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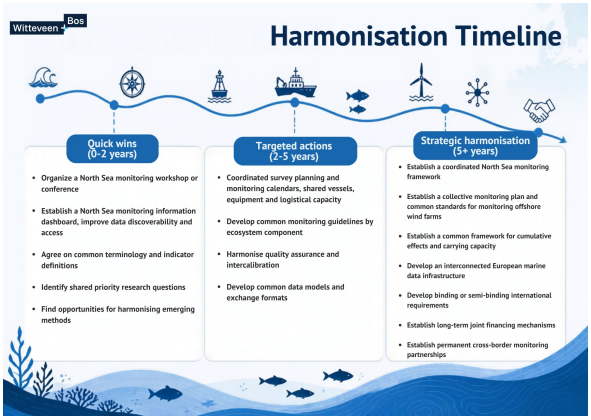
Summary

The North Sea is an ecologically valuable ecosystem under increasing pressure from human activities, including the rapid expansion of offshore wind energy. Effective ecological monitoring is essential to understand changes in biodiversity and ecosystem functioning, assess cumulative and transboundary effects, and support sound policy and permitting decisions. This study provides an initial overview of ecological monitoring practices in the NSEC countries, based on 13 interviews with experts and public authorities, and supplemented by relevant documentation.

Key findings and harmonisation opportunities

- **monitoring is widespread but fragmented**. All countries monitor broadly similar ecosystem components, including benthos, fish, birds, marine mammals, physical and chemical parameters and underwater sound. However, programmes differ in governance, objectives, spatial coverage, sampling frequency, methods and data management. These differences make it difficult to compare trends and cumulative effects;
- **offshore wind monitoring is organised nationally.** Monitoring is generally linked to environmental impact assessment and permitting, with baseline studies before construction and monitoring during construction and operation. The role of developers and the level of government control vary considerably between countries;
- **methods are partly comparable but not harmonised**. Similar monitoring techniques are common, national protocols and monitoring designs differ. New technologies such as eDNA or remote sensing, offer opportunities for future alignment;
- **data access and interoperability remain limited.** Data is stored in diverse national systems and formats. Quality control is generally applied, but raw data may be restricted by ownership, commercial sensitivity or permit conditions. Links with international infrastructures such as OSPAR, ICES and EMODnet are improving.

Afbeelding 0.1 Harmonisation timeline with quick wins, targeted actions and strategic harmonisation measures



Conclusion

The NSEC countries already monitor many of the same ecosystem components and use broadly comparable methods. However, differences in monitoring design, governance, data management and responsibilities continue to limit cross-border comparability. The strategic objective should therefore be practical interoperability rather than complete uniformity. The immediate priority is to improve transparency, coordination and data access. This should be followed by targeted technical harmonisation and, ultimately, more integrated (regional) monitoring programmes. Such a phased approach would give room to the different countries to adapt to a harmonised monitoring approach.

Reading guide report

This report is divided in different sections:

- the main report (including appendix I and II), containing the analyses of the differences and similarities in monitoring practices between countries;
- appendix III, containing the summaries of the 13 interviews, which were used as the primary input for the analyses in the main report;
- appendix IV, containing the full transcripts of the 13 interviews.

1

Introduction

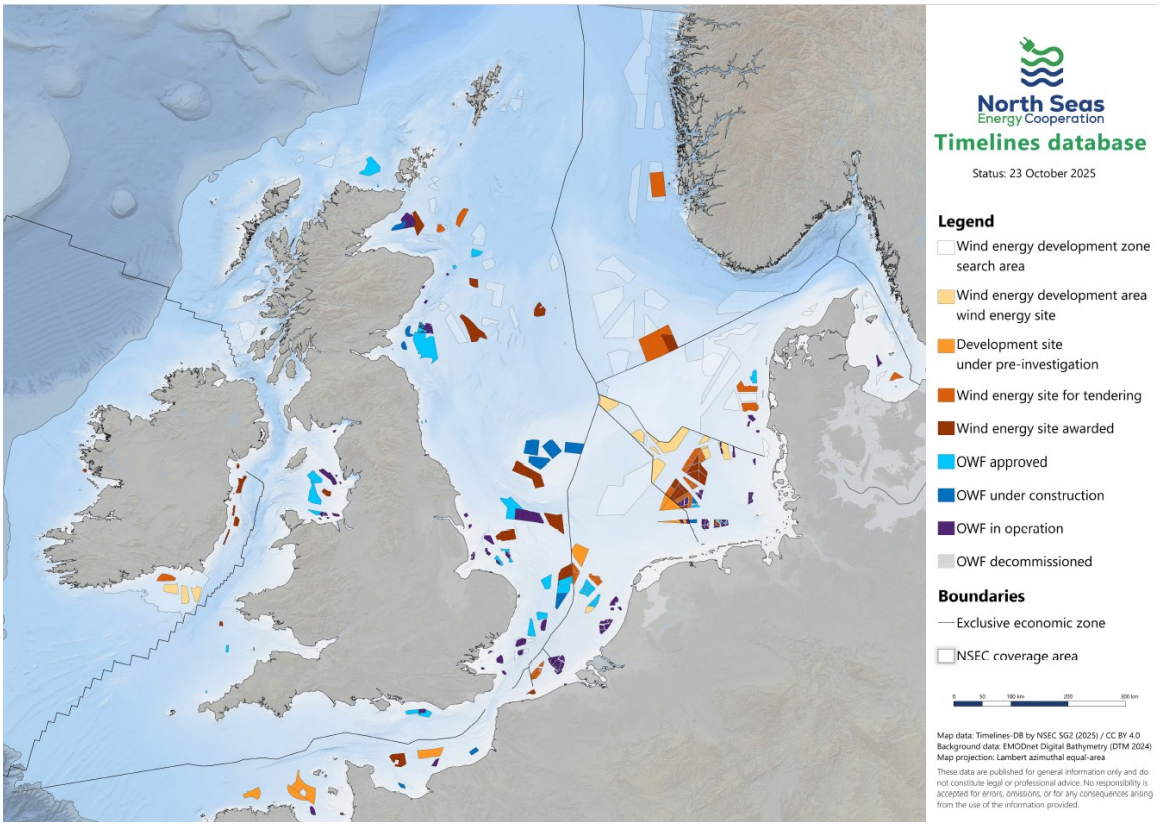
1.1 Background

The North Sea is a highly productive and ecologically valuable marine ecosystem that is subject to a wide range of human activities and pressures (Baptist & van Aar, 2025). Effective ecological monitoring is essential to understand changes in biodiversity and ecosystem functioning, assess the impacts of human activities, and support effective management and policy decisions. However, monitoring the marine environment is challenging due to the dynamic nature of marine ecosystems, the mobility of species and ecological processes across national boundaries, and the practical and logistical constraints associated with offshore monitoring.

Monitoring programmes have therefore developed differently across the countries bordering the North Sea, reflecting differences in national legislation, policy objectives, monitoring priorities, and the timing of their implementation. As a result, countries use a range of monitoring methods, indicators, and spatial and temporal approaches. While there are regional cooperation and coordination bodies in place, including the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), International Council for the Exploration of the Sea (ICES), North Seas Energy Cooperation (NSEC) and the Greater North Sea Basin Initiative (GNSBI), differences in monitoring approaches can make it challenging to compare and integrate data across national boundaries.

At the same time, a fast-evolving development of offshore wind energy has increased the need for ecological monitoring in the North Sea (as indicated by OWF planning data obtained from Noordzeeloket (2026) in figure 1.1). Research is incorporated in all project phases, from planning, to construction and operation of OWF to improve understanding of their (potential) effects on species, habitats, and ecosystems. Since no decommissioning of OWF in the North Sea has taken place as of yet, research and monitoring into ecological effects of decommissioning are not present and pose potential opportunities for future research. In some countries, wind farm monitoring also represents an important source of ecological data for areas where broader monitoring is limited. For example, Germany discovered an ecological hotspot during offshore wind monitoring. At the same time, knowledge of the long-term and cumulative effects of offshore wind development on species, habitats and ecosystems remains incomplete (Jongbloed et al., 2023). With the continued expansion of offshore wind in the North Sea, there is therefore a growing need to ensure that monitoring conducted at individual wind farms contributes to a broader understanding of ecological change at the scale of the North Sea ecosystem.

Figure 1.1 International map of offshore wind farm (OWF) sites in the North Sea, from the 'concept/early planning' to the 'fully commissioned' phase (Noordzeeloket, 2026)



This need is reinforced by the transboundary nature of marine ecosystems and the potential for cumulative effects. The pressures associated with offshore wind development, such as Underwater sound, disturbance, and changes to seabed habitats, extend beyond individual wind farms or even national boundaries. These pressures also interact with those arising from other human activities and wider environmental changes, such as climate change (Philippart et al., 2024). Assessing such effects requires monitoring to support comparisons across wind farms and countries.

Project information

This report was developed as part of NSEC Work Programme 2025-2027. The programme focuses on the development of offshore renewable energy in the North Sea region, with participating countries and the European Commission promoting cross-border cooperation.
Within the programme, NSEC Support Group 2 strives for ecologically responsible spatial planning by using an integrated approach to balance offshore wind development with the protection and enhancement of marine biodiversity. An important aspect of this is ecological monitoring. Each country has its own monitoring methods, and indicators vary considerably among countries, thereby complicating cross-border cooperation and coordination.

Therefore, there is potential for synergies between countries, specifically on alignment of monitoring methods and/or programmes. This current project has been established to provide a first overview of the different monitoring programmes within NSEC countries. This inventarisation of monitoring practices will serve as input for the ultimate goal of the project: developing initial harmonization options for ecological monitoring techniques.

Objective

The objective of this study is to answer the following main question: 'How can the various monitoring techniques within the NSEC countries be harmonized in the future?'

The answer(s) to this question forms the basis for potential alignment of monitoring practices. In order to answer this main question, the following research questions must first be addressed:

- what are the generic monitoring programmes and site-specific monitoring programmes for offshore wind per NSEC country and per international organization?
- how are data storage and analysis organised per NSEC country?
- what are the similarities and differences in monitoring techniques among the NSEC countries?
- what is the relation between those monitoring programmes and international initiatives?
- what gaps are present in ecological indicators (for example, abundance, biomass or presence of species), monitoring coverage, measurement frequency, data processing, or other relevant aspects?
- what are observed challenges in the harmonization of these monitoring techniques?

Method

To answer the research questions, information was obtained through conducting semi-structured interviews with public servants involved in offshore monitoring for each NSEC country (Belgium, Denmark, France, Germany, the Netherlands, Norway, Ireland, the United Kingdom). Additionally, an interview with representatives from OSPAR was executed. For some countries, multiple interviews were conducted, resulting in a total of 13 interviews (see appendix I for the interview questions). The interview sessions were held for a duration of approximately 2 hours.

The results of these interviews were summarized and structured into transcripts, according to the following structure:

- introduction;
- monitoring programmes: scope and set-up;
- ecosystem components and indicators;
- methodology and measuring methods;
- sampling and monitoring frequency;
- data formats and data processing;
- comparability: differences and similarities;
- responsibility;
- harmonisation - international cooperation;
- closing.

The transcripts were sent for review to the interviewees, and interviewees were asked to share documentation regarding offshore monitoring in their country. This documentation was used to fill in any gaps from the interviews.

Reading guide

Chapter 2 of this report contains the analyses of the similarities and differences in monitoring practices based on the outcomes of the interviews with:

- section 2.1 discussing the current national and/or offshore monitoring programmes in place;
- section 2.2 outlining monitoring methods, monitored ecosystem components, indicators, measuring method and sampling frequency;
- section 2.3 detailing the main findings with respect to data formats and data processing;
- section 2.4 detailing the current co-operation between the NSEC-countries and/or international initiatives;
- section 2.5 containing an overview of the monitoring responsibilities;
- section 2.6 outlining the needs and ideas for harmonisation of monitoring efforts.

Chapter 3 outlines possibilities for harmonisation practices. In chapter 4 recommendations are given based on the outcomes and limitations of this project. The last chapter, chapter 5, contains a list of references used in this report. The interview template, interview summaries and full transcripts are included as an appendix.

2

Ecological monitoring practices

This chapter discusses the similarities and differences in monitoring practices between countries. The interviews were used as the main input for this analysis, as well as related documentation provided by the interviewees. A summary of the interview outcomes for the different topics discussed below is given in appendix III. For the full transcripts please refer to appendix IV.

2.1 Monitoring programmes: scope and set-up

National monitoring

Across the countries, ecological monitoring programmes assess the condition of marine ecosystems and support national and international obligations, including the Marine Strategy Framework Directive (MSFD), Birds and Habitats Directives, Natura 2000, OSPAR, the Water Framework Directive (WFD) and ICES advice. Monitoring is conducted at national, regional and site-specific scales, with mobile species often monitored over broad areas, and benthic habitats or protected areas monitored at specific locations. Locations are selected based on ecological importance, the presence of vulnerable species or habitats, legal and policy requirements, knowledge gaps, and practical feasibility.

National monitoring systems differ considerably between the countries in terms of governance, objectives, spatial coverage and level of integration. **Germany** operates a relatively decentralised system, with monitoring responsibilities divided between federal authorities, coastal states and specialised programmes for different ecological components. The **United Kingdom** has a highly specialised and multi-agency structure, with organisations such as CEFAS, JNCC, Natural England and the Environment Agency responsible for different aspects of marine monitoring, although they also work together in some monitoring programmes. **Denmark** has a more centralised approach through the NOVANA programme, which provides national environmental baselines and long-term ecological time series. **The Netherlands** combines several mature statutory, fisheries and ecosystem-based programmes, allowing monitoring data to support a broad range of policy objectives, including water management, nature conservation, fisheries management and international reporting. **Norway** focuses strongly on ecosystem-scale monitoring and seabed mapping through programmes such as MAREANO, while **Belgium** has a more activity- and permit-driven approach and aims to use monitoring data to meet multiple legislative and policy requirements simultaneously. **Ireland's** monitoring is primarily linked to European and international obligations, including the MSFD, WFD, OSPAR, ICES and the Habitats and Birds Directives, although some programmes are still being developed. The national monitoring programme of **France** was not discussed in the available information and therefore cannot be compared reliably.

Offshore wind monitoring

Offshore wind monitoring is generally linked to environmental impact assessment and permitting and commonly includes baseline surveys before construction and impact monitoring during and after construction. The main objectives are to assess effects on the marine ecosystem, test impact predictions, evaluate mitigation measures and address knowledge gaps.

The largest difference between countries concerns the organisation of offshore wind monitoring. **Germany** has the most formalised regulatory framework.

The Federal Maritime and Hydrographic Agency (BSH) in Germany requires developers to conduct baseline, construction and post-construction monitoring according to the mandatory Standard Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment (StUK4), with post-construction monitoring for new projects being extended from up to 5 to up to 10 years. **Belgium** has a dedicated national programme, WinMon.BE, coordinated by the Royal Belgian Institute of Natural Sciences (KBIN) and funded by both the government and wind farm operators; monitoring is concentrated in 3 representative wind farms and reference areas rather than all 9 Belgian offshore windfarms. **The Netherlands** has several coordinated offshore wind programmes which focus on different aspects of offshore wind. **France** organises monitoring by project stage, with the state coordinating pre-tender baseline studies and developers undertaking permit-based monitoring before, during and after construction. In contrast, the **United Kingdom** (UK) has no dedicated national offshore wind monitoring programme. Developers in the UK are mainly responsible for offshore wind monitoring, while the Joint Nature Conservation Committee (JNCC) and the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) provide research, advice and support for environmental impact assessments (EIAs) and policy. **Denmark** combines NOVANA with dedicated offshore wind monitoring. **Ireland** and **Norway** are still developing their approach, with Norway a bit further in the development process.

2.2 Monitoring methods: ecosystem components, indicators, measuring methods and sampling frequency

Ecosystem components and indicators

Across the different countries, the key similarities are that they all select ecosystem components and indicators to support environmental assessment and policy reporting, typically combining ecological components (e.g. benthos/benthic habitats, fish, birds, marine mammals) with pressure- and abiotic-related measures (e.g. sediment characteristics, water quality, and sometimes Underwater sound).

They also all describe monitoring as something that evolves over time, aiming for either comparability across methods/time series (where relevant) or adaptation based on outcomes, new knowledge, or governance needs. There is also a great overlap between the ecosystem component measured by all countries. Figure 2.1 shows the ecosystem components that are nationally measured. For example, physical/chemical parameters, marine mammals, migratory birds, resting birds, fish and benthic habitats and benthos are measured by all countries in their national monitoring programmes, whereas jellyfish and seagrass/macro algae are only measured by 1 or 2 countries.

Figure 2.2 shows the ecosystem components measured specifically for offshore wind.

Regarding offshore wind, all countries measure Underwater sound, bats, marine mammals, fish and benthic habitats and benthos. Seabirds are monitored standardly for wind farms in most countries. Airborne noise, landscape, sea turtles and plankton are only measured in 1 or 2 countries, mostly in France.

In relation to these ecosystem components, abundance, biomass, species composition, distribution and presence/absence are mostly monitored. There are also countries monitoring bycatch, reproduction, diversity indices and behaviour, but this is not common in all countries.

Figure 2.1 Ecosystem components measured within national monitoring programmes

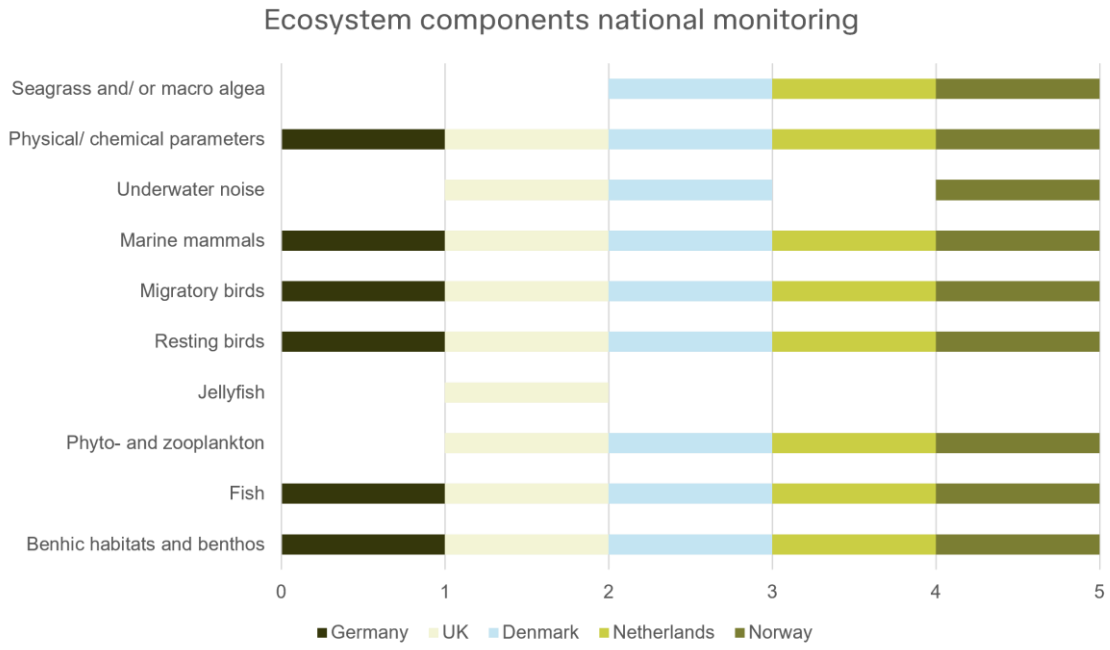
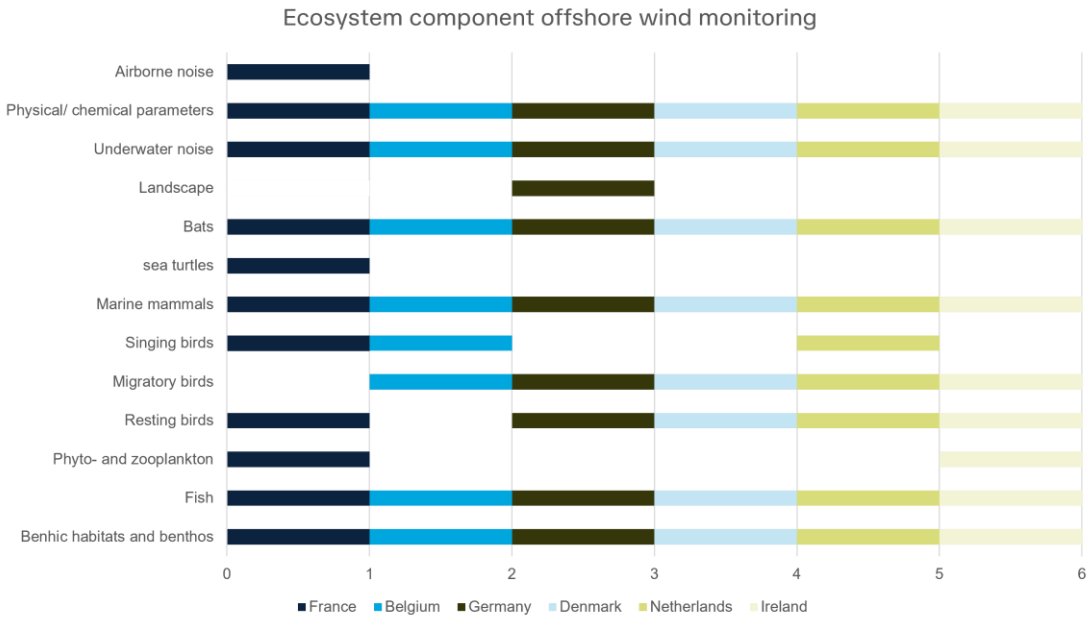


Figure 2.2 Ecosystem components measured within offshore wind monitoring programmes



Methodology and measuring methods

For national monitoring measuring methods are quite similar between countries as most data feeds into OSPAR or is used in regard to the MSFD. OSPAR has standard guidelines for measuring ecosystem components and indicators, which are often used by countries although not by all. For example, for seabirds, all countries make use of ship, aerial or land-based surveys. For marine mammals ship or aerial surveys are mostly used for monitoring. For benthic habitats and benthos grab samplers, trawlers and video/camera technology is mostly used. Fish are mostly monitored with nets and trawlers. There are also countries that are already using newer monitoring techniques like eDNA. This is, however, not (yet) standardised within all countries.

