will carry out the work, to ensure everyone is clear on roles and responsibilities. Advantages of early collaboration include having scientists work with the design and development team from the outset to plan for the mounting of monitoring sensors on wind turbine jackets, so they can be factored into weight loading calculations and construction plans. There is also a need to co-ordinate activities of different stakeholders active in the offshore sites, especially to ensure that monitoring vessels or C-PODs (Cetacean and Porpoise Detectors) do not obstruct construction vessels and vice versa, and to adapt programmes based on unexpected delays. It might also be worthwhile to explore opportunities for collaborating on biodiversity monitoring with other users of the seas around offshore wind farms, such as fisheries and shipping companies. Such collaboration is widely encouraged in the sector (e.g., Thaxter & Burton, 2009; Macleod et al., 2011). For example, in the UK, expert input on site-specific survey and monitoring design is typically carried out during an early consultation process between industry and government bodies (Statutory Nature Conservation Bodies and regulatory bodies) to sign off on the survey methods and study design to be used (Piggott et al., 2021).

3e Survey design considerations

Proper sampling methods need to be used. For example, analyses of transect surveys need to use distance sampling (Buckland et al., 2001) and DISTANCE[4] software (Thomas et al., 2010). Other software is available to help account for the differing detectability of different species in different habitats; as well as DISTANCE for distance sampling, PRESENCE[5] can be used for occupancy, and SPECRICH[6] for species richness.

Power analyses should be used to determine how much data is sufficient to answer the monitoring question (Scheidat & Porter, 2019). This helps avoid being data rich but information poor. Several protocols highlight the minimum number of observations needed to detect change. For example, Buckland et al. (2001) recommend that at least 60-80 sightings are required for distance sampling analysis. All surveys should correct for observer bias and availability bias by verifying detection probability using standard methods (Macleod et al., 2011; Sheidat & Porter, 2019). Furthermore, survey design needs to ensure that all portions of the study area have an equal probability of being surveyed; for mammals, this might mean placing at least 10-20 replicate transect lines in a systematic but randomised manner "*to provide a basis for an adequate variance of the encounter rate and a reasonable number of degrees of freedom for constructing confidence intervals*" (Sheidat & Porter, 2019). Other aspects of the monitoring protocols will need

[4] https://distancesampling.org/Distance/
[5] https://www.mbr-pwrc.usgs.gov/software/presence.shtml
[6] https://www.mbr-pwrc.usgs.gov/software/specrich.shtml

to be adapted as necessary for local conditions. For example, during digital aerial bird surveys, flight height (usually about 450 m) can be lowered if no disturbance is caused to species, and increased resolution is required for species identification (Thaxter & Burton, 2009).

Wherever possible, all biodiversity-related surveys should be conducted using a before-after control-impact (BACI) design or a before-after-gradient (BAG design) to demonstrate or infer cause and effect. While both methods can be effective, for certain indicators, such as fish or bird distribution and abundance and impact variables such as noise from pile driving, a BAG design may be more effective at detecting meaningful change (Vanermen & Stienen, 2019; Scheidat & Porter, 2019; Methratta, 2020) and so is preferred in the design of offshore wind biodiversity monitoring. In a BAG analysis, the offshore wind farm is placed in the centre of a large survey area and its effects are assumed to be a function of distance from the wind farm. A significant before-after change that declines with distance from the wind farm provides evidence that the wind farm is the cause of the change. The same approach can be used for submarine power cables.

3f Minimum monitoring requirements

Based on the finding of the RGI monitoring review (Stephenson, 2021), the following represent the minimum requirements for biodiversity monitoring around offshore wind developments and associated grid infrastructure and the main methods of use (to be complemented by additional monitoring where necessary depending on the phase and type of operation, site-specific or species-specific needs, legal requirements and budget).

Monitoring marine birds and bats – The presence, diversity and abundance of birds and bats, as well as habitat use, should be monitored during all four operational stages (planning, construction, operation and decommissioning). Threats such as collisions with turbines also need to be monitored. Favoured methods are digital aerial surveys, static passive acoustic monitoring and targeted telemetry, complemented by vessel-based surveys (especially for behaviour data or where other options are not feasible).

Monitoring marine mammals – The presence, diversity and abundance of seals and toothed cetaceans should be monitored at all four operational stages, as well as habitat use and anthropogenic noise levels. Favoured methods are digital aerial surveys, static passive acoustic monitoring and targeted telemetry, complemented, when necessary, by vessel-based surveys.