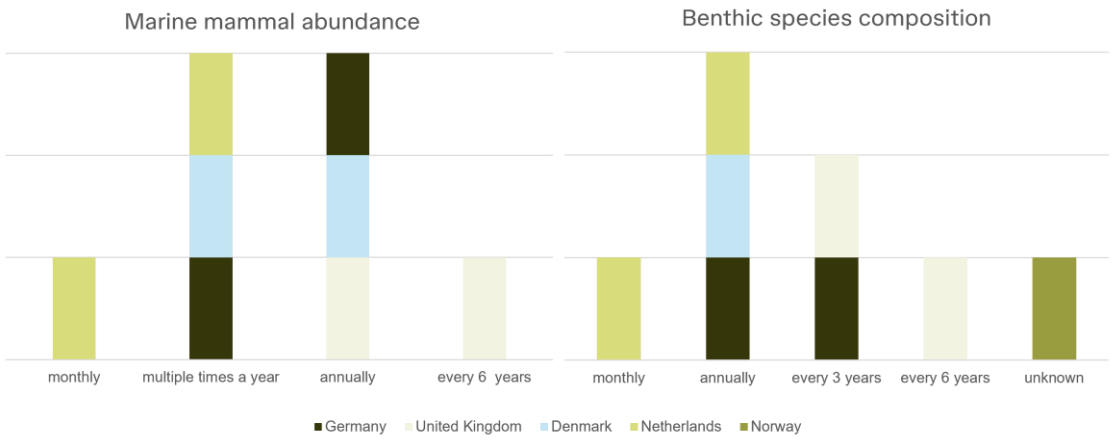
For offshore wind, methods to study bat and bird behaviour/migration are quite comparable between countries, existing of detectors, radars and cameras. Abundance of birds is often determined by aerial surveys. Also, the methods in place to monitor marine mammal behaviour in regard to Underwater sound Jdisturbance are often the same, consisting of Passive Acoustic Monitoring (PAM), C-POD and/or F-POD. For benthos monitoring often grab sampling is in place, with some countries also using newer technologies such as Remotely Operated Vehicles (ROV) and video surveys.

Sampling and monitoring frequency

Sampling frequencies differ greatly between ecosystems components, countries and also between national monitoring and monitoring in regard to offshore wind. Most commonly ecosystem components are nationally measured annually. However, this can also be more frequent - continuously, monthly, multiple times a year or seasonally, or less frequent - every 3 years or every 6 years. As an example, the sampling frequency for marine mammal abundance and benthic species composition, which are nationally monitored, are given in figure 2.3. Both indicators are measured by multiple countries and therefore give a good indication of the variance in sampling frequence between countries. As some countries monitor these indicators under different programmes, multiple sampling frequency can be given per country as these differ between the different programmes.

For offshore wind, the sampling frequency is often lower, especially during the operation phase. During the operation phase monitoring often becomes less over time. Nonetheless, there are also methods in use, especially for birds and bats, that measure continuously. Moreover, there are countries that have specific project in place in which monitoring is more frequent compared to the required monitoring frequency for wind farm developers. Monitoring during baseline studies is also often more frequent and takes place over a period of 1 to 2 years.

Figure 2.3 Sampling frequency of marine mammal abundance (left) and benthic species composition (right)



2.3 Data formats and data processing

National monitoring

For national monitoring, data formats are diverse and depend on the environmental component being measured. Structured spreadsheets and standardized tables (such as Excel and CSV files) are widely used for biological parameters, while specialized formats are used for other types of data, such as data on acoustic recordings, sediment and water quality assessments. This is seen across countries, although the degree of standardization differs. For example, **Denmark** follows standardized NOVANA formats for relevant monitoring components, while Norway increasingly uses purpose-built digital systems that can transfer measurements directly into databases. In **Germany**, monitoring organizations generally provide data to BfN in Excel sheets, after which the data are processed and made available through standardized web services.

Across the countries, monitoring data are generally subjected to quality checks, standardization and validation before publication. However, the level of accessibility varies. **Germany** provides both raw and processed national monitoring data through public web services, whereas **Denmark** requires an approved user account for access to raw data. In the Netherlands, processed or validated data are generally publicly available, while raw data may remain with the original data owner or research institute. Government-funded data are increasingly brought together through national marine data infrastructures and made available through web services, download portals or Application Programming Interfaces (APIs). Several countries, including **Germany, the Netherlands** and **Belgium**, link national monitoring data to EU-websites such as EMODnet, while others are still developing these connections.

Offshore wind monitoring

In offshore wind monitoring, data formats are often structured around standardized tables or requirements from regulatory authorities, alongside raw sensor data and specialized acoustic datasets. However, the organization and accessibility of these data differ substantially between countries. **Germany**, for example, uses standardized tables provided by BSH and dedicated databases such as Marlin and MarinEARS, while **Ireland** is still working towards establishing a central offshore wind monitoring database. In the **UK**, developers are generally required to upload monitoring data to the Marine Data Exchange, although the availability and timing of publication can vary.

Data ownership and commercial sensitivity are common factors limiting access across countries. In **Germany** and **France**, for example, offshore wind monitoring data collected after permitting are generally owned by the wind farm developer, meaning that raw data are not necessarily publicly available. Similar restrictions occur in Ireland, where developer-collected data may not be released when considered commercially sensitive. Connections to international data infrastructures also differ. Dutch national monitoring data are linked to OSPAR, ICES and EMODnet, while **Germany** has more limited international integration. France's baseline monitoring data are not yet linked to EMODnet, and Ireland reports that data are fed into EMODnet where possible. Overall, efforts are being made to connect offshore wind monitoring data to national and international data infrastructures, but these connections remain inconsistent and, in several countries, are still under development.

2.4 Comparability: differences and similarities

International coordination of monitoring programmes across NSEC countries is primarily organised through established multilateral frameworks such as OSPAR, ICES and, depending on the topic, the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS), HELCOM (Baltic Sea), the Global Ocean Observing System (GOOS) and EU/MSFD-related networks. These frameworks support common methodologies, data exchange, and joint assessments.

The degree of coordination varies considerably between countries and monitoring themes. Some countries have active bilateral and research-based cooperation, particularly for birds and marine mammals, while others mainly contribute data to international frameworks without structural coordination with neighbouring countries.

OSPAR and ICES play a central role as platforms connecting national monitoring efforts, whereas newer participants and countries outside EU obligations tend to align voluntarily or selectively with these frameworks.

Figure 2.4 Logos of different multilateral frameworks active in the North Sea



2.5 Responsibility

Overall, offshore wind farm-specific monitoring is generally linked to the developer and the permitting authority, while national monitoring is primarily a government responsibility. In **Germany**, BSH oversees offshore wind monitoring by approving the design and supervising compliance, while developers collect and store the data and commission consultants to process and report it. The BfN is responsible for national biodiversity monitoring in the German EEZ, including Natura 2000 and MSFD monitoring, supported by research institutes and consultancies. Similar arrangements apply elsewhere, although responsibilities vary: developers play a major role in project-specific monitoring in the **UK, France and Belgium**, while national monitoring is led by public authorities such as JNCC, CEFAS (UK) and the French state. **The Netherlands** and **Norway** use more government-led models, **Denmark** divides responsibilities between DEA and Energinet, and **Ireland** is still developing its arrangements. Under OSPAR, countries carry out and fund their own monitoring, while OSPAR coordinates and analyses the submitted data.

The main differences in offshore monitoring concern the extent of government control and the division of responsibilities. In **Germany and Denmark**, government authorities approve or determine monitoring designs, while developers implement or fund the required monitoring. In the **UK**, developers have greater flexibility and are not necessarily required to follow JNCC guidance, while Ireland is still developing its institutional and funding arrangements. **France** places more responsibility for wind farm monitoring on developers, whereas **Belgium** retains central responsibility within KBIN, despite substantial developer funding. **The Netherlands and Norway** rely strongly on government-led national programmes, with developer involvement varying by project, while Norway has not yet finalized its future model.

2.6 Harmonisation - international cooperation

All countries regard the current lack of international harmonisation as a problem, especially because it limits data comparison and assessment of cumulative effects. Therefore, all support improved access to monitoring data and better information about ongoing and planned surveys. Most countries also stretch the importance of coordination in monitoring across borders. Countries generally agree, however, that harmonisation should not disrupt valuable long-term datasets or established national programmes. Moreover, no country supports harmonisation that ignores ecological, legal or national circumstances. Complete uniformity is generally not considered realistic. Bottlenecks in achieving harmonisation are limited funding, staff shortages, equipment and expertise.

New monitoring programmes are considered easier to harmonise than long-running programmes with established methods and requirements. eDNA, Artificial Intelligence (AI), digital monitoring, remote sensing, automated image analysis and satellite imagery are therefore seen as promising in regard to harmonisation, but most countries want these methods validated first. Although all countries agree that harmonisation is desirable, the ideas about first steps in achieving this differ (figure 2.5). The **UK** suggest organising a workshop/conference to bring together relevant parties.

This could also be achieved by creating an online platform on which you can find who monitors what, when and where. They also suggest shared vessel use for monitoring and coordinating survey planning. The ideas of **the Netherlands** are quite in line with those of the UK. Moreover, they suggest improving cross-border use of tracking data by expanding receiver networks, coordinating satellite observations and expanding shared automated systems. **Ireland** thinks a quick win could be to use the standard methods as supplied by OSPAR and ICES for all monitoring. **Germany**, however, thinks this is already quite aligned and would therefore want to focus more on greater cooperation in data collection. This idea is in line with **the UK** and **the Netherlands**. For first steps and quick wins, **Denmark** suggests starting with harmonized (or at least comparable) guidelines, ensure responsible authorities are committed to implementing them, and begin by identifying mismatches between existing methodologies. **France** goes one stap further and suggests starting with harmonising methods for megafauna monitoring, as these methods already quite align. **Belgium** would start with aligning the research agenda by setting up a regional research programme.

Figure 2.5 Summary of proposed steps in realising monitoring harmonisation



3

Harmonisation

3.1 Need for harmonisation

Every country that was interviewed, acknowledged and recognized that there is a need or desire for harmonising ecological monitoring across the countries. However, further harmonisation does not equal complete uniformity. Broadly, the countries found that harmonisation should focus on:

- making monitoring results comparable, rather than requiring identical monitoring programmes;
- preserving existing long-term time series and avoiding unnecessary breaks in established methods;
- retaining local flexibility where ecological, legal or environmental conditions differ;
- applying the principle of 'collect once, use many times', so data can support several objectives;
- harmonising new monitoring methods before countries develop incompatible national approaches;
- improving access to information about who monitors what, where, when and using which methods.

Countries were asked to identify opportunities for harmonisation that can be applied in the near future, as well as opportunities that require a more long-term approach. These measures have been divided into quick wins, targeted actions and strategic harmonisation. Figure 3.1 gives an overview of a possible timeline that summarizes the opportunities most mentioned. Below these opportunities are further explained in detail.

The timeline provides an indicative overview of the possible implementation of this measures and is not binding. The timing and selection of measures, are ultimately up to the countries and institutions involved and may evolve as they work together.

Figure 3.1 Harmonisation timeline with quick wins, targeted actions and strategic harmonisation measures



3.2 Quick wins

Measures that are regarded as quick wins, are relatively easy measures that can be implemented through a small project. Generally, these can be implemented within the next 0-2 years.

Organize a North Sea monitoring workshop or conference

The countries interviewed noted that they are unfamiliar with colleagues in neighbouring countries, despite often working towards the same monitoring objectives. Building these connections is essential for fostering trust and further harmonisation. A monitoring workshop or conference could be a useful first step, allowing experts from North Sea countries to meet and exchange information, with the report's findings serving as a basis for discussion. Additionally, the workshop could facilitate as the starting point for implementation of other measures.

The workshop could span over more than one day or session. The first session can focus on an exchange of information, as well as on identifying what information is still missing. A second session can be more interactive and focus on working out a roadmap on when and how to proceed with the measures described in this report.

Within the next year, NSEC can appoint a coordinating organisation, or choose an existing and planned conference, where a workshop can be organised with participation from the North Sea countries.

Establish North Sea monitoring information dashboard, improve data discoverability and access

This was specifically proposed by the UK, including the idea of a shared planning portal and contact-information website. A North Sea monitoring information dashboard could be created from the information that was gathered for and within this report, with the possibility for countries to later add information. The proposal is to establish links to national and international databases (such as Het Noordzeeloket (NL), the Marine Data Exchange (UK), EMODNet (EU) or (SeaDataNet (EU)), rather than develop a new data platform. In this manner, users can access dedicated monitoring platforms relatively quick. This action is seen as a quick win, as it avoids the need for full harmonisation of national databases. This can be done in cooperation with the GNSBI working track on knowledge sharing.

The dashboard could provide an overview of:

- monitoring programmes by country and organisation;
- ecosystem components and indicators;
- monitoring locations and reference areas (shared spatial monitoring map);
- survey periods and sampling frequencies;
- monitoring methods and equipment;
- data owners and access conditions;
- relevant contact persons;
- planned surveys and available vessel capacity;
- offshore wind farms and associated monitoring requirements;
- national and international reporting obligations.

Moreover, links to data portals could be added for each country to make the data collected more accessible to other countries. Such a platform would also help address the practical problem that organisations often do not know which authorities or organisations are responsible for monitoring activities in neighbouring countries.

To implement this measure, a lead organisation can be appointed to develop a minimum viable dashboard using the information collected in this report. A first version can be published within the next year and should at a minimum contain: 1 validated record (of one of the above bullet points) for each participating country, a shared map, programme and contact information, and links to national data portals. Each country can nominate a data steward responsible for validating and updating its information at least once per year, or this can be done by the lead organisation.

Agree on common terminology and indicator definitions

The terminology and indicator definitions countries use are largely the same, in part because of the requirements for existing international frameworks such as OSPAR or ICES. However, small differences might remain, for example non-English speaking countries that largely work in their native language, or differences in the way indicators are calculated (e.g., in number of species/number of eggs et cetera).

To double-check the terminology and definitions between countries, a shared glossary and indicator framework could be created. Such a document could include a common understanding of the term and in what way it is measured, for example for:

- abundance;
- density;
- biomass;
- species composition;
- presence/absence;
- distribution;
- habitat condition;
- diversity;
- breeding productivity;
- displacement;
- avoidance;
- collision rate;
- habitat use;
- behaviour;
- underwater sound exposure;
- habitat loss;
- physical disturbance.

This would help avoid situations in which similar indicators are calculated differently. This could require some of the first changes to national documenting of monitoring (for example by converting the current method), without changing the underlying method of **how** the data is gathered.

This measure can be implemented by establishing a terminology working group within the next year, ideally with at least 1 representative from each participating North Sea country and relevant international organisations. Within the next 2 years, the working group can publish a glossary and indicator catalogue, which can then be tested within a larger NSEC project or call, or within 1 or more individual monitoring programs of the participating countries.

Identify shared priority research questions

Another first step in working towards harmonisation, would be to develop a common research agenda that aims to answer shared research questions. This idea was first proposed by Belgium.

As a start, the research agenda could focus on questions for different regions, for example, questions for 2-3 neighbouring countries. In the short-term, it might be easier for smaller regions to cooperate and answer these questions together, rather than for the whole North Sea. It also takes local differences into account. Over time, the agenda can be expanded with questions that are related to the whole North Sea. The initiative could build on existing networks such as GNSBI, OSPAR, ICES and relevant EU programmes, and aim to answer the questions in relation to those networks.

Questions could focus on:

- cumulative effects of multiple offshore wind farms;
- cross-border seabird movements and displacement;
- marine mammal movement across national boundaries;
- effects of underwater sound at the North Sea scale;

- changes in benthic communities across wind farm clusters (several wind farms in proximity to each other);
- impacts on food webs and lower trophic levels;
- bat migration routes;
- collision risk and avoidance behaviour;
- interaction between offshore wind, fisheries and protected areas.

To implement a research agenda, a research agenda working group can be created. Within the next year the working group can formulate 5 priority questions to start with. They can start answering them by appointing a lead organisation and participating countries for each question, and specify the expected data, method, output, and funding source. Ideally, at least 2 questions could be taken forward as pilot projects/studies within the next 2 years, with results reported through GNSBI, OSPAR or ICES.



Find opportunities for harmonising emerging methods

Germany, Denmark, Ireland, the Netherlands, France and OSPAR all identified emerging technologies as opportunities to harmonise methods from the start, before they are fully implemented within a country. Emerging new methods such as eDNA were discussed in every interview, and while not every country was using eDNA yet, those that were not did mention an interest in it or were planning on using it once they knew more about it.

Therefore, now is the time to address harmonising these methods, before national practices become too divergent. However, this can only be done once a new technology is established enough. Especially in the beginning, new technologies might be subject to too much change still. Therefore, it should first be studied for which new technologies it is already possible to develop harmonised methods. Once the dust has settled, harmonisation can be achieved by developing protocols for these methods that will be used by all North Sea countries. Priority methods could include:

- AI-based image analysis;
- automated bird detection;
- digital aerial surveys;
- thermal imaging;
- automated acoustic monitoring;
- autonomous underwater vehicles;
- eDNA/eRNA.

To start harmonising emerging methods, within the next year, the NSEC countries can select 2 priority methods from the above. For example, 2 methods that several countries plan to start using (more) within the next few years. For these methods, a pilot can be run. Within the pilots, the NSEC countries can collectively create a monitoring plan which they can start implementing. This can be a first exercise in how to agree on 1 monitoring method. A method should only be recommended for wider use after the pilot has demonstrated its minimum performance requirements and identified its limitations. JOMOPANS or JONAS program, existing programmes for joined monitoring of ambient noise in the North Sea, can be used as examples for setting up joined monitoring for other monitoring methods.

3.3 Targeted actions

Measures that are regarded as targeted actions, are measures that are as doable as quick wins, but require more resources (time, budget, capacity) to implement than quick wins. Generally, these can be implemented within the next 2 - 5 years.



Coordinated survey planning and monitoring calendars, shared vessels, equipment and logistical capacity

Germany highlighted the importance of coordinated monitoring in border areas, for example between Germany and the Netherlands. This is also important for other countries that share borders.

Moreover, coordinated monitored could be set up for designated Natura 2000 areas that lie within different countries, such as the Borkumse Stenen and Borkum Riffgrund.

Germany noted that surveys conducted at different times can reduce comparability. Monitoring the same ecosystem component during comparable periods would improve data comparability, even where countries continue to use different national methods. A fairly quick win would be for neighbouring countries to coordinate their survey planning, and to go out at the same time. Over time, they can expand on this by performing joint monitoring, for example by sharing vessels, equipment or logistical capacity. In some countries, such as the UK and Scotland, this is already done. By conducting coordinated surveys, bottlenecks such as sufficient capacity, cost and consistency can also be tackled. Sharing vessels, equipment and logistical capacity could be particularly useful for:

- coordinated cross-border transects;
- simultaneous sampling across the North Sea;
- offshore wind cluster (several wind farms in proximity to each other).

Within the next few years, neighbouring countries should establish a shared annual monitoring calendar covering at least 2 border areas. The calendar should identify the ecosystem component, survey period, responsible organisation, vessel or equipment requirement, and opportunities for joint implementation. Within 3 years, at least 1 joint survey should be completed in each participating border area.



Develop common monitoring guidelines by ecosystem component

To take harmonisation of monitoring methods 1 step further, countries can start developing common monitoring guidelines for each ecosystem component. Denmark specifically supported harmonised or at least comparable guidelines between countries.

These guidelines can build upon the measures taken in the short term, such as the mismatch analysis, common terminology, indicator definitions and meta-data requirements. It would be recommended to develop these guidelines in English and translate them to the country-specific languages (while making sure the definitions stay the same after translations). The guidelines could start by defining:

- minimum indicators;
- minimum spatial coverage;
- minimum temporal coverage;
- recommended sampling seasons;
- acceptable alternative methods;
- quality-assurance requirements;
- minimum reference-area requirements;
- reporting units;
- uncertainty reporting.

These guidelines do not need to prescribe identical methods for each situation due to local differences for which specific guidelines are needed.

To start developing these guidelines, establishing a working group within the next few years would be a place to start. The working group can then first select 2 ecosystem components for which common guidelines are most urgently needed and establish a technical drafting group for each component. Once these draft guidelines are done, they can be shared for review with other participants from the NSEC countries. Once finalized, the guidelines can be applied in existing monitoring programmes of the participating countries, who can evaluate them after the next reporting cycle.

Harmonise quality assurance and intercalibration

Besides common monitoring guidelines, countries can also focus on harmonised quality assurance. While not specifically mentioned by the interviewees, the UK's use of standard operating procedures and the North-East Atlantic Marine Biological Analytical Quality Control framework could provide relevant experience.

Quality assurance would ensure the guidelines are followed correctly and be a helpful double-check on the comparability of the gathered data. Some ways in which this could be done include:

- common field-training requirements;
- intercalibration exercises;
- quality-control checklists;
- shared audit procedures.

The harmonisation of quality assurance and intercalibration can start by establishing a small working group that works closely together with common monitoring guidelines working group. This group can start by defining a minimum quality assurance for each common monitoring guideline. These can be tested simultaneously with the testing of the guidelines.

Develop common data models and exchange formats

Within the next years, countries could start working (in a working group) on developing common data models and exchange formats. The objective should be interoperability between existing national systems, rather than replacing all national databases. These could later be uploaded into a European marine data infrastructure (see strategic harmonisation).

The working group can start by developing a data model for up to 3 monitoring components, for example the same as for which common guidelines are first written. The models can be tested by exchanging existing datasets from at least 3 different countries and documenting any data loss or conversion problems.

3.4 Strategic harmonisation

Measures that are regarded as strategic harmonisation, are measures that require a long-term approach. These require significantly more time, budget, capacity and cooperation between stakeholders. Some can be built upon measures that are taken as quick wins or targeted actions. These take a longer time to implement, over a period of 5 or more years.

Establish a coordinated North Sea monitoring framework

A long-term objective could be a coordinated monitoring framework covering the entire North Sea. This framework can build upon earlier measures such as the common monitoring guidelines. The framework could be an overarching measure that could integrate national monitoring, offshore wind monitoring, OSPAR and ICES reporting and cumulative-effects monitoring.

It could define common strategic objectives, and include common monitoring guidelines, coordinator survey planning, shared data standards, cross-border reference areas, a joint analysis of cumulative effects (see below) and long-term financing (see below).

The framework should not necessarily create 1 central monitoring organisation. It could instead coordinate existing authorities and programmes. Within the next 2-3 years, the NSEC countries should establish a steering group that can start laying the groundwork for such a framework. First, the group should agree on the framework's scope, governance, objectives and decision-making procedures.

Within 5 years the group should publish a draft North Sea monitoring plan that links national, offshore wind, OSPAR and ICES monitoring activities and identifies remaining gaps.



Establish a collective monitoring plan and common standards for monitoring offshore wind farms

Currently, the methods that countries use to monitor offshore wind farms differ. Creating a collective monitoring plan and common standards for offshore wind monitoring, can help increase the comparability of monitoring results. The framework could also build on existing national systems such as:

- Germany's StUK4;
- Belgium's WinMon.BE;
- the Netherlands' Wozep (research program);
- Denmark's developing offshore wind guidelines;
- France's increasingly standardised baseline surveys.

Germany identified this as a major long-term opportunity, to monitor the effects of offshore wind farms together, rather than treating each wind farm as an isolated project. Monitoring offshore wind farms collectively would be too difficult due to differences in permits and permission of wind farm developers. Therefore, the responsibility to monitor remains with different states.

However, using the same monitoring methods paves the way for larger studies into the effects of all wind farms in the North Sea, because data can be bundled and easily compared. This would also aid in monitoring the cumulative effects of the farms across the whole North Sea.

A North Sea offshore wind monitoring framework could define common minimum requirements for:

- baseline duration;
- construction monitoring;
- post-construction monitoring;
- control and reference areas;
- BACI design;
- monitoring of several wind farms within 1 area;
- monitoring of cumulative effects;
- transition between project phases;
- minimum monitoring duration;
- data quality;
- reporting and publication.

A common framework should allow national permit authorities to add requirements based on local ecological or legal conditions.

Within the next 2 - 3 years, the groundwork for such a monitoring plan and standards can be laid, by appointing a working group. The group can start by agreeing on the minimum standards for at least 3 monitoring topics. These standards can then be trialled within the next 5 years in several wind farm monitoring programmes. After these first standards are finalized, the monitoring plan can slowly be expanded upon within the next decade.



Establish a common framework for cumulative effects and carrying capacity

The Netherlands called for clearer European requirements for ecological carrying capacity and cumulative effects. A long-term framework could address:

- cumulative habitat loss;
- cumulative underwater sound;
- cumulative bird displacement;
- cumulative collision risk;
- cumulative effects on marine mammals;

- combined effects of multi-use on the North Sea;
- effects on food webs;
- cross-border pressures;
- ecological thresholds;
- regional carrying capacity;
- geogenic and biogenic reef systems;
- sea scapes and delta connections;
- underwater migration (between reproduction areas).

The North Sea monitoring framework can be used as a base, from where this measure can be worked out further, within the next decade. This can be done in cooperation with the GNSBI working track on cumulative impact assessments. A working group can start working on the framework parallel to the North Sea monitoring framework. A draft framework can be tested for at least 3 of the pressures described above.



Develop an interconnected European marine data infrastructure

Several countries mentioned the long-term ambition for developing an interconnected European marine data infrastructure. While similar structures already exist, such as EMODnet, a future infrastructure could build upon those structures while adding more data. This infrastructure could draw from previously agreed guidelines, requirements and terminology. It can be a part of the North Sea monitoring framework and include not only data but also information on the framework on its website.

This infrastructure could be a future iteration or evolution of the North Sea monitoring information platform (mentioned as short-term measure), that can start development within the next decade. The system should accommodate national ownership and legal differences while still enabling cross-border discovery and analysis.



Develop binding or semi-binding international requirements

OSPAR noted that harmonisation would be stronger if supported by binding legislation and a coordinated joint effort, similar to the approach used in European fisheries policy. Using the North Sea monitoring framework as a base, countries could develop requirements for countries to adhere to the framework, accompanying guidelines, requirements and data infrastructure. Requirements can be binding or partially binding (e.g., a fulfilment of a requirement is binding, but how it should be implemented is non-binding).

After the North Sea monitoring framework and its common standards have been tested for at least 1 reporting cycle (within the next decade), the participating countries should assess which elements require binding, semi-binding, or voluntary implementation. This can be laid out in a legal and policy options paper, that identifies the steps needed for national implementation.



Establish long-term joint financing mechanisms

Several countries mentioned (the lack of) funding as a major barrier. Because the amount of funding available differs between countries, it may not be possible for all of them to adhere to shared guidelines or requirements (binding or not). To aid one another and to ensure that all countries can participate, a joint financing mechanism might be favourable. This can also be implemented as part of the North Sea monitoring framework. Existing funding programmes that could be looked at are LIFE Programme and INTERREG.

A long-term solution could include:
- a North Sea monitoring fund;
- joint funding for cross-border surveys;

- developer contributions to regional monitoring;
- shared funding for reference areas;
- funding for data infrastructure;
- financing for shared vessels and equipment;
- financial support for countries with lower monitoring capacity.

The UK mentioned that they are possibly implementing a Marine Recovery Fund, to help compensate for impacts a wind park might have, and to pay for monitoring of wind park sites, funded by developers. This model, as well as Belgium's WinMon.BE model, in which developers and government contribute financially, could provide examples.

Within the next 5 years, the NSEC countries can establish a pilot project, in which a joint financing mechanism is tested.



Establish permanent cross-border monitoring partnerships

Lastly, as part of the coordinated North Sea monitoring framework, permanent partnerships could be developed between neighbouring countries and organisations. Neighbouring countries that monitor next to each other's borders, in similar marine environments, could establish long-term partnerships that are built upon the measure of coordinated survey planning, vessel, equipment and logistics sharing. This is an expansion of the coordinated survey planning mentioned as a medium-term measure, and aims to establish permanent partnerships rather than trial surveys.

Within the next 3-5 years, at least 2 of the neighbouring NSEC countries can start such a partnership, by signing an agreement and by performing at least 1 jointly planned or jointly executed monitoring activity per year and publishing a short progress report. After 5 years, the partnerships should be evaluated to determine whether they should be expanded to additional borders or ecosystem components.

4

Considerations and recommendations

4.1 Considerations

Ecological monitoring of the North Sea is a well-established practice for all its surrounding countries. Though the extent of the monitoring programmes might differ between them, as well as the status at which they are implemented, all countries recognize the need to better understand our shared marine ecosystems. International programs and institutions like OSPAR, ICES and GNSBI emphasize this.

However, the way in which the North Sea is monitored remains fragmented by (inter)national borders, different national objectives and legal frameworks, jurisdiction, methods and resources. This report offers a first overview of these differences, as well as of the similarities and what opportunities those bring with them. A task still remains in (further) harmonising the ecological monitoring that is being done for all regions of the North Sea.

All countries that were interviewed were curious about the outcomes and expressed satisfaction in the fact that this research was being carried out. That is a positive attitude that should be fostered and can help give a boost to harmonisation, especially in the short-term after publishing of this research.

By focusing on what is possible, and by further strengthening the cooperation between the NSEC countries, ecological monitoring of the North Sea can set an example for other shared marine regions across Europe.

4.2 Recommendations

Based on the outcomes of this report and in addition to the measures proposed in Chapter 3 we recommend the following:

- develop a jointly agreed implementation roadmap. The measures proposed in this report can be translated into a roadmap that specifies priorities, responsibilities, indicative timelines, required resources and expected outputs. A phased approach allows countries to take their time to adapt to the harmonisation of methods;
- we recommend starting with the quick win measures, which can be taken within the next 2 years and require fewer resources. These are easy wins that nevertheless can have a large impact, in bringing the energy and good faith that was encountered during the writing for this report further;
- building on the success of the quick win measures, targeted actions can be taken. Strategic measures require more time and an overarching strategy. Existing platforms such as GNSBI can lead the way;
- when implementing measures such as the North Sea monitoring information dashboard, ensure that it is not a separate entity, but well-connected to existing platforms such as EMODnet, OSPAR, ICES and national marine data websites. This will increase findability and legitimacy;
- for this report, as many experts from as many different countries as possible were interviewed. However, due to constraints in time and availability, it was not possible to interview an expert for both offshore wind and generic ecological monitoring for each country. To get a full understanding, it is recommended to obtain the necessary information at a later stage. This can also be done as part of creating the North Sea monitoring information dashboard;

- ensure that harmonisation measures preserve existing long-term time series, while leveraging opportunities to adopt new techniques. A ‘break’ in time series was mentioned by several countries as undesirable. Coordinating the adoption of new techniques early is therefore important, before monitoring methods diverge too far to maintain comparability. When methods differ, countries should document the differences, assess their implications for comparability and, where possible, develop conversion, calibration or bridging approaches;
- before introducing harmonised requirements, ensure that for each country funding and capacity are secured. This is particularly important for countries with an already limited monitoring capacity. A joint financing mechanism, proposed as a strategic measure, can aid with this.

5

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Appendices

Appendix: Abbreviations

Table I.1 Overview of abbreviations used throughout the document

Abbreviation	
AI	Artificial Intelligence
API	Application Programme Interface
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
AUVs	Automated Underwater Vehicles
AWI	Alfred Wegener Institute
BACI	Before-After Control-Impact
BLMP	Bund-Länder Messprogramme
BnF	Federal Agency for Nature Conservation
BRUV	Baited Underwater Video
BSH	Federal Maritime and Hydrographic Agency
CDOM	Colored Dissolved Organic Matter
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CEMP	Coordinated Environmental Monitoring Programme
COBAM	Coordination of Biodiversity Assessment and Monitoring
CPR	Continuous Plankton Recorder
CSIP	Cetacean Strandings Investigation Programme
CTD	Conductivity, Temperature, Depth
CTDO	Conductivity, Temperature, Depth, Oxygen
DCE	Danish Centre for Environment and Energy
DCEE	Department of Climate, Environment and Energy
DDA	Dachverband Deutscher Avifaunisten
DEA	Danish Energy Agency
DEFRA	Department for Environment, Food and Rural Affairs
DEM	Digitalisation of Ecological Monitoring
DGEC	Directorate General for Energy and Climate
DGT	Diffusive Gradients in Thin Films
EA	Environment Agency
EBT	English North Sea Bottom Trawl surveys
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EMODnet	European Marine Observation and Data network
EPA	Environmental Protection Agency
EU	European Union
FAIR	Findable, Accessible, Interoperable, Reusable
GNSBI	Great North Sea Basin Initiative
GNSBI	Geological and Natural Sciences of the Built and Infrastructure
GOOS	Global Ocean Observing System
GPS	Global Positioning System

Abbreviation	
HAPS	High-Altitude Platform System
HELCOM	Helsinki Commission, Baltic Marine Environment Protection Commission
HPMA	Highly Protected Marine Areas
IBTS	International Bottom Trawl Survey
ICES	International Counsil for the Exploration of the Sea
ICG	Intersessional Correspondence Group
IFREMER	French Institute for Ocean Science
ITAW	Institute for Terrestrial and Aquatic Wildlife Research
JNCC	Joint Nature Conservation Committee
KBIN	Royal Belgian Institute of Natural Sciences
MDI-DE	Marine Data Infrastructure Germany
MIVSP	Maritime Information Provision Service Point
MMO	Marine Management Organisation
MONS	Monitoring and Research Programme for Nature Enhancement and Species Protection
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
MWTL	Monitoring of the Water Management Condition of the Country
NE	Natural England
NINA	Norwegian Institute for Nature Research
NIOZ	Royal Netherlands Institute for Sea Research
NIVA	Norwegian Institute for Water Research
NMBAQC	National Marine Biological Analytical Quality Control Scheme
NSEC	North Sea Energy Cooperation
NVE	Norwegian Water Resources and Energy Directorate
OC	Organic Carbon
OH	Organohalogens
OSPAR	Oslo-Paris Convention, Convention for the Protection of the Marine Environment of the North-East Atlantic
OWF	Offshore wind farm
PAM	Passive Acoustic Monitoring
PELTIC	Pelagic Ecosystem Survey in the Western Channel and Celtic Sea
PSA	Particle Size Assessment
QSR	Quality Status Report
REM	Remote Electronic Monitoring
ROV	Remotely Operated Vehicle
RSPB	Royal Society for the Protection of Birds
RVO	Netherlands Enterprise Agency
SCANS	Small Cetaceans in the European Atlantic and North Sea
SMASS	Scottish Marine Animal Stranding Scheme
StUK4	Standard Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment
TOPAS	Topographic Parametric Sonar
UK	United Kingdom
UWTV	Underwater Television
WFD	Water Framework Directive
WGIBTS	Working Group of International Bottom Trawl Surveys
WOT	Statutory Research Tasks
Wozep	Offshore Wind Ecological Programme

II

Appendix: Interview questions

A. Monitoring programmes: scope and set-up (10 min)

1 what ecological monitoring programmes for the North Sea are in place within your country?
2 at what spatial scale are these monitoring programmes conducted? (national, regional grids, site-specific wind farm);
3 how and on what basis are monitoring locations selected?
4 what is the purpose of these monitoring programmes (monitoring objectives/expected outputs)?
5 which organisations are part of these monitoring programmes?

B. Ecosystem components and Indicators (10 min)

6 which ecosystem components (i.e. mammals, invertebrates, fish, birds, habits, phytoplankton) are monitored per monitoring programme?
7 which ecological indicators (i.e. abundance, biomass, presence) are monitored in the monitoring programmes?
8 how are the relevant ecosystem components and indicators determined per monitoring programme?
9 when are these updated or added to monitoring programmes?

C. Methodology/measuring method (10 min)

10 which methods are used per ecosystem component (or ecological indicator)?
11 which protocols/standards are followed?
12 does your country make use of standardization? Did methods change over time (and how)?

D. Sampling/monitoring frequency (15 min)

13 what is the frequence for each monitoring programme?
14 how is the monitoring schedule coordinated for offshore wind programmes with project phases (e.g., before/during/after wind farm development)?
    1 how is baseline monitoring handled in relation to monitoring after the construction of an offshore wind farm?
    2 do you make use of the Before After Control Impact approach and how low is the monitoring of T0?
15 do frequence between the ecosystem components differ?
    1 if yes; how do they differ?
    2 if no; what is the set frequency?
16 how long have monitoring programmes been in place?

E. Data formats & data processing (10 min)

17 in which data formats are the collected measurements stored for each monitoring programme or is this the same?
18 in which language is the data stored?
19 is there a national data base or central data collection framework?
20 is the data open source?
    1 Is the data Findable, Accessible, Interoperable, and Reusable (FAIR Principles - GO FAIR)
21 who owns the data?
22 Is the data linked to international systems such as EMODnet?

F. Comparability: differences & similarities (15 min)

23 is there currently any coordination with monitoring programmes from other NSEC countries?
   1 if yes; how does this coordination look like?
   2 if no; next question;

24 does overlap exist between the national monitoring programmes and international frameworks (ICES, GNSBI and OSPAR)?
   1 if yes; how does this coordination look like?
   2 if no; next question;

G. Responsibility (10 min)

25 who is responsible for design, implementation and data storage/analysis?

26 how is monitoring funded? By the government or the developer?

27 how be is/will cooperation organized between the government and the wind farm constructer (public-private)?

H. Harmonisation (20 min)

28 do you see (the lack of) international harmonisation as an obstacle?

29 at what level do you think harmonization is desirable: indicators; methods; data formats; or perhaps even at the decision-making/governance level and what is your need for international harmonisation?

30 what are potential bottlenecks/challenges for harmonising monitoring programmes?

31 what should absolutely not be harmonized (local differences)?

32 what works well in your monitoring approach?

33 what do you think are the first steps to harmonise monitoring efforts? i.e. what do you consider to be low-hanging fruit/quick wins, and what is more of a long-term effort?

34 what is your opinion regarding harmonisation for new monitoring methods (like eDNA)?

35 what would you do differently if you were to start over?

III

Appendix: Summary interviews

Below a summary of the transcripts is given. The summary is given per topic, in the same order as chapter 2 of the main report. The summaries were used as the main input for the analyses in chapter 2, in which the differences and similarities in monitoring practices between countries is discussed.

III.1 Monitoring programmes: scope and set-up

Germany

National monitoring

Germany has several ecological monitoring programmes in place for the North Sea, coordinated primarily through the Bund-Länder Messprogramme (BLMP) and led by the Bundesamt für Naturschutz (Federal Agency for Nature Conservation) (BfN). The monitoring programmes conducted by BfN cover seabirds, resting and migrating birds, whales, benthic habitats and biotopes, and the monitoring of protected areas. Monitoring of non-indigenous species is carried out in cooperation with the federal states. Seabed monitoring in the EEZ is carried out jointly by BSH and BfN. BfN does not conduct monitoring of hydrochemistry, nutrients or water conditions. Anthropogenic pressures are assessed as part of the relevant reporting obligations. A pilot programme for minke whale monitoring on the Dogger Bank is also being developed, while pelagic habitat and fish monitoring is currently in a pilot phase and plankton monitoring remains under development. Most programmes cover the German Exclusive Economic Zone (EEZ). For scientific reasons, bird and whale monitoring flights sometimes cross into, or partially include neighbouring or German coastal waters.

Monitoring locations are selected based on ecological and conservation priorities, including the presence of reefs, sandbanks, areas where harbour porpoises congregate for mating and giving birth, areas with high numbers of rare species and areas with large concentrations of birds. The programmes aim to establish long-term trends in population size and distribution, assess protected species and habitats, evaluate the achievement of conservation objectives and support measures under the Habitats Directive, Birds Directive, MSFD and OSPAR. Monitoring of pressures such as fisheries and shipping is not yet comprehensive, partly due to difficulties in obtaining reliable fisheries data. BfN carries out some activities directly but commissions much of the fieldwork to research institutes, universities and consultancies. Current contractors include the Dachverband Deutscher Avifaunisten (DDA) for bird monitoring, the Institute for Terrestrial and Aquatic Wildlife Research (ITAW) for whale monitoring, the Alfred Wegener Institute (AWI), and BioConsult (Bremen) for benthic monitoring. These contracts are subject to regular re-tendering, and the organisations involved may therefore change over time.

Germany's coastal areas (within 12 sea miles from the coast/circa 20 km) are the responsibility of the nearby states (Niedersachsen and Schleswig-Holstein). These states have their own monitoring programmes. BfN also executes monitoring.

Offshore wind monitoring

In Germany, ecological monitoring for the North Sea related to offshore wind energy is implemented through a combination of activities carried out by BSH, as well as by wind farm developers.

BSH's monitoring applies specifically to the EEZ and is designed to capture environmental baseline conditions, as well as potential impacts of wind farms, by requiring monitoring before, during, and after construction, typically including species-specific data collection. This is done according to the regulatory framework programme StUK4. StUK4 defines mandatory minimum requirements and baseline survey guidelines for assessing and monitoring ecological effects of offshore wind farms on marine life. For some sites, preliminary investigations are undertaken by the German state, before tenders are issued. Where such prior data is absent, developers are responsible for generating the baseline through required monitoring programmes.

The spatial extent of monitoring depends on the target species, with broad-scale coverage for species such as harbour porpoise and birds, while benthos and fish are generally monitored at the wind farm site scale. BSH may also encourage wind farms to be grouped into clusters and to be monitored together, to improve efficiency and coverage. The monitoring objectives include supporting the EIA and informing any operational measures after construction, as well as evaluating potential negative impacts over time. Post-construction monitoring is currently mandatory for up to 5 years. Future legislation, which is expected to be implemented, will extend this up to 10 years for new projects.

In table III.1 an overview of the current monitoring programmes in Germany is given.

Table III.1 Current monitoring programmes Germany

	Name	Objective	Organisations
national monitoring programmes	N/A, there are dedicated monitoring programmes for different components	(1) establish long-term trends in population size and distribution, (2) assess protected species and habitats, (3) evaluate the achievement of conservation objectives, (4) support measures under the Habitats Directive, Birds Directive, MSFD and OSPAR	BfN, research institutes, universities, and consultancies (e.g., DDA, ITAW, AWI, and BioConsult SH), with opportunities arising periodically through new tendering procedures.
monitoring programmes offshore wind	StUK4	(1) EIA, (2) monitoring effects	BSH and the wind farm developers/ contractors

United Kingdom

National monitoring

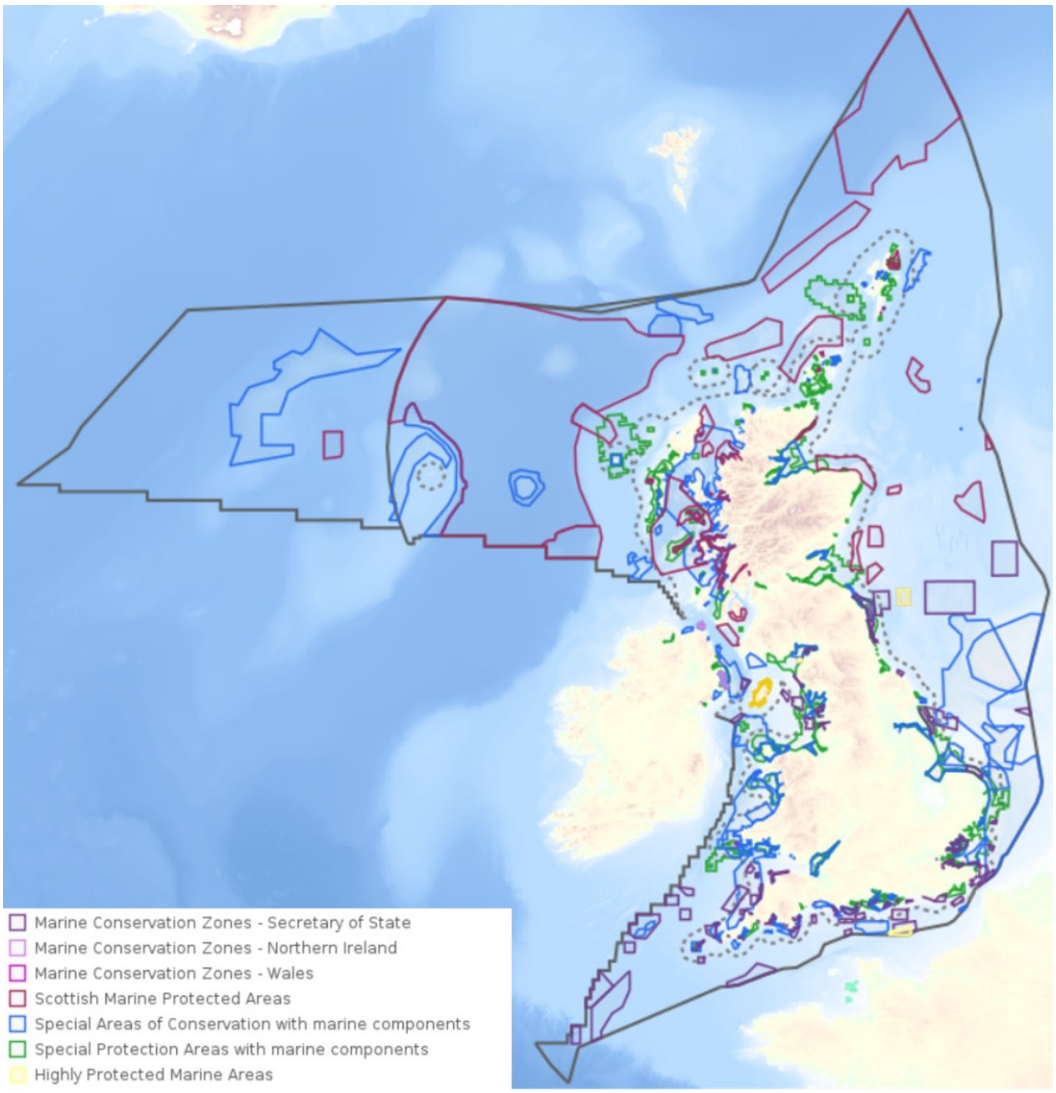
In the UK there are multiple bodies responsible for different parts of offshore monitoring:

- the JNCC is responsible for marine offshore monitoring in the area that is 12 miles/circa 20 km out from the coast. They cover monitoring, not only of Marine Protected Areas (MPAs) but also monitoring of species, such as cetaceans, seals, sea birds, bird conservation outside MPAs. Additionally, JNCC is responsible for monitoring terrestrial, freshwater and air pollution, and they have a strong international focus, working in overseas territories;
- CEFAS operates a wide range of ecological monitoring programmes in the North Sea. These focus mainly on fish and fisheries, but also cover plankton, benthic invertebrates, sediments, water and chemical quality, marine noise, habitats and marine protected areas;
- Natural England (NE) is responsible for inshore monitoring, so the area within 12 miles from the coast. NE also covers other statutory and regulation requirements;
- the Environment Agency (EA) carry out monitoring around coastal areas, estuaries and particularly in fresh waters;
- Marine Management Organisation (MMO) has a responsibility for monitoring and reporting on specific criteria under the Marine and Coastal Access Act.