Monitoring fish and seabed communities – The presence, diversity and relative abundance of fish species and benthic invertebrates and plants, the extent and quality of natural habitats, and key threats such as noise, pollution and invasive alien species should be monitored. Favoured monitoring methods are grab sampling and video (drop-down/ROV/AUV) for habitats and benthic species and fyke-net sampling for fish complemented, when necessary, by scuba diving for all species telemetry and BRUVs for fish, and acoustic mapping of the seabed habitats

Step 4: Manage, share and analyse data

If data on common indicators can be collated in standard formats, using standard typologies and definitions, they will be easier to aggregate and share, thereby enhancing our ability to conduct meta-analyses, to contribute to new EIAs, and to improve our understanding of cumulative effects. In addition to data collection protocols and standards for specific monitoring methods, there are general data standards that can provide the shared rules and conventions to describe, record and structure datasets and facilitate management and sharing of data. These are numerous biodiversity data standards (Biodiversity Information Standards, 2020) but the three most commonly used (GBIF, 2024) are:

- The Darwin Core Standard - a stable, straightforward and flexible framework for compiling biodiversity data from varied and variable sources.
- Ecological Metadata Language or EML - a metadata standard that records information about ecological datasets in a series of modular and extensible XML document types.
- BioCASe Access to Biological Collections Data (ABCD) data exchange standard – developed by the Biological Collection Access Service (BioCASe), an international network linking biological collections data from natural history museums, botanical/zoological gardens and research institutions.

There is also a Maritime Spatial Planning Data Framework that explains how to structure input data for MSP process, monitoring and evaluation (Abramic et al., 2023).

People are less likely to be willing to use biodiversity data when the data are difficult to interpret, so data providers and data users need to collaborate on producing data and data-derived products in formats, such as dashboards or maps, that facilitate interpretation and aid decision-making.

All actors should consider it compulsory to openly share the data from offshore wind monitoring so that it can be used by other stakeholders and help contribute to national, regional or global biodiversity monitoring efforts (Annex 2 – Case Study 4). Data should be added to national, regional and global data sources, and through platforms such as EurOBIS (European Ocean Biodiversity Information System) and EMODnet, with a focus on ensuring it is freely and openly accessible. In addition, "*increased reporting of survey and monitoring results in the peer-review literature and other accessible venues would greatly advance the scientific community's understanding of wind farm effects*" (Methratta & Darcik, 2019). Reports from EIAs and SEAs that assess offshore wind sites, and reports generated by ongoing biodiversity monitoring systems around planned and operational sites, should be published and posted online to disseminate lessons and trends.

Factors that provide a suitable enabling environment for data sharing include the existing regional efforts to set common indicators and collate data through HELCOM and OSPAR. There are also efforts to standardise data collection formats for Europe through EurOBIS and EMODnet. If common data standards are applied more widely, data could then be aggregated or disaggregated at multiple levels and be linked across databases. Several regional data sources are linked directly to, and share data with global data sources. For example, data from EurOBIS feeds into OBIS (Ocean Biodiversity Information System) which is itself linked to GBIF (Global Biodiversity Information Facility). A similar level of effort to use common data collection protocols and share data needs to be applied to the offshore wind sector (e.g., Fox et al., 2006; Bennun et al., 2021), but this will require some form of coordination and leadership to make it happen.

Some examples exist of biodiversity data from offshore wind developments being shared in countries such as Australia, Belgium (Annex 2 – Case Study 4) and Canada (see Bennun et al., 2021), and these efforts should be built on to create a data-sharing culture within the sector. Furthermore, opportunities should be examined for increasing the scope and use of other existing information sharing platforms, such as the WREN Knowledge Base (Tethys, 2024) and the Marine Data Exchange (Crown Estate, 2024).

Step 5: Use data

There is no point in collecting data if they are not used. It is vital that offshore wind operators and other stakeholders set aside time to discuss and act on monitoring data in formal and informal meetings. Review of results should be used not only to inform maritime spatial planning and adaptive management (to continue and replicate what works well, and to change what is not working well) but it should also be used to determine if the monitoring system is delivering. If any indicators are not working or methods are not providing the data needed, the indicator or the method should be changed as soon as possible.