JNCC monitoring of the different ecosystem components is divided in specific departments. In relation to benthic monitoring, JNCC has 2 main offshore monitoring programmes for the North Sea: An Offshore MPA Monitoring programme (called the English benthic MPA monitoring programme) and a newer Highly Protected Marine Areas (HPMAs) monitoring programme. The Offshore MPA Monitoring programme assesses the condition of benthic habitats and MPA features across a subset of offshore MPAs (since monitoring all MPAs is not feasible). The JNCC has also begun baseline work for HPMAs, which represent the strictest protection level (no extraction and no deposition). The first HPMAs in its scope are Dolphin Head (English Channel) and Northeast Fans Deep (North Sea), with time-series monitoring expected to start in 2027. The baseline survey of the HMPA's already took place in 2023.

In figure III.1 a map of the MPAs in the UK is provided. Monitoring locations are selected using a combination of ecological risk and feasibility, originally prioritising areas with high fishing pressure and sufficient evidence. It involves identifying sites that can provide robust evidence of changes in conditions over time. The primary objective is to determine whether MPAs are meeting their conservation objectives and to detect changes over time.

Figure III.1 Map of MPA's in the UK (JNCC, n.d.)



For seabirds, the UK has a nationwide annual Seabird Monitoring Programme, supported by a seabird census approximately every 10 years, to assess breeding productivity, population trends and distribution.

Monitoring is coordinated by organisations including JNCC, the British Trust for Ornithology, the Royal Society for the Protection of Birds (RSPB), universities, local groups and volunteers, using standardised methods set out in the Seabird Monitoring Handbook. Annual monitoring focuses mainly on larger, accessible colonies and provides a baseline for assessing potential offshore wind impacts. Monitoring sites are selected based on colony size, geographic coverage, accessibility, species presence and emerging offshore wind development areas. Overall, the focus has evolved from measuring direct effects such as displacement and collisions to understanding population-level consequences and improving the evidence used in environmental assessments.

CEFAS has around 52 dedicated monitoring programmes, focusing on different aspects of the marine environment. These are long-term monitoring programmes. Some have been running since 2 circa 1930 - 1970's. Moreover, they work on individual research programmes that run over a period of a few years (circa < 5 years). The monitoring programmes of CEFAS include fisheries-dependent and fisheries-independent surveys, such as the internationally coordinated International Bottom Trawl Survey (IBTS) and the English North Sea Beam Trawl (EBT) Survey, as well as shellfish, plankton, benthic invertebrate, sediment, water and chemical quality, marine noise, marine protected area and pilot eDNA monitoring. These programmes operate at a range of spatial scales, from international North Sea coverage to regional, local and site-specific surveys.

The monitoring programmes have a range of objectives, depending on their specific focus. Fisheries monitoring provides data for fish-stock assessments, quota advice and sustainable fisheries management, while other programmes support OSPAR reporting and assessment of the UK's good environmental status. Monitoring is also used to inform licensing and impact assessments for activities such as dredge disposal and offshore renewable-energy developments. In addition, long-term surveys provide baseline and trend data on fish, invertebrates, plankton, sediments, habitats, water quality and chemical conditions. The programmes also support MPA management, emergency assessments following incidents such as oil spills or vessel accidents, and the development of new monitoring methods, including environmental DNA techniques.

Most monitoring is executed by CEFAS staff, and where necessary supported by subcontractors and partner organisations, such as JNCC, NE, EA and MMO. The relevant monitoring programmes executed by JNCC and CEFAS are given in table III.2.

Offshore wind monitoring

The JNCC and CEFAS are not directly responsible for monitoring the impact of OWF, this responsibility lies with the wind farm operators. However, both work on funded projects relating to research questions about offshore wind. CEFAS, for example, conducts time-limited research projects, projects that run over a couple of years, related to offshore wind and JNCC often works together with industries such as offshore wind, providing advice and supporting processes like EIAs and policy related to MPAs and fisheries.

Moreover, for seabirds wind farm developers often investigate seabird displacement, with some projects also examining flight behaviour, movements, survival and collision risk. Larger collaborative research programmes may cover multiple UK locations to develop representative parameters for impact and collision-risk models. The Offshore Wind Environmental Evidence Register supports this process by identifying existing knowledge gaps and priorities for future research.

Table III.2 Current monitoring programmes UK

	Name	Objective	Organisations
national monitoring programmes	CEFAS Observer Programme, International Bottom Trawl Survey (IBTS) - England, English North Sea Beam Trawl (EBT) Surveys, Sea angling survey, PELTIC acoustic small pelagic survey, King Scallop dredge survey, Scallop UWTV Survey, Nephrops UWTV surveys	fish-stock assessments, quota advice, scientific advice	Cefas

	Name	Objective	Organisations
	Coastal/inshore fixed point sampling programmes	ecosystem functioning, environmental variability, model validation	Cefas, EA
	Plankton Monitoring Programme	MSFD, OSPAR	Cefas
	Integrated eutrophication, water quality and ambient noise monitoring programme	MSFD, OSPAR	Cefas, EA
	English benthic MPA monitoring programme	MPA site condition assessment	JNCC, Cefas, EA, NE
	Dredge disposal	support licensing process	Cefas, MMO
	Premium Monitoring Coordination Cell	coordinate post-spill environmental monitoring	Cefas
	Marine and Fisheries Research and Development Programme	validate innovative monitoring techniques	Cefas
	Clean Seas Environmental Monitoring Programme	MERMAN, ICES, OSPAR, MSFD	Cefas
	Marine Spatial Prioritisation Programme	mapping of marine landscapes	JNCC, Cefas, NE
	Seabed Habitat Mapping Programme	MPA monitoring and marine spatial planning	JNCC
	Seabird Monitoring Programme, Seabird Census	assess breeding productivity, population trends and distribution	JNCC
	SCANS	assess distribution marine mammals	Sea Mammal Research Unit, JNCC
	CSIP	strandings	JNCC, defra, the Scottish and Welsh government
	SMASS	strandings	University of Glasgow, CSIP, the Scottish government, defra
	UK Bycatch Monitoring Programme		university of St Andrews, Scottish fishermen's foundation, Cefas, UK centre for ecology & hydrology, marine Scotland science, nffo
monitoring programmes offshore wind	N/A, adhoc project based on relative research questions and monitoring by windfarmdevelopers		

Ireland

National monitoring

Ireland carries out ecological monitoring for the North Sea and surrounding Irish waters in relation to different directives and initiatives, covering the WFD, monitoring inputs for OSPAR and ICES, and ongoing monitoring for the Habitats Directive and Birds Directive. The ObSERVE programme supports implementation of the MSFD and separate monitoring for cetaceans and sea birds along the Irish coast. Moreover, the Marine Institute conducts extensive fisheries surveys (notably in the Celtic Sea) for commercial fisheries and broader purposes. A new plankton monitoring programme is being launched this year for the Irish coast (zooplankton and phytoplankton) using permanent stations, with results intended to feed into the wider programmes.

Most of the monitoring covers the Republic of Ireland (excluding Northern Ireland), while fisheries surveys may be more region-specific (e.g., Irish Sea or Celtic Sea). The spatial extent varies by parameter and species, covering the whole coast for mobile species like birds and cetaceans, and smaller regions for less mobile groups. Monitoring locations are selected through the Department of Climate, Environment and Energy's (DCEE) Marine Ecosystems and Ornithology Working Group, using indicator needs and appropriate spatial scale. Overall, the monitoring programmes aim to support OSPAR and ICES, contribute to Good Environmental Status under MSFD, and meet requirements under WFD and the Habitats and Birds Directives.

Offshore wind monitoring

Ireland does not yet have a monitoring programme for offshore wind, which is currently being developed. Ireland currently has only 1 small, fully operational offshore wind farm. For offshore renewable energy, monitoring will likely be approached at a regional scale. Monitoring stations are chosen based on the zone of influence and expected impact range, and on the presence of vulnerable habitats (e.g. benthos reef areas). For migratory species such as birds and bats, station design is informed by baseline studies due to limited prior information, using EU guidance only where suitable. Key organisations involved are DCEE, the Environmental Protection Agency (EPA), and the Marine Institute, with DCEE still developing parts of its own monitoring programme in regard to spatial mapping.

Denmark

National monitoring

The main long-term national monitoring falls under NOVANA (until 31 December 2003: NOVA), a national environmental monitoring programme that tracks the overall environmental status across Denmark (including marine areas). Overall, NOVANA provides baselines and time series for ecological status assessment. The Danish Centre for Environment and Energy (DCE) operates NOVANA.

Offshore wind monitoring

Denmark currently does not have a specific offshore wind monitoring programme and relies on the NOVANA programme. However, as NOVANA is not designed to detect offshore wind effects specifically, it is difficult to demonstrate causal impacts from offshore wind using NOVANA data alone. Therefore, dedicated offshore wind monitoring is used for future permitting requirements. Denmark has conducted dedicated offshore wind surveys on some projects, including historical programmes from the late 1980s and a more complete monitoring control programme between 1999 and 2006, focusing on impacts during and after construction. More recently, Energinet (in collaboration with DCE, which operates NOVANA) is contributing to guidelines and a monitoring scheme for offshore wind. The new guidelines are operated by Danish Energy Agency and contracted to external consultancies. The guidelines are under review but will include requirements for post construction monitoring as a supplement for pre-construction monitoring and baseline for the construction permits. These dedicated surveys are generally site-specific, covering the wind farm area and, depending on the ecological component, sometimes an added buffer/reference area (e.g. for birds to capture displacement and distribution changes outside the wind farm footprint). For EIA monitoring, the monitored area is typically larger than the footprint and is adjusted by ecosystem component and expected impact scale. Monitoring locations are selected primarily through NOVANA's legal and regulatory framework rather than offshore wind needs, and for offshore wind projects Energinet/DEA also check whether national monitoring stations could be affected. If this is the case, then dispensation or re-positioning may be required. Dedicated offshore wind monitoring aims to generate baseline information for EIA permitting, support impact assessments for biological parameters (e.g., marine mammals, birds, bats, fish, and habitats), and reduce knowledge gaps. Dedicated offshore wind monitoring schemes are operated under requirements set by the DEA. Energinet is involved through contracts, coordination, and method development.

In table III.3 an overview of the current monitoring programmes in Denmark is given.

Table III.3 Current monitoring programmes Denmark

	Name	Objective	Organisations
national monitoring programmes	NOVANA	baseline and time series for ecological status assessment	DCE
monitoring programmes offshore wind	N/A, instead there is dedicated offshore wind monitoring	(1) EIA, (2) IA for biological parameters and (3) reduce knowledge gaps	DEA, Energinet

France

National monitoring

During the interview the national monitoring programme of France was not discussed.

Offshore wind monitoring

In France, offshore wind ecological monitoring is organised per project stage and by the authority leading each step. Before construction, an EIA is developed, led by the French Directorate General for Energy and Climate (Direction générale de l'énergie et du climat, DGEC). Baseline studies are performed across a defined tender zone (often larger than the eventual wind farm area) for approximately 2 years. The resulting data and reports are provided to the OWF developer to support the EIA and permitting. The developer is responsible for writing the EIA. After a permit is granted, the developer must implement monitoring before, during, and after construction. These obligations are explicitly stated in the permit. This monitoring primarily covers the wind farm area, but usually also includes a wider surrounding zone and reference/control locations outside the influence of the project. Baseline study locations and zones are selected with input from environmental consultants and scientific experts coordinated and validated by DGEC, while permit-based monitoring is proposed by the developer and then set through the permit.

Monitoring protocols are discussed with local authorities and sometimes a scientific council to refine parameters and spatial extent. The purpose of baseline studies is to precisely describe the zone before the offshore wind farm project - which is the first 'part' that is required in the EIA, while construction-phase monitoring aims to verify that impacts are not significant, that mitigation measures are effective, and to confirm EIA conclusions. Organisations involved include the developer, DGEC, contracted environmental consultancies (and other support from the state), the local administration that grants permits and receives results, and potentially external scientific bodies/experts such as IFREMER.

Belgium

National monitoring

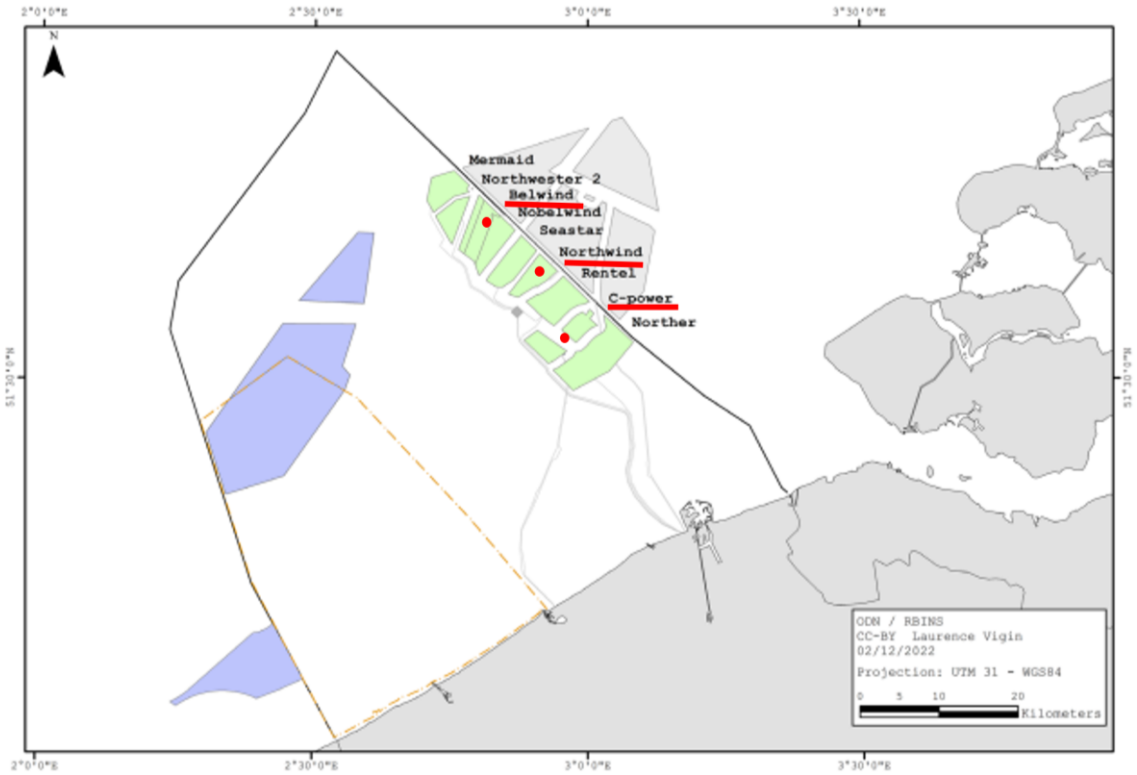
Belgium has monitoring programmes associated with offshore industrial activities, such as extraction, dredging/disposal, aquaculture and offshore wind (see below). Each activity requires an environmental permit, which includes a legally binding monitoring programme. In addition, Belgium has monitoring programmes arising from European legislation, with distinct cycles and reporting duties, including the MSFD, Birds and Habitats Directives, and where applicable the WFD. Belgium aims to combine these monitoring programmes where possible, since there is limited public funding for all legal requirements. The overarching idea is therefore to reuse data collected for human activities at sea (at least in part) to fulfil multiple directives.

Offshore wind monitoring

The WinMon.BE programme is a dedicated monitoring programme for OWFs. It is designed to assess the ecological impacts of offshore wind farms, with monitoring carried out mainly within the relevant wind farm areas and a smaller portion in reference areas for comparison (approximately 80 % inside and 20 % outside the wind farms). Belgium has 9 OWFs, which are largely located on similar dynamic sandbank habitats near the Dutch border. Because of similarities in habitat and location, monitoring is concentrated in 3 of the 9 windfarms (with increasing distance to the shore). The remaining 6 OWFs are barely covered by monitoring, though their wind farm operators still contribute financially to monitoring under WinMon.BE.

Monitoring locations are also linked to the outputs of the EIAs produced by the different wind farm developers. The programme aims to ensure no unexpected or unacceptable environmental damage occurs, to check whether predicted effects actually occur, and to improve understanding of the mechanisms behind observed impacts. WinMon.BE is coordinated by KBIN, with financial contributions from both the wind farm operators and the Belgian government.

Figure III.2 Current and planned zones for renewable energy in and around the Belgian Part of the North Sea. Operational wind farms in Belgian waters are shown in green. Windfarms that are monitored under WinMon.BE are shown with a red dot/ stripe (Degraer, Brabant, Rumes, & Vigin, 2022)



In table III.4 an overview of the current monitoring programmes in Belgium is given.

Table III.4 Current monitoring programmes Belgium

	Name	Objective	Organisations
national monitoring programmes	N/A through directives and initiatives	-	-
monitoring programmes offshore wind	WinMon.BE	(1) monitor effects, (2) improve understanding of mechanisms behind effects	KBIN, wind farm operators and the Belgian government

The Netherlands

National monitoring

The Netherlands has several national, long-term and project-based ecological monitoring programmes for the North Sea. The most relevant include:

- monitoring of the Water Management Condition of the Country (MWTL), covering morphology, water quality, chemistry and biology;

- statutory Research Tasks (WOT) Nature & Environment and WOT Fisheries, supporting nature conservation and fisheries management;
- monitoring and Research Programme for Nature Enhancement and Species Protection (MONS), which improves knowledge of the North Sea ecosystem and supports nature restoration and species protection. Includes, among other things, the FerryBox, the Digitalisation of Ecological Monitoring (DEM) buoys, and additional monitoring of protected areas, such as the Borkum Stones;
- fisheries monitoring.

Locations are selected primarily according to information needs, policy objectives, legal requirements, international obligations, project requirements and regional management priorities. Relevant frameworks include the MSFD, WFD, Birds and Habitats Directives, Natura 2000, OSPAR, and the North Sea Agreement. Therefore, the monitoring programmes support water and environmental management, nature conservation, fisheries management, OSPAR and other statutory reporting obligations. MONS aims to improve understanding of the North Sea ecosystem, strengthen nature and protect species.

The programmes are led primarily by Rijkswaterstaat, the Ministry of Infrastructure and Water Management, the Ministry of Agriculture, Fisheries, Food Security and Nature and the Ministry of Economic Affairs. WOT programmes are led by Wageningen Research, including Wageningen Marine Research, Wageningen Environmental Research and Wageningen Economic Research. Other contributors include Deltares, NIOZ, Sovon, specialist research institutes and consultancy firms.

Offshore wind monitoring

Offshore wind monitoring in the Netherlands is primarily conducted through the Offshore Wind Ecological Programme (Wozep), the Maritime Information Provision Service Point (MIVSP) sensor infrastructure programme, the Start/Stop programme and site investigations commissioned by the Netherlands Enterprise Agency (RVO) for designated offshore wind areas. Monitoring focuses on the effects of wind farms on birds, bats, marine mammals and other marine species. The data are used to validate ecological impact models, support environmental impact assessments and licensing, develop mitigation measures and inform offshore-wind planning. Rijkswaterstaat manages much of the monitoring infrastructure and implementation, and where necessary supported by subcontractors and partner organisations.

Table III.5 Current monitoring programmes the Netherlands

	Name	Objective	Organisations*
national monitoring programmes	MWTL	Provides information for national water-management objectives, the Water Framework Directive and the Marine Strategy Framework Directive	Rijkswaterstaat, Ministry of Infrastructure and Water Management
	WOT Nature & Environment	Provides information supporting the Birds Directive, Habitats Directive and Natura 2000 conservation objectives	Ministry of Agriculture, Fisheries, Food Security and Nature, Wageningen Environmental Research, Wageningen Marine Research
	WOT fisheries	Supports the Common Fisheries Policy and the assessment of fish stocks	Ministry Agriculture, Fisheries, Food Security and Nature, Wageningen Economic Research, Wageningen Marine Research

	Name	Objective	Organisations*
	MONS	established under the North Sea Agreement and aims to improve knowledge of the North Sea ecosystem, support nature enhancement and protect species	Rijkswaterstaat, Ministry of Infrastructure and Water Management, Ministry of Agriculture, Fisheries, Food Security and Nature,
monitoring programmes offshore wind	Wozep	assesses the ecological effects of offshore wind energy and supports decision-making on offshore-wind development	Rijkswaterstaat, Ministry of Economic Affairs
	MIVSP sensor infrastructure programme	validating models and assess effect of offshore wind on ecology	Rijkswaterstaat, Ministry of Economic Affairs
	Start/Stop programme	fewer bird collisions	Rijkswaterstaat, Ministry of Economic Affairs, Ministry of Agriculture, Fisheries, Food Security and Nature
	baseline studies	preparation for tenders	RVO

* Besides the organisations mentioned other research institutes and consultancy firms are involved, but don't have a coordinating role.