In Europe, legislative frameworks are shifting towards more non-financial disclosures (European Commission, 2024), as demonstrated by the EU's Non-Financial Reporting Directive (Directive 2014/95/EU) and the new Corporate Sustainability Reporting Directive (Directive 2022/2464/EU). The combination of growing interest and engagement and increasing policy and legislation incentives will facilitate a significant upsurge in corporate biodiversity commitments in coming years, with Europe as a key hub (Stephenson & Walls, 2022). Such approaches will be further adopted by companies keen to demonstrate their contributions to global commitments, such as the Kunming-Montreal Global Biodiversity Framework and the Sustainable Development Goals. Therefore, effective monitoring will enable energy companies and TSOs to report on their biodiversity disclosures.

The Way Forward

Fill knowledge gaps

Further research and development are required to improve our knowledge of key pressures and impacts that may need to be monitored and to integrate new technologies into more holistic monitoring systems. Priority research topics include the following:

- The levels of collision experienced by bats, and the adverse effects of offshore wind energy on marine turtles.
- The impacts on marine biodiversity of electromagnetic fields (especially from submarine power cables) and pollution such as oil spills from vessels involved in construction, maintenance and decommissioning.
- The most Nature-Positive way of decommissioning offshore wind infrastructure, and if, and how best, to restore sites.
- The potential for new techniques to be integrated into offshore monitoring systems, especially environmental DNA metabarcoding techniques for assessing species diversity and relative abundance, baited remote underwater video for fish and possibly crustaceans, light traps for benthic invertebrates, acoustic soundscapes for fish and crustaceans, and the systematic monitoring of ship hulls for invasive alien species.

Cumulative impacts need to be assessed to find out how multiple offshore wind farms can impact species populations and add to other anthropogenic pressures. Although such assessments remain challenging (e.g., Lindeboom et al., 2015; Scheidat & Porter, 2019), cumulative impact assessment frameworks (e.g., van Oostveen et al., 2018) need to be developed further and will be better facilitated if data are shared between stakeholders.

Enhance regional and sectoral collaboration on standardising monitoring protocols and data collection formats that facilitates data sharing and results-based decision-making

An abundance of effort and resources is already invested in researching and monitoring marine biodiversity around offshore wind farms and, to a lesser extent, the submarine power cables that make up the offshore grid. If stakeholders could enhance the level of collaboration and coordination across borders and sites to identify common indicators and standardise methods and data collection formats, then the availability and use of data for decision-making in the offshore wind sector would be greatly enhanced, and cumulative impacts better understood. Such collaboration and adoption of more standardised approaches would improve results-based management and decision-making and ultimately reduce the impacts of offshore wind and associated power grids on biodiversity, enhancing the sustainability of energy production.

All key stakeholder groups will need to work together more closely across projects and countries. Existing initiatives, such as the Offshore Coalition for Energy and Nature (OCEaN), would be a good starting point, building on collaborative reviews of monitoring already conducted for birds (Piggott et al., 2021) to consider how to enhance and harmonise monitoring of other taxa and of habitats.

Other collaborative initiatives should also be engaged and opportunities sought for their input into offshore wind monitoring. Examples include the Joint OSPAR/HELCOM/ICES Working Group on Seabirds[7] whose applied science work includes the development of common bird indicators under the EU's Marine Strategy Framework Directive. Similarly, the ICES Working Group on Marine Mammal Ecology[8] reviews information on, for example, population sizes, distribution, and management frameworks for marine mammals in the North Atlantic and impacts on marine mammals from marine industries. These bodies could be engaged in helping to agree on and apply common offshore wind indicators. Efforts to enhance co-ordination in the offshore wind sector should also learn lessons from other Europe-wide monitoring schemes, such as those in place for monitoring contaminants, radioactivity and sea temperature (Bean et al., 2017), as well as looking to other parts of the world. Canada and the USA have active national marine monitoring schemes and an expanding offshore wind sector. Australia is a world leader in marine science and is at the forefront of many of the newer monitoring methods that should be tested, like BRUVs and multi-beamer echosounder sonar (Przeslawski et al., 2019).

Ultimately, greater teamwork and enhanced partnerships (such as those provided by GINGR) will be a key factor in ensuring marine actors share lessons and data and improve biodiversity monitoring around offshore wind developments.

[7] https://www.ices.dk/community/groups/Pages/jwgbird.aspx
[8] https://www.ices.dk/community/groups/Pages/WGmme.aspx

Annex 1: Links to Key Resources and Tools for Biodiversity Monitoring

1.1 Tools for Developing Biodiversity Indicators and Monitoring Plans

There is abundant guidance on how to define or choose biodiversity indicators and develop monitoring plans, including:

- The Conservation Standards
  - CMP - Conservation Measures Partnership, 2020. Open Standards for the Practice of Conservation. Version 4. Bethesda, USA: CMP. Available at: https://conservationstandards.org/download-cs/#downloadcs
- IUCN guidelines for business
  - Addison, P. F. E., Carbone, G. and McCormick, N., 2018 The development and use of biodiversity indicators in business: an overview. IUCN, Gland, Switzerland. https://portals.iucn.org/library/sites/library/files/documents/2018-049-En.pdf
  - Stephenson, P.J. and Carbone, G., 2021. Guidelines for Planning and Monitoring Corporate Biodiversity Performance. IUCN, Gland, Switzerland. https://portals.iucn.org/library/node/49301
- UNEP-WCMC guidelines
  - Brown, C., Reyers, B., Ingwall-King, L., Mapendembe, A., Nel, J., O'Farrell, P. et al., 2014. Measuring Ecosystem Services: Guidance on developing ecosystem service indicators. United Nations Environment Programme World Conservation Monitoring Centre, Cambridge, UK. https://resources.unep-wcmc.org/products/WCMC_CB001
- Aid agency project guidelines
  - UNDP - United Nations Development Programme, 2009. Handbook on Planning, Monitoring and Evaluating for Development Results. UNDP, New York, USA. https://www.undp.org/turkiye/publications/undp-handbook-planning-monitoring-and-evaluating-development-results
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- Advice offered in various journal articles (e.g. Stephenson, 2019; Addison et al., 2020)
  - Addison, P.F., Stephenson, P.J., Bull, J.W., Carbone, G., Burgman, M., Burgass, M.J., Gerber, L.R., Howard, P., McCormick, N., McRae, L., Reuter, K.E., et al., 2020. Bringing sustainability to life: A framework to guide biodiversity indicator development for business performance management. Business Strategy and the Environment, 29(8), pp.3303-3313. https://onlinelibrary.wiley.com/doi/full/10.1002/bse.2573
  - Stephenson, P.J., 2019. The Holy Grail of biodiversity conservation management: monitoring impact in projects and project portfolios. Perspectives in Ecology and Conservation, 17(4), pp.182-192. https://www.sciencedirect.com/science/article/pii/S2530064418301743
- Guidelines tailored for the corporate sector may also sometimes be of use to offshore wind energy projects
  - Natural Capital Coalition, 2016. Natural Capital Protocol. NCC, London, UK. www.naturalcapitalcoalition.org/protocol

  - TNFD, 2023. Recommendations of the Taskforce on Nature-related Financial Disclosures. https://tnfd.global/publication/recommendations-of-the-taskforce-on-nature-related-financial-disclosures
- Guidance specifically aimed at biodiversity monitoring in the offshore wind energy sector includes:
  - Stephenson, P.J., 2021. *A Review of Biodiversity Data Needs and Monitoring Protocols for the Offshore Wind Energy Sector in the Baltic Sea and North Sea.* Report for the Renewables Grid Initiative, Berlin, Germany. https://renewables-grid.eu/publications/study-offshore-biodiversity.html
  - Kershaw, F., Jones, A., Folsom-O'Keefe, C., Johnson, E., Newman, B., Liner, J., Clarkson, C., Swanson, R., Fuller, E., Krakoff, N., et al., 2023. *Monitoring of Marine Life During Offshore Wind Energy Development—Guidelines and Recommendations. Report by American Bird Conservancy.* https://tethys.pnnl.gov/publications/monitoring-marine-life-during-offshore-wind-energy-development-guidelines

1.2 Data Sources of Potential Use in Monitoring

Source: Stephenson, 2021

National Data Sources

Many signatories of regional seas conventions, such as HELCOM and OSPSAR nations, are monitoring biodiversity indicators. These data are usually stored in national databases, which may be managed by governments, universities or NGOs. These data sources are diverse and often unconnected. Some countries will have multiple data sources for certain taxa depending on who collects the data and how, and where they decide to store it. For example, BirdLife International identified 183 data sources for birds in 12 Baltic and North Sea countries (Piggott et al., 2021). These data sources covered anything from a single species to all seabirds, with data that had a temporal range of one year to over 40 years. Other national databases used for regional assessments include MUMM (Management Unit of the Mathematical Model of the North Sea) by the Royal Belgian Institute of Natural Science, the JNCC Offshore Wind Strategic Monitoring and Research Forum data in the UK, and data used in applying the Symphony marine spatial planning tool in Sweden. In the UK, the Crown Estate (2021) has also established a Marine Data Exchange website to provide access to survey data and reports collected on offshore renewables. Many national data sources have information on species distribution and relative abundance (especially for marine mammals and marine birds) that is of potential use to offshore wind sites, especially during the pre- and post-consent survey and development phases.