Norway

National monitoring

Norway's national marine monitoring programme covers fish, water quality and wider ocean conditions across all Norwegian waters, using ecosystem cruises, physical transects and other observations. Monitoring is led by the Institute of Marine Research, in cooperation with ICES and other research organisations. The MAREANO programme complements this work by mapping benthic habitats, vulnerable marine ecosystems and areas of environmental importance. The Institute of Marine Research, the Geological Survey of Norway and the Norwegian Mapping Authority comprise the Executive Group which is responsible for carrying out the MAREANO field sampling. The Programme Group, led by the Norwegian Environment Agency, has the executive responsibility for the MAREANO activities. Together, these programmes provide broad-scale information on the condition and distribution of marine species, habitats and environmental characteristics.

Offshore wind monitoring

Dedicated offshore wind monitoring is under development in Norway. They are currently focused on establishing baseline conditions in potential development areas. Monitoring is expected to cover both wind farm sites and surrounding areas, using gradient studies and, where possible, before-after/control-impact (BACI) designs. The objectives are to assess changes associated with construction and operation, including effects on habitats, species, currents, noise and electromagnetic fields. Monitoring locations will be selected based on species and habitat distribution, hydrography, environmental variability and modelling results. The work will support environmental assessments and future offshore wind decisions, with developers responsible for project-specific monitoring plans. Key organisations include the Norwegian Water Resources and Energy Directorate (NVE), the Norwegian Offshore Directorate, the Institute of Marine Research, the Norwegian Institute for Nature Research (NINA), the Norwegian Institute for Water Research (NIVA), and other research institutes.

OSPAR

OSPAR itself does not monitor directly and does not conduct its own data collection. Instead, it compiles and harmonises data provided by countries in order to coordinate the assessment of the state of the marine environment. OSPAR uses Coordinated Environmental Monitoring Programme (CEMP) guidelines, which specify what information and minimum data quality are required, but they do not require countries to use

exactly the same field methods or to monitor at the same intensity. As a result, the quality and continuity of monitoring vary between countries (e.g. due to temporary projects and limited resources).

For data assessments, the process often runs through indicator leads and expert groups (for biodiversity, for example via Intersessional Correspondence Groups (ICG)/Coordination of Biodiversity Assessment and Monitoring (COBAM).

For some indicators, data can be processed automatically, whereas for other components (such as benthos) data are first collected nationally and only submitted to OSPAR when a data call is issued. In OSPAR, assessments are produced through harmonised assessment processes, after which results such as 'data snapshots' are made available on the website. In addition, there are pilot assessments and various working groups (with the bird working group mentioned as particularly well developed).

Regarding offshore wind, reporting is included in a way that it falls under human activities. Ecological effects, in contrast, mainly appear through biodiversity indicators such as habitat loss (BH4) and possibly through assessments related to Underwater sound.

III.2 Monitoring methods: ecosystem component, indicators, measuring methods and sampling frequency

Germany

National monitoring

Germany monitors harbour porpoises and other whales, seabirds, benthic communities, non-indigenous species, and selected chemical and physical conditions ((table III.6), Monitoring of pelagic fish and habitats, plankton and minke whales is still under development or at a pilot stage, while anadromous and commercial fish are monitored by other programmes. Germany's ecological monitoring programmes were initially established to meet the requirements of the Habitats Directive, Birds Directive and Natura 2000, with the MSFD later using much of the existing monitoring data. The data support assessments of biodiversity, food webs and seafloor integrity. Monitoring methods are periodically refined, with increasing use of digital, video and image-based techniques to improve efficiency and reduce the need for invasive dredging. Programmes follow the German federal and state joint monitoring framework (BLMP), alongside OSPAR and other European standards, to ensure consistency, comparability and avoid duplicated monitoring.

Frequencies vary by component: bird surveys are generally annual, porpoise monitoring is more intensive during spring and summer, benthic stations are sampled annually or every 3 years, and non-indigenous species are monitored year-round (table III.6). Most core monitoring programmes began around 2002, although bird data extend back to the 1990s. Monitoring of non-indigenous species, chemical and physical conditions, and minke whales was introduced more recently, while pelagic fish and habitat monitoring began in 2026 and remains at a pilot stage. BfN is not directly responsible for offshore wind monitoring but uses data from BSH wind farm surveys in its bird and whale models.

Table III.6 Ecosystem components and indicators monitored by the national monitoring programme under BfN

Ecosystem component	Indicator	Monitoring method	Frequency
Marine mammals	abundance, density, distribution, reproduction	ship and aerial surveys (for harbour porpoise only aerial) and acoustic monitoring (for minky whales)	Multiple times a year, with higher frequencies in spring and summer
Resting and migrating birds	population trends, abundance, density, distribution	ship and aerial surveys	annually; some survey areas several times a year
Macro zoobenthos	species composition, abundance, biomass, diversity, community structure, indices	grab samples, video surveys, van Veen grab (for infauna) and before dredging (but not anymore)	some parts annually, other every 3 years
Pelagic habitats/fish	presence/absence sharks, rays and non-commercial fish species	eDNA and 1 other method (not defined)	pilot phase
Non-indigenous species	presence/absence new species	with structure in the harbour (structure not defined)	continuous
Physical/ chemical parameters	salinity, temperature, waves, noise and other	currently 2 measuring buoys; more will be installed shortly	continuous

Offshore wind monitoring

The ecosystem components and indicators monitored by BSH under the offshore monitoring programme StUK4 are given in table III.7. The relevant ecosystem components and indicators are defined in accordance with the StUK document. This document was developed through an extensive stakeholder process, and its content is grounded in expert judgement and relevant literature, while also taking into account the practical feasibility of available monitoring methods. The current version of StUK dates from 2013 - only minor amendments have been made so far, and an updated version was initially planned for this year. However, StUk will now likely be updated next year (in 2027). There is no fixed update interval. When adjustments are made, BSH tries for everyone to use the old and new methods at the same time, so they can compare the data (standardized). All official amendments are published on the relevant website.

In table III.7 the monitoring method and frequency of monitoring are also given. For fish and invertebrates, baseline and post-construction monitoring is coordinated using clearly defined monitoring stations located both within the wind farms and in surrounding reference areas outside. This enables straightforward before/after comparisons. For migratory species, BSH aims to monitor approximately the same geographic area before and after construction to maintain interpretability of the 'before vs. after' dataset, though minor shifts can occur when wind farms are clustered. Acoustic monitoring is handled differently because stations may be relocated during the project lifetime, but BSH has established a set of long-term acoustic stations (around 12) that remain in the same positions for roughly 10-15 years. While monitoring is not continuous and may include gaps (e.g., when a developer is not obliged to monitor for a period of time), it has provided an acceptable dataset.

The overall monitoring approach has been in place since around 2010, following the construction of the first North Sea wind farm, and has seen standardization over time, with methods largely consistent for the last decade. An additional trend is that, for newly built wind farms, migratory bird monitoring may use alternative approaches such as collision modelling rather than the StUK method used for existing farms. Moreover, newer methods (including AI-based approaches) are currently under development, with developers discussing method and monitoring frequency with BSH beforehand, although these approaches are not yet fully standardized and collision monitoring remains challenging. Finally, the monitoring during the operation phase covers a period of 5 years. In the update version of StUK this will be prolonged to 10 years.

Table III.7 Ecosystem components, indicators, monitoring method and monitoring frequency under the monitoring programme StUK4 (BSH, 2011; 2013)

Ecosystem component	Indicator	Monitoring method	Frequency
benthic habitats and benthos	sediment and habitat structure - ground morphology and substratum type	side scan sonar (sss), grab sampling	once during baseline study, and in the third and fifth year of operation
	epifauna, macrophytes and habitat structure - abundance, frequency, presence and disturbances of sediment surface	video survey	two consecutive complete seasonal cycles prior to the start of construction (baseline study)
	infauna - abundance, biomass, dominance structure, occurrence and distribution and diversity	grab sampling survey	two consecutive complete seasonal cycles prior to the start of construction (baseline study), and in the first, third and fifth year of the operation phase
	epifauna - abundance, biomass, dominance structure, occurrence and distribution and diversity	beam trawl survey	two consecutive complete seasonal cycles prior to the start of construction (baseline study), and in the first, third and fifth year of the operation phase
	infauna - abundance, biomass, dominance structure and occurrence and distribution	grab sampling surveys	third and fifth year of operation phase
	growth and demersal megafauna on the underwater construction structure - abundance, biomass, dominance structure, coverage	up to 10 m water depth, pile survey to be made by research divers; at greater depths video footage of the technical construction monitoring**	third and fifth year of operation phase
	benthos and habitat structures in the context of installation of cable routes - abundance, biomass, dominance structure, occurrence and distribution and diversity	infauna: van Veen grab (grab sampler); epifauna: beam trawl	once during the baseline study and once during the operation phase 1 year after commissioning of the cable
	sediment properties - grain size distribution and loss on ignition	sediment sample	once during the baseline study and once during the operation phase 1 year after commissioning of the cable
fish	abundance, biomass, dominance structure, diversity, average number of species per haul, length frequency distribution of dominant species	beam trawl/otter trawl survey (wind farm trawl)	two consecutive complete seasonal cycles prior to the start of construction (baseline study), and in the first, third and fifth year of the operation phase
resting birds	seasonal mean values, density, abundance, total number of species	ship transect survey, aircraft transect survey	two consecutive complete seasonal cycles prior to the start of construction (baseline study), throughout the whole construction phase, and at least 3 years up to 5 years after commissioning (operation phase)
Migratory birds	bird movements (migration, foraging, flights between feeding and resting grounds), migration intensity and flight altitudes	radar survey (vertical radar)	two consecutive complete seasonal cycles prior to the start of construction (baseline study), throughout the whole

Ecosystem component	Indicator	Monitoring method	Frequency
			construction phase, and at least 3 years up to 5 years after commissioning (operation phase)
	seasonal phenology of flight/call intensities, flight direction, bird species	visual observation/recording of flight calls	two consecutive complete seasonal cycles prior to the start of construction (baseline study), throughout the whole construction phase, and at least 3 years up to 5 years after commissioning (operation phase)****
Marine mammals	abundance and distribution	ship transect survey, aircraft transect survey	two consecutive complete seasonal cycles prior to the start of construction (baseline study), throughout the whole construction phase, and at least 3 years up to 5 years after commissioning (operation phase)
	habitat use	C-POD/F-POD	two consecutive complete seasonal cycles prior to the start of construction (baseline study), throughout the whole construction phase, and at least 3 years up to 5 years after commissioning (operation phase)
Bats	bat species, seasonal distribution and call activity	bat detector	two consecutive complete seasonal cycles prior to the start of construction (baseline study)
Landscape	visualisation	not defined	one time during baseline study
Underwater sound	noise emission and immission	hydrophone	one time during the baseline study, throughout the entire construction phase and during the first year of operation
Physical/chemical parameters *	salinity, temperature and oxygen levels at the sea surface and seabed, weather, depth	CTD	two consecutive complete seasonal cycles prior to the start of construction (baseline study), and in the first, third and fifth year of the operation phase

* Abiotic conditions are measured during the benthos and fish surveys.

** There is already a lot of data and in practice these samples are omitted.

*** All new projects (as of last year) have to carry out a 10-year-operational monitoring. This means that the monitoring is stretched out over the first 10 years of the operational phase, not necessarily carried out every year.

**** All newer projects that are in operation starting in 2026 (or in the Baltic Sea since 2025) do not follow the Stuk4-based migratory bird monitoring during the operational phase but are required to carry out a collision monitoring. The baseline study is carried out according to StUK4.

United Kingdom

National monitoring

National monitoring programmes in the UK cover a range of ecosystem components, including fish, shellfish, benthic habitats and invertebrates, plankton, seabirds and environmental conditions. Key indicators include abundance and biomass, supplemented where relevant by length, size, age, breeding productivity and other morphological or biological characteristics. The selection of components and indicators is determined by programme objectives, such as fish-stock assessment, OSPAR reporting, good environmental status monitoring, licensing requirements and the conservation features of individual MPAs. For benthic monitoring, JNCC tailors survey designs to the habitats or species for which each MPA has been designated. For HMPAs, which are intended to protect the wider ecosystem, JNCC is developing approaches that include ecosystem components beyond benthos. Seabird monitoring follows the Seabird Monitoring Handbook and European Seabirds at Sea guidelines, with abundance and breeding productivity as the main indicators.

Methods include sampling from fishing and research vessels, the Continuous Plankton Recorder (CPR), fisheries acoustics, seabed and marine imagery, autonomous monitoring, underwater-noise sensors and eDNA. JNCC uses established protocols and standard operating procedures for offshore MPA monitoring, supported by equipment and sampling-design guidance and the North-East Atlantic Marine Biological Analytical Quality Control framework for image analysis. The UK mostly makes use of standardised procedures. Monitoring methods and indicators are reviewed and updated in response to new research, technologies, management needs, funding and policy changes, while maintaining comparability with historical datasets. Changes generally involve analytical approaches, camera resolution or classification criteria rather than replacing core sampling methods. Monitoring frequency varies from continuous or near-continuous data collection for the CPR and some noise sensors to annual or multiannual surveys conducted every 2, 3 or 5 years. Frequencies are determined by programme objectives, logistics, funding and reporting cycles, and may also reflect the sensitivity, vulnerability and recovery time of habitats or species. The programmes range from long-established surveys, such as the CPR, operating since 1931, and the UK Seabird Monitoring Programme, established in 1986, to newer initiatives involving marine noise, autonomous technologies and eDNA.

The general monitoring methods for the different ecosystem components currently monitored by the JNCC and CEFAS are given in table III.8.

Table III.8 Ecosystem components and indicators monitored by JNCC and/or CEFAS

Ecosystem component	Indicator	Monitoring method	Frequency	Monitoring programme
Benthic habitats and benthos	presence/absence, abundance, and biomass, functional traits and diversity indices	grab sampling: infauna and sediment; drop-down cameras, sledges, towed cameras: reef structures, epifauna; eDNA samplers: collective eDNA; National Oceanographic Centre ROV &AUV's: deep-sea sites; 2 m beam trawl: epifauna	deep-sea sites once every 6 years, non-deep-sea sites once every 3 years	English benthic MPA monitoring programme
	macrofauna species and abundance/biomass, various sediment contaminants	chartered vessel/use of Cefas research vessel. Grab samples taken inside and in the vicinity of disposal sites for macrofauna	annually - 1 or 2 sites are sampled per year, the sites selected represent those with the highest ecological risk. Results are annually reported	Dredge material disposal site monitoring (MMO).
	species identification and qualification/quantification	hamon grab and imagery (drob down camera) for ground truthing habitat mapping	annually	Centre for Seabed Mapping (CSM)
	abundance, age and length and behaviour	king scallop dredge survey - Commercial fishing vessel using commercial and modified queen scallop gear scallop and Nephrops Video survey - Research vessel survey, using video and/or camera	king scallop dredge survey - twice annually, May and September. scallop and Nephrop Video survey - once annually, variable	King Scallop dredge survey, Scallop UWTV Survey, Nephrops UWTV surveys
	habitat mapping, topography, and historical wrecks	multibeam	annually	Centre for Seabed Mapping (CSM)
Fishes (including non-commercial) (and benthic invertebrates)	abundance and/or biomass	Onboard observer sampling of fishing vessels and fish markets. Port records and logbooks (MMO)	continuous	CEFAS onshore and offshore Observer Programmes
	Species identification and distribution	Offsite surveys (questionnaire/ app)	annually	Sea angling survey
	Fish relative abundance	Field survey- Commercial fishing vessel - using 2 and 3 m beam trawls (primary data) and other sampling equipment (oceanography). Daylight only fishing survey.	Annually (14 days in Aug/September)	Inshore survey (Young-fish survey [YFS])
	Fish relative abundance and biomass	Field survey- RV Endeavour - using bottom otter trawl (primary data) and other sampling equipment (oceanography). Survey follows WGIBTS protocols and is a daylight fishing survey only	annually	International Bottom Trawl Survey (IBTS) - England
	Fish relative abundance and biomass	Field survey- RV Endeavour - using 2 x 4m beam trawls (primary data) and other sampling equipment (oceanography). Survey managed by ICES WGBeam protocols and is a 24/7 fishing survey.	Annually (27 days in March)	Q1 South-west Beam trawl survey [ECOS]
	Fish relative abundance and biomass	Field survey- RV Endeavour - using 1 x 4m beam trawls (primary data) and other sampling equipment (oceanography). Survey managed by ICES WGBeam protocols and is a daylight only fishing survey.	Annually (20 days in September)	Irish Sea/Bristol Channel Beam Trawl survey (NWGFS)

Ecosystem component	Indicator	Monitoring method	Frequency	Monitoring programme
	Relative abundance, biomass and species classification	Field survey - RV Endeavour	annually	English North Sea Beam Trawl (EBT) Surveys (Eastern Chanel Beam Trawl Survey)
	Acoustic and biological data; abundance, biomass, biometrics, effort-based abundance of bluefin tuna	Field survey - RV Endeavour operating 24/7; eDNA sampling alongside standard trawl and acoustic transects and oceanographic/water quality sampling.	annually (29 days in September - November); eDNA pilot 2024 - 2026	PELTIC acoustic small pelagic survey (Western Channel and Celtic Sea)
	Acoustic and biological data; abundance, biomass, biometrics	Field survey - Commercial mid-water trawler operating 24/7; standard trawl and acoustic transects and oceanographic/water quality sampling.	Annually (13 days in May)	International ecosystem survey of Nordic Seas (IESNS) - previously referred to as ASH)
	Movements and distribution	Tagging survey (mark-recapture)	Ad hoc	MAKTAG survey (in pilot phase, not yet routine monitoring)
	Stomach contents	Sample collection of dabs from CSEMP fishing sites to carry out fish (dab) stomach content analysis of 20 dab per station.	Biennial survey to collect dab.	No specific programme but data feeds into a fish stomach database - https://www.cefas.co.uk/data-and-publications/fish-stomach-records/
Plankton (phytoplankton, zooplankton, ichthyoplankton)	Relative abundance and biomass	Field survey- RV Endeavour - rod and line fishing and JVDK mid-water trawl (secondary data) and other sampling equipment (GULF-VII). Survey managed by ICES WGMEGS protocols. Fishing for fecundity samples only	Tri-Annually (24 days in June) with intersessional surveys (10 days in year 2 and 3)	Mackerel egg survey MEGS) -inc. intersessional surveys
	Relative abundance and biomass	Field survey - Commercial mid-water trawler operating 24/7; standard trawl and acoustic transects and oceanographic/water quality sampling.	Annually (13 days in May)	International ecosystem survey of Nordic Seas (IESNS) - previously referred to as ASH)
	Relative abundance and biomass	Field survey - RV Cefas endeavour operating hours of darkness	Annually (10 days in April)	Downs Recruitment Survey (DRS)
	Species identification and distribution	Field survey - RV Endeavour operating 24/7; acoustic transects, vertical ring nets, Pi-10, flow cytometry, nets with analysis by microscopy and FlowCam	annually (29 days in September - November); eDNA pilot 2024 - 2026	PELTIC acoustic small pelagic survey (Western Channel Celtic Sea and Cardigan Bay)
	Species diversity, chlorophyll-a concentration, biomass indices.	Continuous plankton recorder (CPR) and net sampling	continuous/ monthly	Note that Cefas does not administer the continuous plankton recorder survey, it is homed at the UK Marine Biological Association
	Biological - Phytoplankton, zooplankton (quantity, distribution, foodwebs)	Field survey (sampling from RV Endeavour and small boats in partnership with EA. Plankton imager, FerryBox, ESMXr, flow cytometry, chlorophyll filtration, net and microscopy, plankton imager; nets (zooplankton), bags (phytoplankton) and automated sample collection on fixed point SmartBuoy	Surveys held quarterly continuous measurements from SmartBuoy and Ferrybox	Integrated eutrophication and water quality monitoring programme
Jellyfish	Relative abundance and biomass	Field survey- RV Endeavour - using 2 x 4m beam trawls (primary data) and other sampling equipment (oceanography). Survey managed by ICES WGBeam protocols and is a 24/7 fishing survey	Annually (27 days in March)	Q1 South-west Beam trawl survey [ECOS]
	Relative abundance and biomass	Field survey- RV Endeavour - using 1 x 4m beam trawls (primary data) and other sampling equipment (oceanography). Survey managed by ICES WGBeam protocols and is a daylight only fishing survey	Annually (20 days in September)	Irish Sea/Bristol Channel Beam Trawl survey (NWGFS)
	Relative abundance and biomass	Field survey- Commercial fishing vessel - using 2 and 3 m beam trawls (primary data) and other sampling equipment (oceanography). Daylight only fishing survey	Annually (14 days in Aug/September)	Inshore survey (Young-fish survey [YFS])
	Relative abundance and biomass	Field survey - RV Endeavour using 1 x 4m beam trawls (primary data) and other sampling equipment (oceanography). Survey managed by ICES WGBeam protocols and is a daylight only fishing survey	Annually (13 days in July)	English North Sea Beam Trawl (EBT) Surveys (Eastern Chanel Beam Trawl Survey)
	Relative abundance and biomass (plus individual	Field survey- RV Endeavour - using bottom otter trawl (primary data) and other sampling equipment (oceanography and plankton). Survey follows WGIBTS protocols and is a daylight fishing survey only	annually	International Bottom Trawl Survey (IBTS) - England

Ecosystem component	Indicator	Monitoring method	Frequency	Monitoring programme
	weights and damage assessment)			
	Species distribution	Field survey - RV Endeavour operating 24/7; eDNA sampling alongside standard trawl and acoustic transects and oceanographic/water quality sampling	annually (29 days in September - November); eDNA pilot 2024 - 2026	PELTIC acoustic small pelagic survey (Western Channel Celtic Sea and Cardigan Bay)
Seabirds	abundance, breeding productivity (counts of birds, nests, eggs and chicks), survival and diet	mainly land-based visual surveys, supplemented by boat and aerial surveys, cameras, ringing and tracking technologies	annually (Seabird Monitoring Programme) and once every 10 years (seabird census)	Seabird Monitoring Programme and Seabird Census
	effort-based abundance of birds	Field survey - RV Endeavour operating 24/7; eDNA sampling alongside standard trawl and acoustic transects and oceanographic/water quality sampling.	annually (29 days in September - November); eDNA pilot 2024 - 2026	PELTIC acoustic small pelagic survey (Western Channel Celtic Sea and Cardigan Bay)
Marine mammals	abundance and distribution	ship surveys and aerial surveys	ca. once every 10 years, but moving towards once every 6 years	SCANS
	identifying cause of death and key health information on dead-stranded marine animals, including contaminant burden	beach surveys	on the go	CSIP and SMASS
	bycatch	Observers on board of commercial fishing vessels	continuous	UK Bycatch Monitoring Programme. *Note Cefas is also trialling remote electronic monitoring technology
	effort-based abundance of mammals	Field survey - RV Endeavour operating 24/7; eDNA sampling alongside standard trawl and acoustic transects and oceanographic/water quality sampling.	annually (29 days in September - November); eDNA pilot 2024 - 2026	PELTIC acoustic small pelagic survey (Western Channel Celtic Sea and Cardigan Bay)
Physical/ chemical parameters**	Wave energy and sea surface temperature	continuous recording through buoy network and partner instrumentation (other buoys and offshore installations)	continuous since 2002	WaveNet
	temperature, salinity, fluorescence, oxygen, nutrients	Field survey - RV Endeavour operating 24/7; eDNA sampling alongside standard trawl and acoustic transects and oceanographic/water quality sampling.	annually (29 days in September - November); eDNA pilot 2024 - 2026	PELTIC acoustic small pelagic survey (Western Channel Celtic Sea and Cardigan Bay)
	Salinity, temperature and depth	CTD and other instruments	deep-sea sites once every 6 years, non-deep-sea sites once every 3 years.	English benthic MPA monitoring programme and Seabed Habitat Mapping Programme. *Note CTD are deployed on almost all Cefas monitoring surveys
	oceanographic/water quality data	Field survey- RV Endeavour - using bottom otter trawl (primary data) and other sampling equipment (oceanography and plankton). Survey follows WGIBTS protocols and is a daylight fishing survey only	annually	International Bottom Trawl Survey (IBTS) - England
	oceanographic/water quality data	Field survey- RV Endeavour - using 2 x 4m beam trawls (primary data) and other sampling equipment (oceanography). Survey managed by ICES WGBeam protocols and is a 24/7 fishing survey.	Annually (27 days in March)	Q1 South-west Beam trawl survey [ECOS]
	oceanographic/water quality data	Field survey- RV Endeavour - using 1 x 4m beam trawls (primary data) and other sampling equipment (oceanography). Survey managed by ICES WGBeam protocols and is a daylight only fishing survey.	Annually (20 days in September)	Irish Sea/Bristol Channel Beam Trawl survey (NWGFS)
	oceanographic/water quality data	Field survey- Commercial fishing vessel - using 2 and 3 m beam trawls (primary data) and other sampling equipment (oceanography). Daylight only fishing survey	Annually (14 days in Aug/September)	Inshore survey (Young-fish survey [YFS])

Ecosystem component	Indicator	Monitoring method	Frequency	Monitoring programme
	oceanographic/water quality data	Field survey- RV Endeavour - rod and line fishing and JVDK mid-water trawl (secondary data) and other sampling equipment (oceanography). Survey managed by ICES WGMEGS protocols. Fishing for fecundity samples only	Tri-Annually (24 days in June) with intersessional surveys (10 days in year 2 and 3)	Mackerel egg survey MEGS) -inc. intersessional surveys
	- Physical (particle size assessment (PSA)) - Chemical (organohalogens (OHs), trace metals) - Organic Carbon (OC) N.B. content only not stock or accumulation	Chartered vessel/use of Cefas research vessel. Grab samples taken inside and in the vicinity of disposal sites for sediment PSA, organic carbon and various sediment contaminants	annually - 1 or 2 sites are sampled per year, the sites selected represent those with the highest ecological risk. Results are annually reported	Dredge material disposal site monitoring (MMO).
	carbon samples and/ or contaminants / porewater nutrients	box-cores or multi-cores (not for carbon)	NA for carbon	English benthic MPA monitoring programme
	contaminants in sediment (metals, PCBs, PBDEs, PAHs, PFAS)	grab (See CSEMP below) - cores are not in routine monitoring	biennially	CSEMP
	Eutrophication monitoring - chlorophyll fluorescence, chlorophyll biomass, nutrient concentrations, salinity, temperature, turbidity, suspended particulate matter oxygen saturation. Phytoplankton species composition and abundance, pCO2 (would fall under ocean acidification rather than eutrophication monitoring)	Field survey (sampling from RV Endeavour and small boats in partnership with EA; autonomous sensors) for water column profiles and surface underway sampling SmartBuoy and ferrybox autonomous sensors for surface sampling	water quality and mooring surveys held quarterly, sampling for surface nutrients (Dec - Feb) and chlorophyll (Mar - Oct) undertaken on other RV Endeavour surveys. Continuous data collection by SmartBuoys and Ferrybox on RV Endeavour.	Integrated eutrophication and water quality monitoring programme
	- Contaminants (metals, PCBs, PBDE's, PAHs, PFAS) being analysed from sediment and biota in the Greater North Sea and Celtic Seas. - Biological effects (The External Fish Disease Index, 7-ethoxyresorufin O-deethlyation (EROD) activity, Micronucleus test, Liver neoplasm, PAH bile metabolites) samples analysed from flatfish (mainly dab) - Additionally, imposex is being assessed in dogwhelks	Fish and sediments are being collected on an annual survey. Fish collected with granton trawl and sediments with a day grab For the biological effects assessments, fish are needed alive. For the imposex study, dogwhelks are being collected from various beaches, and the dogwhelks are analysed for the effects of TBT by assessing their VDS	Biennial survey to collect sediment and biota samples for chemical analysis. Additionally, imposex is being assessed every 3-4 years to investigate the effects of TBT on the marine environment.	Clean Seas Environment Monitoring Programme (CSEMP)

Ecosystem component	Indicator	Monitoring method	Frequency	Monitoring programme
Marine Litter	seafloor litter	imagery (Drop Down Video or Video Sledge)	Annually as part of offshore sampling of MPAs	English benthic MPA monitoring programme and Seabed Habitat Mapping Programme.
	seafloor litter indicator	Field survey- RV Endeavour - using bottom otter trawl. Survey follows WGIBTS protocols and is a daylight fishing survey only	annually	International Bottom Trawl Survey (IBTS) - England
	microlitter, including seabed microplastics	Grab samples	Annually (one year east, next year west)	CSEMP
	seafloor litter	Field survey- RV Endeavour - using 2 x 4m beam trawls (primary data) and other sampling equipment (oceanography). Survey managed by ICES WGBeam protocols and is a 24/7 fishing survey.	Annually (27 days in March)	Q1 South-west Beam trawl survey [ECOS]
	seafloor litter	Field survey- RV Endeavour - using 1 x 4m beam trawls (primary data) and other sampling equipment (oceanography). Survey managed by ICES WGBeam protocols and is a daylight only fishing survey.	Annually (20 days in September)	Irish Sea/Bristol Channel Beam Trawl survey (NWGFS)
	marine litter	Field survey- Commercial fishing vessel - using 2 and 3 m beam trawls (primary data) and other sampling equipment (oceanography). Daylight only fishing survey.	Annually (14 days in Aug/September)	Inshore survey (Young-fish survey [YFS])
	marine litter	Field survey- RV Endeavour - rod and line fishing and JVDK mid-water trawl (secondary data) and other sampling equipment (oceanography). Survey managed by ICES WGMEGS protocols. Fishing for fecundity samples only.	Tri-Annually (24 days in June) with intersessional surveys (10 days in year 2 and 3)	Mackerel egg survey MEGS) -inc. intersessional surveys
Underwater noise	ambient underwater noise levels***	autonomous passive acoustic monitoring using seabed noise recorders/landers	Long-term/ongoing monitoring at WARP, Puffin Island and Rame Head; periodic monitoring at Dowsing (most recently deployed during July-November 2026 to collect comparable summer data from previous years).	Cefas Underwater Noise Programme

* Cefas has none for carbon stocks/burial, though Cefas is trialling carbon stock monitoring (currently research stage rather than routine monitoring).

** Measurements of water quality parameters/abiotic conditions are included in different monitoring programmes.

*** Programme supports UK Marine Strategy Descriptor 11 and OSPAR continuous underwater-noise assessment, with monitoring data contributed to the ICES Continuous Noise Database.

Offshore wind monitoring

Offshore wind developers are not required to follow JNCC or CEFAS monitoring guidelines, because both are government organisations and do not prescribe methods to commercial parties. Therefore, it has not been defined which indicators must be monitoring by windfarm developers. Monitoring of windfarms by developers relates to what is stated in the EIA and permit. Offshore wind monitoring in relation to seabirds uses a wider range of indicators compared to the annual national monitoring, depending on the research question and the conditions of the permit or consent. Table III.9 contains an overview of offshore wind monitoring in relation to seabirds. However, the table does not give a complete overview of all monitoring performed in relation to offshore wind, but only part of it in relation to seabirds.

The frequency of offshore wind monitoring varies between wind farms. Baseline surveys are commonly conducted monthly for approximately 2 years before construction. Monitoring during operation is also often conducted monthly, although it may be restricted to the season in which the relevant species are present. Monitoring generally continues for at least a couple of years after construction, but the duration varies. Wind farm monitoring has been caried out since the early 2000's, since the early phases of offshore wind development in the UK.

Besides monitoring carried out by windfarm developers, JNCC en CEFAS carry out some funded monitoring in relation to offshore wind. These research projects are generally time-limited, typically lasting around 2 or 3 years. Moreover, national monitoring using methods such as acoustic noise monitoring, imagery, autonomous monitoring and eDNA may be relevant to marine environmental assessments in relation to offshore wind.

Table III.9 Ecosystem components and indicators monitored by offshore windfarm developers

Ecosystem component	Indicator	Monitoring method	Frequency
seabirds	abundance, distribution	ship, visual and digital aerial surveys	- baseline surveys monthly for approximately 2 years before construction - post-construction surveys are often monthly for at least several years, although frequency, duration and seasonal coverage vary between wind farms
	displacement, flight paths, behaviour, avoidance rates, collision rates and flight height	turbine-mounted cameras; ringing and tracking devices, including GPS tags, geolocators and flight-height sensors	see above

Ireland

National monitoring

The ecosystem components and indicators monitored in Ireland are given in table III.10. Under the WFD, monitoring is organised using an ecological sensitivity tool developed specifically for WFD implementation. Monitoring focuses on relevant ecological components, including benthic habitats and surveys of the water column and shoreline (including nutrient-related surveys). For OSPAR and the MSFD reporting, monitoring activities are designed to feed directly into the MSFD descriptors. This includes dedicated programmes for plankton (zooplankton and phytoplankton), groundfish surveys, and Underwater sound monitoring.

For the overall national monitoring programme, the selection is guided by directive requirements and the need to produce outputs for MSFD, WFD, OSPAR, and ICES. Therefore, monitoring methodology follows established protocols linked to the relevant directives/frameworks the data feeds into. Updates are made through review of monitoring outcomes to ensure impacts remain acceptable, mitigation is effective, and any unforeseen effects are identified and addressed. Ireland generally does not change methods unless there are EU-wide updates.

Sampling frequency is component and programme dependent. Monitoring under the ObSERVE programme is annual, and OSPAR and ICES monitoring follow their respective frequency standards. Ireland's assessment approach includes BACI.

Offshore wind monitoring

For offshore renewable energy monitoring, ecosystem components and indicators are selected based on whether they fall within the zone of influence, whether they are vulnerable, and which pressures are expected to cause impacts. For offshore renewable energy monitoring, the intent is to replicate regional surveys that have already been carried out, including surveys linked to the ObSERVE programme and approaches consistent with WFD. The monitoring frequency for offshore wind is not fully set yet, but it is expected to include seasonal monitoring for migratory/mobile species, annual monitoring for benthic/static components during the first 3 years and then once every 6 years thereafter, and nutrient surveys every 2 years.

For offshore renewable energy monitoring, Ireland is at an earlier stage and still developing the programme. Baseline studies for some components are therefore still being prepared or initiated. Coordination between project phases is managed by running baseline studies now and through construction, then transitioning to post-construction operational monitoring, using historical time-series data where available.

Table III.10 Planned monitoring of ecosystem components and indicators in relation to offshore wind in Ireland (Marine Institute Ireland, 2021; Silke & Cusack, 2012)

(Ecosystem) component	Indicator	Expected frequency offshore wind monitoring
Benthic habitats and benthos	abundance, sediment particle size, sediment classification an organic matter	annually for the first 3 years and then once every 6 years
Phyto- and zooplankton	biomass and sea surface temperature	annually for the first 3 years and then once every 6 years
Fish	abundance and biomass	seasonally
Seabirds	abundance, biomass and standard indicator outputs	seasonally
Migratory birds	abundance and biomass	seasonally
Marine mammals	occurrence distribution and abundance, including seasonality and the area used	seasonally
Bats	not specified during interview	seasonally
Underwater sound	not specified during interview	not specified during interview
Physical/chemical parameters	coastal processes, water chemistry and dissolved nutrients, salinity, temperature, dissolved oxygen, organic carbon, and related standard parameters	physical and chemical parameters annually; nutrient surveys every 2 years

Denmark

National monitoring

The ecosystem components and indicators monitored under NOVANA in Denmark are given in table III.11. Also refer to AU Ecoscience - Marine Science Data Centre's current technical instructions for more details on the monitoring instructions per component. NOVANA is used as the marine baseline monitoring programme. The programme provides long-term monitoring through established time series.

Table III.11 (Ecosystem) components and indicators monitored under NOVANA in Denmark (Institute of Ecoscience, 2026)

(Ecosystem) component	Indicator	Monitoring method	Frequency
benthic habitats and benthos	sediment type, species distribution, number of individuals per species, biomass	HAPS sampling, deployment of ROV, scientific diving surveys (with video camera)	annually
seagrass	coverage rate	video survey (sled, camera, depth sensor, GPS data logger and digital video recorder)	annually
macro algae	species composition and coverage rate	scientific diving surveys (with video camera)	annually
phyto- and zooplankton	biomass and species composition	Hose or Niskin bottle	~20 times a year
	chlorophyll	water samples GF/F filtered and chlorophyll extracted	~20 times a year
fish	species, number of species, density/ abundance and composition	scientific net and trawlers	not specified during interview or in documentation
seabirds	distribution, population size and trends	aerial surveys, field surveys	once, twice of 3 times a year depending on the species
bats	presence/absence	bat detectors on PAM stations	not specified during interview or in documentation
marine mammals	presence/absence of species, abundance, density and distribution patterns	aerial surveys, PAM stations (C-POD)	aerial surveys harbour porpoise: annually, C-POD: continuous aerial surveys seals: 11 times a year
physical/ chemical parameters	salinity, temperature, conductivity, depth	Vertical CTD probe	together with measurements of other ecosystem components where relevant (i.e. benthic habitats, plankton, oxygen)
	nutrients, hydrogen sulfide	water samples collected using water sampler or a pump/hose system	~20 times a year
	oxygen	oxygen sensor	not specified during interview or in documentation
	nutrients, organic matter, and associated parameters in sediment	kayak sampler, HAPS sampling (corer), box-cores	annually
	presence of environmental hazardous substances in sediment	box-cores, Van Veen grab, HAPS sampling, kayak sampler	annually

(Ecosystem) component	Indicator	Monitoring method	Frequency
underwater sound	noise level, harbour porpoise movements, noise exposure maps	noise recorder	when 1 of the following activities takes place: pile driving, explosions, seismic surveys with airguns, sonar under 10 kHz, and other impulsive noise under 10 kHz

Offshore wind monitoring

In table III.12 the ecosystem components and indicators monitored under specific dedicated offshore wind monitoring programmes are given. This is mostly in relation to baseline studies that have been carried out (Energinet, 2024, b; 2025a, b, c).

In general, the monitoring frequency of dedicated offshore wind monitoring is higher compared to the monitoring frequence used under NOVANA. For example, during preliminary studies (pre-construction) birds monitoring through aerial surveys and radar observation is more intensive for offshore wind than in the NOVANA baseline. NOVANA has long time series, while offshore wind dedicated programmes are more targeted and have higher effort. Since 2020, Denmark has conducted preliminary studies over a two-year period compared to previously, when preliminary studies were conducted over one year.

Dedicated offshore wind monitoring is carried out under DEA requirements by Energinet (with Energinet also drawing on NOVANA data). For new offshore wind projects, the relevant ecosystem components and indicators are selected by aligning with NOVANA's schedule and guidelines to enable comparison, complemented by dedicated monitoring for benthic habitats and geophysics, as well as birds, marine mammals, bats, and fish. Only for fish monitoring, OSPAR recommendations are followed instead of the NOVANA guidelines. Additional monitoring is added when specific EIA permitting needs or knowledge gaps require it. For example, conducting precaution driven studies such as crane migration monitoring using GPS tagging and radar/boat observations.

Monitoring is updated as gaps are identified, including extending baseline duration (e.g. from 1 to 2 years) and improving the programme based on lessons learned from previous projects. Before the DEA started working on guidelines, there was no fully defined methodology, and previous methodologies were used based on professional assessments. Now, with guidelines being developed, it is expected that more standardisation and a stronger follow-up of guidelines is being created.

For the EIA process for the permit, there is generally no monitoring during construction, except for Underwater sound monitoring if piling is used. After construction, monitoring is carried out at specific timepoints (e.g., after 1, 3, 5 and 10 years) depending on the wind farm's permit conditions. It is expected that this approach is to evolve in the future, with upcoming guidelines potentially adding further post-construction monitoring requirements.

Table III.12 (Ecosystem) components and indicators monitored under dedicated offshore wind monitoring in Denmark (Energinet, 2024, b; 2025a, b, c)

(Ecosystem) component	Indicator	Monitoring method	Frequency
Benthic habitats and benthos	species composition, species abundance and coverage	HAPS samples, ROV	2 times a year
	sediment type and characteristics, grain size	HAPS samples, ROV	2 times a year
Fish	length, weight, gonad ripeness, spawning progress, abundance, biomass and species composition	beam trawl, multimesh gillnets and trammel net	2 times a year
Seabirds	abundance, distribution	aerial surveys	8 times a year
	bird migration, flight height and activity	ship surveys (human observers and vertical radar recorder)	8 times a year
Bats	activity, species classification	radar, infrared or thermal video, acoustic monitoring	continuous
	migration routes	Motus VHF-radio receivers, radio-transmitter tags	continuous
Marine mammals	distribution, presence/absence	PAM (F-POD)	continuous
	abundance	aerial surveys	4 times a year
Underwater sound	Underwater sound	PAM	continuous
	noise levels from turbines	noise recorder	once in Kriegers Flak Offshore Wind Farm and once in Horns Reef 3 Offshore Wind Farm
	harbour porpoise movements	PAM, channel hydrophone arrays	annually
	noise exposure map	noise recorder (and values in literature)	monthly
Physical/ chemical parameters	conductivity, temperature, depth and oxygen	CTDO	together with measurements of other ecosystem components where relevant (i.e. benthic habitats, fish)
	chemicals in sediment	HAPS samples, ROV	2 times a year

France

Offshore wind monitoring

The ecosystem components and indicators monitored in France are given in table III.13. In France, the government now leads the monitoring of the initial state for offshore wind farms. At the first wind farm (in 2018), however, the developer carried out the initial baseline monitoring, which meant there was less effort to standardize and harmonize methods. Later wind farms often continued monitoring the same indicators that were used (or not used) at the first site. This changed when monitoring started being led by the government.

For the EIA, however, protocols are quite similar between projects as DGEC made sure to homogenize the surveys so they can be compared. Monitoring before, during, and after construction depends on what the results of the EIA are and what is written in the permit. DGEC, together with IFREMER and the French biodiversity agency, is working to make offshore wind monitoring more standardized. For baseline studies, DGEC relies on experts and scientific input from consultants and IFREMER to decide which components and indicators to study. To be more precise, the French agency for biodiversity works on megafauna (marine mammals, avifauna, bats) and IFREMER works on benthos, sediments, water, fish molluscs and macro invertebrates. Later monitoring follows the EIA results and permit conditions. Updates are made as new experience and improved methods become available, and DGEC is pushing longer-term standardization.

Table III.13 also gives the monitoring method and frequency of monitoring. These have been standardized over time. Methods changed over time due to innovation, or constraints like bad weather or other activities such as fishing.