Regional Data Sources

Several data sources collate biodiversity information from within specific sea basins (e.g., HELCOM and OSPAR data management systems) or from across a region (e.g., EurOBIS, EMODnet). As with national data sources, many of these regional data sources have information on species distribution and relative abundance (especially for marine mammals and marine birds) that is of potential use to offshore wind sites. Examples include:

Data source	Lead agency	Description
EurOBIS - European Ocean Biodiversity Information System	Flanders Marine Institute (VLIZ)	Distribution data on marine species, collected within European marine waters or collected by European researchers outside European marine waters. Over 1,000 data sets. Linked to OBIS and GBIF.
EMODnet Biology Data Portal	European Marine Observation and Data Network (EU)	Free access to data on temporal and spatial distribution of marine species (plus marine species traits) from all European regional seas. EMODnet Biology is part of the EU-funded European Marine Observation and Data Network and is built upon the World Register of Marine Species and EurOBIS. Metadata from almost 1,000 thematic databases.
European Seabirds at Sea (ESAS) database Available from OBIS-SEAMAP	JNCC ICES Data Centre	Ship and aerial at-sea survey data from national parties covering seabird and marine mammal distribution in offshore areas. Over 3 million records of seabirds, cetaceans, pinnipeds, and other marine megafauna from NW European and North Atlantic waters. Largest database of at-sea seabird distributions, with data collected and contributed by the 10 European countries comprising the ESAS partnership.
HELCOM's Map and Data Service	HELCOM	Contains all geospatial data relevant for HELCOM work from status assessments to shipping density maps. Contains various functionalities for viewing datasets.
ICES Data Portal	International Council for the Exploration of the Sea (ICES)	Datasets are organised around specific thematic data portals. The biodiversity database hosts seabird and seal abundance and distribution records and is linked to ICES working groups on seabirds and marine mammals.
SEATrack database	SEAPOP: SEAbird POPulations project	Global location sensor data on the non-breeding distribution of 10 seabird species breeding in colonies encircling the Labrador, Greenland, Barents, Norwegian, North and Irish Seas, which includes colonies in Canada, Greenland, Russia, Norway (incl. Svalbard and Jan Mayen), Iceland, the Faroe Islands, Ireland, and the United Kingdom.
OSPAR's Data & Information Management System	OSPAR	A platform for accessing OSPAR's geospatial maps, data and metadata. Includes datasets on habitats, marine ecosystems and several pressures, though nothing on species populations.

Global Data Sources

There are numerous global data sources of potential use in monitoring biodiversity[9], of which many are of potential use for assessing or monitoring offshore wind sites. Examples include:

Data source	Lead agency	Description
Aqua Maps	FishBase and SeaLifeBase	Generates model-based, large-scale predictions of natural occurrences of marine and aquatic species. Derived from GBIF, OBIS, FishBase, SeaLifeBase & AlgaeBase.
Birdlife Datazone	BirdLife International	Distribution and abundance of bird species worldwide, mostly presented as content of IUCN Red List. Population data only show general trend (as per Red List). Distribution maps need to be requested.
FishBase	FishBase consortium	A global biodiversity information system on finfishes: taxonomy, biology, trophic ecology, life history & uses, and historical data going back 250 years.

[9] https://datasources.speciesmonitoring.org/

Data source	Lead agency	Description
		Now has a BRUV data portal.
Global Biodiversity Information Facility	GBIF	Houses over 3 billion species occurrence records from over 109,000 data sets.
International Waterbird Census Database	Wetlands International	Current and historic estimates, trends and 1% thresholds for over 800 waterbird species and 2,300 biogeographic populations worldwide. More than half the effort for the annual census is concentrated in Europe and includes North Sea and Baltic Sea nearshore and inshore areas.
IUCN Red List of Threatened Species	The Red List Partnership – 10 organisations led by IUCN	Extinction risk of species with data on range, population trends, habitat use, life history traits, use and trade, threats, conservation actions currently in place and conservation actions needed.
Movebank	Max Planck Institute for Ornithology	Animal tracking data. Seabird tracking data can be searched and relevant data holders contacted to request access.
Ocean Biodiversity Information System – OBIS	Intergovernmental Oceanographic Commission of UNESCO	Huge global database on marine species linked to GBIF. Over 164 million records of over 137,000 species from more than 3,300 datasets (as of October 2020).
OBIS-SEAMAP	Duke University	Spatially referenced database aggregating marine mammal, seabird, sea turtle and ray & shark observation data.
Ocean Tracking Network Data Portal	Dalhousie University, Canada	Data from the tracking of aquatic animals
Seabird Information Network	Seabirds.net	A list of databases on sea birds.
Seabird Tracking Database	BirdLife International Seabird Tracking Database	Serves as a central store for seabird tracking data from around the world and holds the largest collection of seabird tracking data (breeding, non-breeding, and foraging ranges; distribution data)