Table III.13 (Ecosystem) components and indicators monitored during baseline/initial state monitoring in relation to offshore windfarms

(Ecosystem) component	Indicator	Monitoring method	Frequency
benthic habitats and benthos	identification of sediment/soil type	grab sampler or dredge depending on the seabed type	twice a year over a period of 2 years during the baseline study
	abundance, species composition	grab sampler or dredge for soft seabeds and imaging for rocky seabeds (RVO, cameras, photogrammetry)	twice a year over a period of 2 years during the baseline study
	biosedimentary of soft seabeds, hard seabed communities	visual surveys (ROV/divers/ camera's)	At least one season should be covered at the end of winter/beginning of spring during operation
	extent and rate of colonisation of submerged structures and deposited materials, particularly the establishment of non-native and potentially invasive species	visual surveys (ROV/divers)	during operation
seabirds	presence/absence, species identification, abundance, distribution, behaviour	ship and aerial surveys (human observations and/or digital acquisition), GPS tags and capture equipment	monthly over a period of 2 years during the baseline study
	distribution and density	ship and aerial surveys	during all phases of the project
	behaviour (meso and micro), collision risk	not defined	during all phases of the project
	seabird population dynamics, identify seabird colonies	not defined	not defined
	behaviour	GPS tracking	during all phases of the project
marine mammals and large pelagic species	presence/absence, species identification, abundance, distribution, behaviour	ship and aerial surveys (human observations and/or digital acquisition), GPS tags, CPOD/FPOD	monthly over a period of 2 years during the baseline study
	distribution and density	ship and aerial surveys	during all phases of the project
sea turtles	presence/ absence, species identification, abundance and spatial repartition	ship and aerial surveys	monthly over a period of 2 years during the baseline study
bats	presence/ absence and species identification	Ultrasonic detector, bat recorder	monthly or continuously from April to October over a period of 2 years during the baseline study
	behaviour (meso and micro), collision risk	not defined	during all phases of the project
	activity/ behaviour along the coast and at sea	not defined	not defined

(Ecosystem) component	Indicator	Monitoring method	Frequency
Fish, molluscs and macro-invertebrates	presence/absence, species identification, developmental stages, species richness, abundance, biomass, alpha diversity (Shannon and Pielou), frequency of occurrence, community composition	trawls, trammels, shellfish traps	once per season over a period of 2 years during the baseline study
	species composition, presence/ absence, behavioural changes	sample adult and juvenile populations of species in the water column at sampling stations within the wind farm and at control stations outside the project area	before and after construction
	species identification in the water column	Bongo net for egg an larval stages sampling	monthly sampling at six stations from December to August during construction
Plankton	presence/absence, species identification, developmental stages, species richness, abundance, biomass, alpha diversity (Shannon and Pielou), frequency of occurrence, community composition	bongo net for zooplankton, niskin bottle for phytoplankton, grab or dredge for phytoplankton cysts	monthly over a period of 2 years during the baseline study
Underwater sound	sound classification, intensity - for marine mammals acoustic : presence, species identification and types of behaviour	autonomous acoustic recorders with hydrophones	continuously for 2 years during the baseline study
	marine mammal presence	PAM	during all phases of the project
Airborne noise	sound level	recorder	continuously over 1 or 2 months for 1 year during the baseline study
Physical/ chemical parameters	detection of contaminants/metallic contaminants and biological parameters	niskin bottle, multiparameter probe for spot sampling, mussel bags and passive DGT (Diffusive Gradients in Thin Films) sensors for permanent stations	monthly over a period of 1 year during the baseline study
	water turbidity, temperature, chlorophyll-a, salinity	multiparameter probe	during pre-construction
	metallic and organic compounds in the water column and sediment	In the water column: use of DGT passive samplers or mollusc bags In sediments: box corers or tube corers	during operation
	Changes in the seabed, underlying structures and the protection of installations	geophysical surveys (multibeam echosounder) and visual surveys (divers)	during operation

Belgium

Offshore wind monitoring

WinMon.BE monitors a wide range of ecosystem components and indicators (table III.14). The selection of ecosystem components and indicators was set in 2008. However, the government can adjust the monitoring programme at any time, allowing flexibility to update or revise indicators and components over time. For example, adding or shifting them when scientifically justified within the available budget.

In table III.14 also the monitoring method and frequency of monitoring are given. WinMon.BE uses, for each ecosystem component, an approach with different monitoring methods and varying monitoring intensities. Where possible, existing (internationally) proven techniques are followed, and the monitoring programmes are publicly reported through annual reports and publications. The monitoring frequency differs per component and phase: in the early phase of a wind farm it is generally higher, while later frequencies may decrease. For example, biofouling is initially monitored every 1-2 months and later about every 2-3 months. In addition to periodic surveys, some components are monitored with continuous measurements, such as underwater sound, current flow patterns, and radar data acquisition, and bats are monitored almost continuously. Where relevant, the monitoring is designed in line with the BACI approach. Although not all aspects are fully standardized at the most detailed level, consistency in applied methods is maintained within selected windfarms, with differences mainly driven by scientific optimisation and windfarm-specific conditions.

WinMon.BE has collected data since 2005, but the programme really began in 2008 (phase 1). Since then, it has been continuously developed and phase 2 is now about to start, although funding is still under negotiation. In phase 2, they aim to continue the long-term time series from phase 1, but with reduced frequency (lower time resolution). For some components, they also want to move towards once every 3 years per windfarm by not visiting every windfarm every year, but rotating annually, so that the overall effects over the lifetime of the wind farms can still be monitored.

Table III.14 Ecosystem components and indicators monitored under the programme WinMon.BE (Degraer et al., 2023)

Ecosystem component	Indicator	Monitoring method	Frequency
Benthic habitats and benthos	abundance, species composition, sediment grain size distribution, total organic matter content	grab samplers (Van Veen), scientific diving, and developments towards eDNA and camera applications	annually
Fish (plaice)	spatial distribution (i.e. attraction to substrate and structure), habitat use (i.e. foraging), diet and condition, presence/absence	beam trawl, ship surveys, GPS-tags/telemetry, acoustic transmitters, scientific diving	annually; acoustic transmitters from May 2020 and August 2021
Seabirds	abundance, behaviour and distribution patterns	ship surveys	5 times a year
Migrating songbirds	movement fluxes and passage patterns	radar	continuous
Bats	spatial and temporal patterns	bat detectors and recorders	continuous (during selected periods)
Marine mammals	presence/absence and abundance, behaviour	aerial surveys, acoustic monitoring (C-POD)	aerial surveys 2 - 3 times a year (sometimes even 4 times); C-POD continuous (during selected periods)
Underwater sound	marine mammal behaviour, SPL, SEL and other indicators related to physical characteristics of sound	acoustic recorder	continuous (during selected periods)
Physical/ chemical parameters	microplastics, water flow patterns	not specified during interview	almost continuous

The Netherlands

National monitoring

National monitoring is carried out through programmes such as MWTL, MONS, WOT Nature and Environment, and WOT Fisheries. These programmes provide long-term information on the condition and development of the marine ecosystem and support national and international policy obligations. The monitored ecosystem components are included in table III.15. The indicators used depend on the monitoring objective and include abundance, density, biomass, distribution, species composition, presence, activity and population trends. For phytoplankton, chlorophyll concentration is used as an indirect proxy for algal biomass. Other indicators include nutrient and contaminant concentrations, water-quality parameters and, within the OSPAR framework, plastic ingestion by northern fulmars as an indicator of marine litter. Monitoring methods include trawl surveys, box-cores sampling, aerial surveys, water sampling, laboratory analysis and acoustic measurements. FerryBox systems and fixed measuring buoys are increasingly used to collect data on plankton, primary production and abiotic conditions. These technologies complement traditional sampling by providing broader spatial coverage or more continuous measurements.

Sampling frequencies vary considerably. Depending on the ecosystem component, monitoring may take place several times per month, monthly, annually or once every 3 years. Seabirds may be counted several times a year, while benthic organisms are often monitored once every 3 years. Many fisheries and environmental monitoring programmes have been operating for several decades, providing valuable long-term datasets.

Monitoring is based on legal obligations, policy and conservation objectives, existing data, technical feasibility and identified knowledge gaps. National monitoring networks are reviewed annually, with broader evaluations generally taking place every 4 or 6 years. Rijkswaterstaat and MWTL protocols provide the main basis for standardisation, supplemented by international frameworks such as OSPAR and ICES.

Table III.15 Ecosystem components and indicators monitored under national monitoring programmes

Ecosystem component	Indicator	Monitoring method	Frequency	Monitoring programme
Benthic habitats and benthos	abundance, biomass and length	bottom sledge, box-cores	once every 3 years	MWTL
	species composition	box-cores	annually	MWTL
	abundance, species composition	kick sampling with a hand net, quantitative sampling with a Surber sampler, sampling from a boat using a grab or core, sampling by divers, or introduction of artificial substrate	monthly	MWTL
Fish	abundance, length, species composition	trawl surveys	not defined	MWTL
	length demersal young fish	trawl surveys	annually	MWTL - DYFS
	abundance	discard sampling on beam trawlers	not defined	MWTL
	abundance, length	survey collecting plankton samples	once every 3 years	MWTL
	distribution and biomass	pelagic survey	annually	MONS
	distribution and behaviour of sharks, rays, and migratory fish	telemetric research with trackers	research (2026-2028)	MONS
Phyto- and zooplankton	abundance, chlorophyll-a concentration	not defined	4 - 19 times a year	MWTL
	species composition	CPR	continuous	-
	species composition, primary production rates, total chlorophyll	Container with Ferrybox system	12 times a year covering the MWTL transects	MONS
	species composition Zooplankton including salinity and temperature	plankton imager en sensors	annually during each fisheries survey with Tridens	MONS
(Sea)birds	abundance	human surveys from the beach	continuous	MWTL
	abundance, presence/absence, population trends	aerial surveys	6 times a year	MWTL
	abundance and distribution	ship surveys	4 times a year	MWTL
	plastic particles in stomachs of fulmars	searching for beached fulmars on the beach	continuous	MWTL

Ecosystem component	Indicator	Monitoring method	Frequency	Monitoring programme
	bycatch gillnet fishing	gillnet	research (2027 - 2028)	MONS
Marine mammals	abundance, distribution, population trend	aerial surveys	6 times a year*/12 times a year	MWTL
	bycatch gillnet fishing	gillnet	research (2024 - 2028)	MONS
	autopsy	reports of strandings	continuous	MWTL
	food availability and diet composition (grey- and harbour seal	not defined	research (2025 - 2026)	MONS
	cause of death stranded animals	human observations which are reported at stranding.nl	research (2024 - 2030)	-
	bycatch (harbour porpoise, grey- and harbour seal)	gillnet	continuous	WOT
	condition (grey- and harbour seal)	aeria; surveys (drones)	research (2026 - 2027)	MONS
	Prescence/ activity (harbour porpoise)	PAM	research (2022 - 2028)	Wozep
	Behaviour and movement (harbour seal)	tagging	research (2025 - 2026)	Wozep
	Behaviour and movement (harbour porpoise)	tagging	Research (2024 - 2026)	Wozep
Physical/ chemical parameters	pH, salinity, nutrients, turbidity, metals, chemical substances, plastics	CTD, water samples	variable	MWTL
	oxygen, CDOM fluorescence, global radiation, conductivity, temperature, turbidity	Container with Ferrybox system	12 times a year covering the MWTL transects	MONS

* In combination with the aerial surveys for seabirds.

Offshore wind monitoring

Offshore wind monitoring is conducted primarily through Wozep and project-specific monitoring programmes. Compared with general marine monitoring, it is more closely linked to individual wind farms, their development phases and specific knowledge or licensing requirements. However, part of the monitoring results is also broader applicable. The main focus is on birds and bats, although marine mammals, fish, benthic communities and Underwater sound are also being monitored. Key indicators include presence and abundance of species, behaviour and activity (including migration, flight height, direction and speed), benthic conditions and underwater sound levels and exposure (table III.16).

Offshore wind monitoring increasingly relies on continuous and automated technologies. Long- and short-range radar are used to monitor bird migration, including movements during both day and night. Cameras and automated image recognition can provide additional information on bird size classes and species groups. Acoustic sensors are used to detect bat echolocation calls, while MOTUS antennas and other receivers can detect tagged birds and bats. Sonar, underwater cameras and benthic sampling are used to investigate the underwater environment. Some of these monitoring techniques are not yet implemented and in use. These techniques are approved or will likely be approved in the near future. This also applies to offshore windfarms that, for example, have yet to be built and won't be completed for about 5 years. Monitoring equipment in and around wind farms generally operates continuously, although cameras may be less effective or switched off at night because of limited visibility. The monitoring programme and equipment are selected based on the characteristics of the wind farm, the availability of existing information, technical feasibility and remaining knowledge gaps.

Monitoring before, during and after construction varies between projects. A BACI approach is used or considered in some cases, allowing conditions at impact sites to be compared with both pre-construction conditions and control sites. However, a complete baseline or T0 measurement was not conducted for every wind farm. Consequently, the availability and quality of baseline data differ between projects and ecosystem components.

Table III.16 Ecosystem components and indicators monitored in regard to offshore wind

Ecosystem component	Indicator	Monitoring method	Frequency	Monitoring programme
benthic habitats and benthos	development soft-substrate habitats	bottom sledge, box-cores	not defined	Wozep
fish	presence/absence pelagic fish	WBATs with echosounder	research 2024/2025	MONS
seabirds	distribution	high-definition camera's	continuous	Wozep
	bird collision and behaviour	camera', bird radar	continuous	Wozep
	distribution, behaviour	digital aerial surveys	continuous	Wozep/DEM
	breeding success, effect of OWFs on breeding birds, distribution and behaviour	tagging birds	continuous	Wozep/MONS
	abundance, behaviour	long-range-radars	continuous	MIVSP
	species identification	short-range-radars and camera's	continuous	MIVSP
migratory birds	migration patterns	bird radar	continuous	Wozep
	extent, timing, and intensity of bird migration	Long-range-radars	continuous	MIVSP
	species identification and bird collision	microphones, thermal imaging camera	continuous	Wozep
	distribution, behaviour	MOTUS tracking of tagged individuals	continuous	MIVSP
bats	distribution, bat collision	bat detector	continuous	Wozep
	abundance migratory bats	telemetric research	continuous	Wozep
	behaviour	radar, bat detector, thermal imaging camera	continuous	Wozep
	genetic variation bat population	blood samples	once	Wozep
	distribution, behaviour	MOTUS tracking of tagged individuals	continuous	MIVSP
marine mammals	behaviour harbour porpoise	tagging	continuous	Wozep
	distribution, behaviour	digital aerial surveys	continuous	Wozep/DEM
	diet	isotope analysis	not defined	Wozep
	behaviour	PAM, C-POD, F-POD	continuous	Wozep
underwater sound	marine mammal behaviour	PAM, C-POD, F-POD	continuous	Wozep

Ecosystem component	Indicator	Monitoring method	Frequency	Monitoring programme
	noise installation wind farm	noise recorder	continuous during installation	MIVSP
physical/ chemical parameters	not defined	not defined	not defined	not defined

Norway

National monitoring

Data collection by the Institute of Marine Research involves the collection of biological samples and measurements of physical, chemical and biological variables to gain knowledge about natural and human-induced changes in ecosystems, including healthy and safe seafood. In December 2014, the Institute of Marine Research finalised a strategy for routine monitoring activities. The monitoring plan divides the Institute of Marine Research's monitoring activities into 6 areas of focus (pillars): (1) Stock surveys, (2) Fisheries management, (3) Health and disease spread, (4) Biodiversity and ecological function, (5) Physical and chemical environment, and (6) Safe and healthy seafood. Relevant monitoring in relation to this project is given in table III.17. Note that not all monitoring activities are shown in the table. For a full overview please refer to Huse et al. (2025) and Expert group for the North Sea and Skagerrak (2012).

For international monitoring, Norway follows ICES standards and other relevant international recommendations. However, when new findings emerge, monitoring efforts are adapted to investigate these findings in greater detail, with a particular focus on specific areas or topics of concern. Standardised methods are applied across international monitoring programmes, including those conducted for ICES and OSPAR. The national marine monitoring programme, in its current form, has been in place for less than twenty years, although the Institute of Marine Research holds observations and data spanning approximately 125 years. The MAREANO programme was established in 2005, with its first survey cruise taking place around 2006. The first MAREANO cruise in the North Sea was conducted in October 2022, while other areas of Norwegian waters had already been mapped. Mapping of the North Sea is expected to continue through additional cruises, including 1 planned for autumn 2026.

Table III.17 Ecosystem components and indicators monitored/mapped under the national monitoring programme

Ecosystem component	Indicator	Monitoring method	Frequency
Benthic habitats and benthos (incl. sponges and corals)	response to environmental variables such as pollution, climate change and ocean acidification	not defined	annually
	species composition soft bottom, benthic fauna deep water (shrimps) and benthic communities hard bottom (corals)	not defined	not defined
	sediment composition, contaminants in sediment topography, biotopes and habitats**	box-cores and multicor surveys, grab samplers, epibenthic sledge, trawl surveys, multi-beam echo sounders (TOPAS), Campod video rig	variable
Algae	presence/absence of harmful algae	not defined	continuous
Fish	abundance, biomass, indices, diet composition, distribution	acoustic surveys, trawl surveys	annually
	spawning grounds, spawning biomass, recruitment	seismic surveys, genetic analysis, double WP2 net	
Phyto- and zooplankton	abundance, biomass, species composition	trawl surveys, double WP2 net	annually
	abundance, species composition, chlorophyll index	Continuous Plankton Recorder (CPR)	continuous
Seabirds	abundance, diet, survival, breeding success, population trends	visual surveys	annually
Marine mammals	abundance/population size	visual surveys, DNA collection	annually
Underwater sound	noise levels from human activities	not defined	not defined
	use and production of sound by fish and marine mammals (behaviour)	hydrophones in combination with underwater cameras and remote-controlled instrument platforms with equipment for recording sounds	not defined
Physical/ chemical parameters*	temperature, salinity, depth, nutrients, biochemical parameters (pH, light, T, S, O2, Chl-a, N, et cetera.), oceanographic indicators	ship surveys, collecting local samples, buoys, CTD	annually

Offshore wind monitoring

Norway is still developing their offshore wind monitoring, which is why no table with monitored ecosystem components, indicators, monitoring methods and frequencies is given. For offshore wind farm monitoring, Norway plans to make use of the international standards from OSPAR and their national monitoring programme.

OSPAR

Following CEMP guidelines, there are different themes and component that are monitored and assessed. There is a total of 6 themes:

1 theme A - Cross-cutting components;
2 theme B- Biodiversity and ecosystems;
3 theme E - Eutrophication;
4 theme H - Hazardous substances;
5 theme O - Offshore oil and gas industry;
6 theme R - Radioactive substances.

The components measured under themes B and E are given in table III.18, as these mostly relate to the ecosystem components from other countries. For the components under the other themes please refer to CEMP Appendices on the OSPAR website.

The ecosystem components and indicators assessed under OSPAR are determined partly in a pragmatic way—by building on what is already being monitored and what is feasible, then feeding this into OSPAR. For the other part, there is a strong policy driver from the MSFD, which requires monitoring and indicators to align with the aspects that will be assessed. New developments such as offshore wind can trigger expansion or adjustment of indicators, particularly those addressing effects like noise and habitat loss. Indicators and assessment approaches are therefore updated periodically. However, monitoring itself tends to remain more conservative because long time series are difficult to break or change, but the assessment methodology and statistical methods are refined more regularly, with the timing of data delivery also linked to OSPAR's assessment planning and the cycle of MSFD assessments.

Methods vary considerably by ecosystem component. The CEMP guidelines provide general frameworks and quality boundary conditions (see table III.18), but countries can implement them differently. For some components, monitoring is highly harmonized because data flows through central, EU-wide databases. For others, such as benthic habitats, monitoring is organized nationally first and only delivered later. CEMP is regularly updated, mainly in the assessment methodology (e.g., statistical methods), while field monitoring tends to remain more conservative. Indicator values may shift when it becomes clear that an indicator does not perform as expected; these changes are more likely in the assessment approach than in the monitoring itself.

Regarding frequency, OSPAR assessments are generally aligned with the MSFD frequencies, often yielding biological data once every 6 years because OSPAR assesses on a 6-year cycle. Some components (e.g., protected species and habitats) follow an about 10-year assessment cycle, although actual monitoring can be more frequent. Most ecological monitoring programmes have been running since the early 1990s. Some chemical monitoring has started even earlier. Offshore wind monitoring largely falls outside OSPAR, but monitoring occurs under the EIA committee, focusing on coverage and presence of wind farms.

Table III.18 Ecosystem components and indicators within OSPAR CEMP under theme B (biodiversity and ecosystems) and E (eutrophication)

Ecosystem component	Indicator	Monitoring methods	(Data submission) frequency
benthic habitats and benthos	condition of benthic habitat defining communities	Epibenthic species: quadrats counts or optical, non-destructive methods Endobenthic species: standardized grabs or corers	once every 6 years; once every 2 years
	extent of physical disturbance to benthic habitats	marine recorder, sonar equipment, sample collection or photography	annually
	sentinels of the seabed	(I) the distribution of benthic habitats, (II) the distribution and intensity of pressures that disturb these habitats and (III) biological sampled data of the abundance (preferably biomass although also works with density) of benthic species from each habitat across a pressure gradient (including no pressure) low-pressure areas)	once every 6 years, as needed
fish	abundance	trawl surveys	annually
	proportion of large fish	trawl surveys	annually
	size composition in fish communities	not defined	annually
	mean maximum length of demersal fish and elasmobranchs	trawl survey, acoustic surveys	once every 3 months
plankton	lifeforms	Use of existing monitoring programme, which employ various sampling and analysis methodologies	annually
	biomass and abundance	Use of existing monitoring programme, which employ various sampling and analysis methodologies	monthly
	diversity index	Use of existing monitoring programme, which employ various sampling and analysis methodologies	annually
seabirds	abundance	Aerial and ship surveys; observers visiting breeding colony or at the coast for non-breeding birds	annually
	breeding productivity	observers visiting breeding colony, time-lapse photography	annually
	bycatch	at-sea observers Remote Electronic monitoring (REM)	annually
	plastic particles in stomachs of fulmars	searching for beached fulmars on the beach	continuous
Marine mammals	abundance and distribution of seals	ground-based surveys or aerial imagery techniques	seasonally

Ecosystem component	Indicator	Monitoring methods	(Data submission) frequency
	abundance and distribution of cetacean	Aerial and ship surveys	once every 6 years
	grey seal pup production	Aerial survey, ground counts or ship surveys	annually - once every 5 years
	bycatch	REM, strandings monitoring	annually
Sea turtles	bycatch	data from fisheries observer programme and coastal observing/ stranding network	annually
	loggerhead turtle abundance at sea	Aerial and ship surveys	once every 6 years
	litter ingestion	quantifying the litter found in the digestive tract extracted during necropsy of dead individuals (mostly found stranded or by-caught by fishermen) or excreted by live animals in rescue centres after 1 to 2 months	annually
Underwater sound	impulsive noise	not defined	annually
	ambient noise	not defined	annually
Physical/ chemical parameters	Marine litter on beaches	human surveys on the beach	every 3 months
	Marine litter on seafloor	trawl surveys	annually
	encounters with dumped chemical and conventional weapons	N/A	annually
	dumping and placement of wastes or other matter at sea	core sampling, grab sampling	annually
	nutrient concentration in seawater	not defined	annually
	direct and indirect eutrophication effects	not defined	annually
	nutrient inputs from land-based sources	water quality monitoring stations	annually
	nutrient inputs (Comprehensive Atmospheric Monitoring Programme)	EMEP guidelines	annually
Ecosystem	trend in arrival of new non-indigenous species,	varies between countries, but in most cases will be based around existing biodiversity monitoring efforts	annually

Ecosystem component	Indicator	Monitoring methods	(Data submission) frequency
	changes in average trophic level of marine predators	trawl surveys; stomach content analysis; stable isotopes analysis	annually
	area of sealed habitat loss	modelling approach (based on pressure data from human activities and on the extent and distribution of benthic habitats)	annually
	area of unsealed habitat loss	modelling approach (based on pressure data from human activities and on the extent and distribution of benthic habitats)	annually
	offshore renewable energy developments	N/A	annually

III.3 Data formats and data processing

Germany

National monitoring

For BfN, monitoring organisations generally provide data in Excel sheets, after which BfN processes the data and makes it openly available through web services (including WFS services) that can be accessed by everyone. Both raw and processed data are made available, including data calculated on an EEA grid and modelled distribution data for birds. The online available data is provided in the form of downloadable (standardized format) tables (e.g. CSV, Excel, or another table-based format). The data are subjected to quality checks before publication, and updates are generally made approximately once per year, instead of after every monitoring survey. The Marine Data Infrastructure Germany (MDI-DE) brings together all available governmental data from Germany, excluding private data.