Annex 2: Case Studies Related to Monitoring in Offshore Wind Farms

Case Study 1 (scope): Example of spatial scope of monitoring for offshore wind farms

Source: BSH, 2013.

The BSH StUK4 standard provides guidance for the spatial scope of faunal monitoring around offshore wind as follows:

- Aerial surveys of birds and mammals: The area must cover at least 2,000 km^2. The wind farm shall be at the centre of the assessment area. The distance between the sides of the wind farm and the margins of the assessment area shall principally be at least 20 km.
- Ship based surveys of birds and mammals: The assessment area must cover at least 200 km^2. The distance between the sides of the wind farm and the margins of the assessment area shall principally be at least 4 km.
- Benthos/fish: The size of the assessment area corresponds to the current size and location of the wind farm.

Case Study 2 (indicators): Example of using the same abundance metrics around offshore wind farms

Source: Methratta & Dardick, 2019.

An analysis of abundance trends in fish populations around offshore wind farms was only made possible by using the same type of abundance indicators. Data could only be included in the meta-analysis if they (1) measured fish abundance during the operational phase inside of a wind farm and at one or more reference locations, and (2) included the sample size, mean, and standard deviation or standard error. The study showed that fish favouring soft or complex seabeds were significantly more abundant around wind farms. However, the study only found 13 papers with data that met the criteria for inclusion, highlighting the need for greater collaboration and standardisation of monitoring.

Case Study 3 (methods): Integrating methods for offshore biodiversity monitoring

Source: Smith et al., 2020.

A study in Canada demonstrated that monitoring tools used together can increase animal detection probabilities or increase the number of indicators that can be measures at one site. Overall detection rates of cetaceans increased when three complementary methods were used:

- In good visibility, marine mammal observers, infrared cameras and passive acoustic monitoring increased detections when used together.
- Marine mammal observers and passive acoustic monitoring are likely the most effective combination in high seas and during precipitation.
- Passive acoustic monitoring and infrared cameras can be used in darkness.

Case Study 4 (monitoring systems): Example of an existing offshore wind energy monitoring system

Source: OCEaN, 2022b.

The Belgian Offshore Wind Monitoring Programme (WinMon.be), led by the Royal Belgian Institute of Natural Sciences (RBINS), is a post-decision monitoring programme for the construction and operation phases of offshore renewable energy projects. Key characteristics of this system that make it suitable for nature-friendly expansion of offshore wind include:

- All Belgian offshore wind farm concession holders contribute on a yearly basis to the funding of this monitoring programme as part of their environmental license conditions. In exchange, environmental monitoring is conducted centrally and independently by advising authorities, RBINS and other partners, for all projects.
- The programme creates a framework for the systematic collection of long-term marine environmental data. RBINS and partners conducting the monitoring ensure that environmental data is continuously collected and streamlined through standardised protocols and harmonised monitoring as per latest scientific knowledge.
- Environmental data are shared through the Belgian Marine Data Centre and contribute to international databases such as EMODnet.

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Author
Dr. PJ Stephenson
Conservation & Sustainability Consultant
Crassier, Switzerland
stephenson@gmail.com

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GINGR – the Global Initiative for Nature, Grids and Renewables aims to support the just and sustainable energy transition by providing assessment tools to quantify contributions to Nature- and People-Positive goals. To facilitate this, GINGR will develop monitoring and reporting systems that are globally aligned and standardised. GINGR is a joint effort by the Renewables Grid Initiative (RGI) and the International Union for Conservation of Nature (IUCN).

Address
GINGR – Global Initiative for Nature, Grids and Renewables
c/o Renewables Grid Initiative e.V.
Manfred-von-Richthofen-Str 4
12101 Berlin, Germany

gingr.org