Whether the data is owned by the government depends on several factors and the type of funding or procurement. In the case of grants (Zuwendungen), the authorship remains with the recipient, whereas under service contracts (Aufträge), it transfers to BfN. In practice, however, all data is freely available and can be used, provided that authorship is properly credited. The BfN data is linked to EMODnet via links and access routes provided by BfN. Data from OSPAR is handled differently because its data model and protocols change frequently. Data are therefore sometimes submitted by email or through download platforms.

Offshore wind monitoring

In Germany, wind farm developers receive standardized tables from BSH which they need to fill out with their data. These tables are later uploaded into a database called Marlin. For acoustic monitoring there is a different database called Marinears. Baseline monitoring data is uploaded into a database called Marlin. Data from pre-investigation sites is uploaded into PINTA.

The data is stored in German in Marlin and Pinta and in English in Marinears. Reports written by consultancies based on the data in Marlin and Pinta are also in English.

The raw data is owned by the wind farm developers, and therefore not publicly available. It is available upon request for agencies like BfN, but NGOs might have a harder time receiving it.

The data is not linked to any international systems like EMODnet, and only specific acoustic data is uploaded to ICES.

United Kingdom

In the UK, the JNCC's evidence team takes care of managing all data. The data is publicly owned and open source. Before data is stored, the JNCC processes it through an ingestion protocol. All data storage follows the FAIR (Findable, Accessbile, Interoperable, Reusable) principles and is Medin compliant. Data is stored in English, and biotoped according to the UK classification system.

Most of the data gets stored in an online national database called Marine Recorder Online, or in UK Data Archive Centres (DAC's). Metadata is also stored in the DACs. The JNCC encourages other organisations such as NGO's to also use Marine Recorder Online for data storage. Organisations use their own quality control procedures before uploading and have to go through a verification process to do so.

For offshore wind monitoring and wider research projects, the Marine Data Exchange is the main central repository (hosted by the Crown Estate). Developers are generally required to upload data, although availability and publication timing of their data may vary due to data being considered commercially sensitive, and ownership depends on the type of data. The annual monitoring data is relatively accessible and structured, but access to offshore wind monitoring data is inconsistent. Wind farm monitoring data is generally owned by the developer, while data from larger research projects is usually owned by the funding body.

The NCDD data is used to feed into international systems like EMODnet, and for reporting to international bodies such as ICES and OSPAR.

Ireland

Ireland follows different protocols for data storage for the different programmes. For offshore wind, the discussion on how and where to store the data is ongoing. They are looking for a solution where the data will be openly accessible for everyone. Data is always stored in English.

Some of the collected data is open source, some is available on request only. Data collected by the wind farm developers is not always released, when it is regarded as commercially sensitive. Who owns the data differs too: the Marine Institute owns some of it, as well as the developers, the DCEE, MARA, and the Environmental Protection Agency. Monitoring data is fed into EMODnet whenever possible.

Denmark

Denmark adapts data formats to the requirements of the NOVANA programme and follows those guidelines where relevant. Data formats differ per component. For example, for benthic fauna monitoring, there is a national database and therefore specific format requirements exist for data transfer. For other components, birds, bats, marine mammals, there is no national database, but for each parameter there is a dedicated format: a mix of spreadsheets, sound files from PAM stations, and outputs from different apps that analyse the data. The DEA is the central data collection framework. For NOVANA, data can be found through a public service called Aerial Information. They are working on a shared database.

Data is stored in English, but EIA reports need to be in Danish. NOVANA reports are also in Danish, while technical reports are generally done in English. The data is open to the general public on request; 1 needs a reason to access the data. Reports are publicly accessible, but raw data requires an approved user account to access. NOVANA data is owned by the state, offshore wind surveys are owned by the DEA. Both the DEA and NOVANA contribute to EMODnet.

France

For baseline monitoring, data formats differ per component. Species identification results are stored mainly in spreadsheet-type Excel files (tables) for megafauna, fish, benthic habitats, et cetera. Water quality and sediment-related analyses are primarily stored as reports (Word/PDF style). For very specific components with huge volumes, data is stored as raw files (e.g., acoustic recordings using WAV files). Processed results for acoustics are also included in tables (Excel). For benthic habitat work, photogrammetry/video products are stored as video formats, and there are also photos/videos in formats linked to the techniques used.

The data is stored in French, English, and Latin for the scientific names. Baseline monitoring data is stored by the DGEC using a website. It is not completely open source, but they are working on improving that. The reports are public on the DGEC website, processed data is available from there upon request. Raw data is not fully open, partly due to file sizes and storage costs. DGEC is working with IFREMER to find a more long-term solution for an online archive.

The baseline monitoring data is owned by the French state/the DGEC. The monitoring data from after permitting, is owned by the wind farm developer. The baseline monitoring data is not yet linked to EMODnet.

Belgium

Data management is momentarily being optimised in Belgium. They do have a central database called EDOPS, but they are running behind in uploading data into it. In some cases, data is stored on personal OneDrive's of the researchers collecting the data.

Data is stored in English or Dutch, depending on the dataset. The data should be open source once it is uploaded, but this is not fully implemented yet because of the lag in uploading.

The Belgian state owns the data, both for WinMon.BE as for other monitoring programmes. Some of the Belgian data is also uploaded to EMODnet, mostly data from monitoring for the MSFD. They also upload into OSPAR.

The Netherlands

In the Netherlands, ecological monitoring data are stored in different formats and systems, depending on the type of data and monitoring programme. National data from Rijkswaterstaat are made available through systems such as Aquadesk, Waterinfo and Waterinfo Extra. Biological data, including information on birds and fish, are not all stored in Aquadesk and may be managed through other systems.

In many cases, processed or validated data are made publicly available, while the raw data remain with the original data owners or research institutes. Project data may be stored in separate repositories, and efforts are being made to make these data available through EMODnet and other international standards.
Data from big projects such as MONS and Wozep form an exception. Big datasets belonging to such projects are saved in data repositories and managed by other parties. For the data repository of Wozep please refer to https://wozep.nl/en/.

Informatiehuis Marien plays an important role in bringing together and providing access to data for the MSFD. Data from sensors in wind farms are connected to the Informatiehuis Marien, while some data may also be stored on local Rijkswaterstaat servers.

The data are in principle owned by the Dutch government. Data are stored in both Dutch and English. The data are generally publicly available, and efforts are made to follow the FAIR principles. Temporary embargoes may apply, and data are generally made public only after quality control and validation have been completed. Some data, collected by wind farm owners, may formally belong to the wind farm owner.

Dutch monitoring data are linked to international systems including OSPAR, ICES and EMODnet, as well as European reporting systems.

Norway

In Norway data are stored in different systems, depending on the ecosystem components and the type of measurements. Purpose-built internal programmes are increasingly used for data collection and storage. The Institute of Marine Research is working towards making data available as soon as possible during or after monitoring. Processed data may take longer because they require quality control, interpretation and analysis. For fish measurements, digital measuring boards transfer measurements directly into a database. MAREANO has a dedicated subgroup focusing on data sharing and FAIR data.

Species names are provided in Latin, and metadata for international data services are available in English. Some reports and documentation are in Norwegian, although many include an English summary.

In Norway, the Norwegian Marine Data Centre functions as a national oceanographic data centre. The country is working towards a more integrated data system that can provide data from different sectors to the public in an accessible way. Already much of the data can be accessed by the public or requested from the relevant institute, but access is not always straightforward.

Ownership of the data depends on how the data were collected and funded. For research and monitoring carried out by the Institute of Marine Research, the Institute retains the right to use the data. Where data are collected in cooperation with industry or developers, ownership may be associated with the party funding or supporting the activity, although the Institute generally retains rights to use the data for independent research.

Processed data are shared through the Norwegian data-sharing platform GeoNorge and, where relevant, international repositories such as GBIF. Physical and lower-trophic-level data may also be available through the Copernicus Marine Service, while fish data are available through ICES data services.

OSPAR

For an OSPAR datacall, the format can be more like a template, where OSPAR requests data from countries in a set Excel-like structure. For components that run through central databases like ICES, the data format is decided upon by ICES. Data is stored in English.

Sometimes OSPAR uses external databases like EMODnet, for other aspects OSPAR holds the data themselves, for example for data from MPA's. OSPAR has its own data- and information management system.

Not all data OSPAR collects is publicly available, because some countries do not want it to be. In those cases, the data is stored centrally at OSPAR but is not available to the public. They are working on storing the data following the FAIR principles.

III.4 Comparability: differences and similarities

Germany

Offshore wind monitoring

Currently, there is no coordination between BSH and other countries. Internationally, BSH sends some data to ICES, but they do not share data with other international framework.

National monitoring

As bird monitoring has been international for many years, there is coordination and cooperation between BfN and other countries. Countries around the North Sea cooperate and use comparable methods, including the CBOS at-sea methods. BfN works together with organisations and researchers in other North Sea countries, including Wageningen University and Aarhus University.

There is also long-standing international cooperation for whale monitoring (through ASCOBANS), for which BfN cooperates with Wageningen University and Danish colleagues in Aarhus.

German monitoring programmes overlap with OSPAR, ICES frameworks, and ASCOBANS.

United Kingdom

Coordination between the UK and other NSEC countries happens mainly through shared groups like OSPAR and ICES and monitoring programmes thereof. Besides those, there is no coordination for monitoring. This also applies for the Seabird Monitoring Programme, for which there is no coordination with other European of NSEC countries. For the Seabirds Count census, (some) coordination takes place with the Republic of Ireland.

Ireland

There is no active coordination between Ireland and other countries, but Ireland does look at what other countries are doing for monitoring and tries to identify the best practices that can also be implemented in Ireland. Ireland also fully participates in international frameworks such as ICES, GNSBI and OSPAR and follows the procedures and guidance provided.

Denmark

Denmark coordinates with Rijkswaterstaat in the Netherlands and BSH in Germany. DEA also participates in international programmes such as NSEC, and people from DEA are involved in networks and EU-based coordination. There is also data exchange with international frameworks such as HELCOM, OSPAR, and ICES.

France

There is limited coordination with other NSEC countries, because France has only joined NSEC recently. The DGEC links monitoring approaches to the MSFD and OSPAR when relevant. When they set protocols for baseline monitoring, they consulted colleagues who work on the MSFD and reused those protocols wherever necessary and relevant.

Belgium
There is no structural coordination for monitoring between Belgium and other NSEC countries, though there are some interactions, for example through research projects. Belgium does deliver input for ICES and OSPAR.

The Netherlands
Coordination takes place with/via OSPAR and ICES. Once gathered data are stored nationally and validated, they are delivered to organisations such as OSPAR and ICES and used for international assessments and reports.

Norway
There is international cooperation between Norway and other countries, although the level of coordination differs by ecosystem component and monitoring purpose. Norway participates in several research and infrastructure initiatives, GOOS and EU-related observation activities. The Institute of Marine Research is involved in international working groups and initiatives concerning common standards and data comparison. Norwegian monitoring is connected to ICES, OSPAR and GOOS. Norway is not formally bound by the EU MSFD, but it is inspired by the framework and maintains dialogue with OSPAR regarding the development of indicators.

OSPAR
OSPAR coordinates with all other NSEC countries, since it is a cooperation platform between countries. They also have a long history of good cooperation with ICES.

III.5 Responsibility

Germany
In Germany, responsibility for monitoring is divided between the authorities and wind farm developers. National monitoring is the responsibility of the BfN, in particular biodiversity monitoring in relation to Natura 2000 and the MSFD in the German EEZ (with exclusion of the coastal zone). BSH is more particularly tasked with the approval, assessments of environmental impact and subsequent monitoring of offshore wind.

For offshore wind farm-specific monitoring, the design is ultimately determined by BSH. Wind farm developers prepare an initial concept design and submit it to BSH, which reviews, revises and finalizes the plan. The developer must then follow the approved plan and apply to BSH for permission if it wishes to deviate from it. BSH evaluates and approves or rejects the application.

The wind farm operators or developers are responsible for collecting and storing the monitoring data, sharing the raw data with BSH, and hiring consultancies to process the data and prepare reports, which are also submitted to BSH. BfN is responsible for the design, implementation, data storage and analysis of monitoring programmes within its own remit, supported by scientific institutes, universities and consultancies, although BfN retains overall responsibility.

BFN is the responsible authority for the design, implementation and data storage and analysis of monitoring programmes within its remit. BfN works together with scientific institutes, universities and consultancies, which carry out fieldwork and support data processing, but BfN remains responsible for the programmes.

Monitoring is funded by the German government or the developer, depending on the stage of the project: for sites still in the tender phase, the government initially funds the preliminary investigations, after which the successful developer reimburses the government. If a site already has a developer before the preliminary investigations begin, the developer pays for the monitoring from the outset.

United Kingdom
In the UK, monitoring of MPAs is led by the JNCC. They are responsible for design, implementation, and data storage and analysis.

Other organizations are responsible for their own data. CEFAS, in parallel, is the primary provider of evidence and advice for the UK Department for Environment, Food and Rural Affairs (DEFRA) in relation to the marine environment.

For wind farm monitoring, developers themselves collect, store and report the data, usually with support from consultancies, while the design is agreed collaboratively with conservation authorities.
Monitoring by the JNCC is partly funded by DEFRA and partly by the Scottish government (for the monitoring in Scottish waters). CEFAS monitoring programmes are also funded directly by the UK government. Monitoring of wind farms is funded by the windfarm developers. Whereas seabird monitoring was more a responsibility of the JNCC in the first place, the British Trust for Ornithology is now mainly responsible for the annual seabird monitoring programme, while the JNCC and other conservation bodies provide input.

A new development is the Marine Recovery fund: a fund to help compensate for impacts a wind farm might have, and to pay for monitoring of wind farm sites. Developers are potentially going to be asked to pay into this fund, but it is not yet implemented.

Cooperation between the UK government and wind farm developers happens through programmes like the Offshore Wind Evidence Change Programme, where the government and developers discuss strategic monitoring and standards. Windfarm developers are not obliged to follow JNCC guidance. Instead, developers typically follow industry-accepted standards (such as NMBAQC).

Ireland

The DCEE and the Marine Ecosystems and Ornithology Working Group are responsible for designing regional level surveys for offshore wind monitoring. However, implementation roles, oversight roles, data storage and analysis responsibilities still have to be worked out.

Who funds the monitoring is not yet finalized. It will likely be a cooperation between and a combination of developer and government funding, with developers contributing at a local level and government at a broader level.

Denmark

For offshore wind monitoring, the responsibility for design, implementation and data storage + analysis, lies between DEA and Energinet. When Energinet has a contract with a consultancy, the consultancy can provide suggestions and propose improvements, but DEA and Energinet still make the decisions based on the scoping and needs. Energinet coordinates the contract operation and deliverables, while DEA is the overall responsible party for the monitoring programme and the data within the relevant framework. Energinet will always coordinate with the DEA.

Monitoring is first funded by the Danish state, but once a developer is granted a permit/contract, they need to pay for the monitoring. For future wind farms, it is likely that permits will include requirements for developers to carry out monitoring.

France

Baseline monitoring design and implementation is done by the state, data analysis is done by consultancies. Data storage is handled by the DGEC.

For wind farm monitoring, the developers are responsible for the design and implementation. They work with private consultants, who also perform the data analyses.

Baseline monitoring is funded by the state, wind farm monitoring is funded by the developer. Cooperation between the state and developers is mostly organized through the permitting process. The developer proposes monitoring measures in the permit file; local authorities grant the permit and approve protocols with scientific council input where relevant, then the developer commissions execution of monitoring by private consultancies; results are provided to the administration.

Belgium

Responsibility for monitoring design, implementation and storage lies with KOBINE. Within that organisation there is 1 team (BMM) that takes up this responsibility.

Monitoring within WinMon.BE is largely funded by the wind farm developers. Implementation and budget management are done by the Belgian state. Monitoring of any human activity on the North Sea, is always funded by the permitholder. Monitoring that is not directly coupled with a specific activity or permit is funded by the state, but often there are insufficient funds available.

Every activity at sea requires an environmental permit. This happens through a so called 'steering committee'. Within that committee, the government and other parties come together yearly to discuss permit requirements and monitoring.

The Netherlands

The government has overall responsibility for the design and quality assurance of monitoring, while research institutes and private companies execute the monitoring. Implementation, data storage and analysis may be distributed among organisations such as Rijkswaterstaat, Wageningen Marine Research, consultancy firms and other contractors working on behalf of the government.

National monitoring programmes are government-funded, with MSFD monitoring jointly financed by the Ministry of Agriculture, Fisheries, Food Security and Nature and the Ministry of Infrastructure and Water Management. A significant share of international fisheries research is funded by the EU. Wind farm developers must cooperate with research but are not necessarily required to contribute financially to Wozep.

Cooperation is organised through government-led programmes involving stakeholders, including the wind industry. In some tenders, developers can gain additional points for nature-inclusive measures and ecological research, which may make them responsible for their own research programmes. The resulting data are shared and made publicly available as far as possible, subject to permit conditions.

Norway

In Norway, monitoring responsibilities are shared among ecosystem experts, technical specialists and organisations such as the Institute of Marine Research.

This institute is responsible for research and observation, which it conducts itself. Simultaneously, when it conducts mapping or monitoring for another organization, responsibilities for this commissioned work are defined in collaboration agreements.

The national monitoring programme is mainly funded by the Norwegian government. Additional funding may sometimes be obtained from international programmes, the EU, ICES and other ministries. Offshore wind monitoring is currently largely government-funded, but developers may be required to contribute in the future. It is likely that developers may be required to finance part of the monitoring that is associated with their projects.

OSPAR

For OSPAR, the responsibility of data design, implementation and storage lies largely with the countries themselves, as long as they do so within the frame of OSPAR. ICES, OSPAR and EMODnet are also responsible for storage of the data they receive from the countries. OSPAR is also responsible for the analysis of that data.

OSPAR does not do its own monitoring, nor does it fund monitoring. Monitoring for OSPAR is being done and funded by the countries themselves, in general it is their government that pays for it. The OSPAR secretariat is financed through contributions from participating countries.

III.6 Harmonisation - international cooperation

Germany

The current lack of international harmonisation is seen as an obstacle, largely because of the difficulty to compare data between different countries as coordination between countries is mostly lacking. Even where similar methods are used, surveys conducted at different times can reduce the comparability of results. Especially in border zones between countries, for example between Germany and the Netherlands, this is a missed opportunity for using similar methods, making data easily comparable. Coordinated monitoring across large areas of the North Sea, ideally during the same period, would improve data quality.

Harmonization at the methodology level would therefore in regard to offshore wind monitoring be the most important. Germany ranks the different levels for harmonization, in order from which to harmonize first, as: methods, then indicators, then data formats. Lastly harmonization at the decision-making/governance level, which Germany believes would be hardest to implement. As for data storage, ideally, all data across countries would be open source. In regard to national monitoring, the main need is greater cooperation in data collection rather than further harmonisation of indicators or basic methods, which are already largely aligned through the MSFD and Natura 2000 requirements.

Harmonizing legislation and taking specific monitoring requirements per country into account would be the most challenging, as well as changes for countries whose monitoring methods are very different from others. Furthermore, funding is seen as a large obstacle, as well as staff shortages and difficulties in maintaining long-term expertise and monitoring capacity.

Germany sees opportunities for harmonisation in new monitoring methods: it is easier to agree on a standard method before countries have established their own. eDNA could be an example, because the method is already applied internationally in a similar way . Digital monitoring, AI, image-based methods and satellite imagery could also provide efficient solutions by enabling larger areas to be monitored and processed more quickly.

If they could start over, Germany would monitor all wind farms (and their effects) together, rather than monitor the separate wind farms. Ideally this would be done for all wind farms on the North Sea, to monitor their combines effects as a whole. For national monitoring, Germany would implement the newer techniques and knowledge they gained to set-up their monitoring programme.

United Kingdom

The JNCC expressed a need for more international harmonisation, to be able to (1) compare their data to that of other countries, (2) share their data with other countries, and (3) to have monitoring access in other countries. With the current lack of harmonisation there is a missed opportunity for additional valuable data. For example, seabirds do not respect national boundaries and may interact with wind farms and other pressures in several countries. Monitoring conducted within only 1 country therefore provides only part of the picture. They would prioritise harmonisation of indicators, methods and data first, to make cross-country assessments possible. However, changes to established methods or indicators must be carefully managed to avoid disrupting valuable long-term time series. Therefore, first, an understanding of what and how other countries are monitoring is needed.

The biggest bottleneck for harmonisation is the difference in national and legal frameworks between countries, especially since Brexit, and funding. A practical barrier is knowing who to contact in other countries. A working group, contact information website, or shared planning portal would be beneficial for harmonisation, so countries can understand who is doing what monitoring and when. No active contact would be required, but at least the possibility to contact one another would be there when the need arises. Another challenge would be ensuring cooperation and participation from all relevant programmes and countries due to different research questions countries may have.

A first step towards harmonisation would be a North Sea Basin monitoring conference or workshop, to bring together all relevant parties. Moreover, a platform could be established were data and information is shared.

From there a longer-term shared monitoring approach could be set up. A quick win could be gained by improving survey coordination and integration, for example through shared vessel usage and more coordinated survey planning. To get this started, a shared map of monitoring coverage across the North Sea would help to identify spatial gaps, including gaps around offshore wind farms and reference areas.

Integration and aligning indicators and methods could be seen as long-term efforts. Integration could happen by making use of existing harmonised surveys that are funded through other mechanisms, such as fisheries surveys. Having a holistic view is the key rather than not having much commonality between projects and data sources. That would take a bit of time to implement.

New monitoring methods provide an opportunity to develop guidance standards that are the same across all countries, but at the same time, we cannot yet fully rely on new techniques. Once a method has been validated, however, it may be easier and more beneficial to standardise than older methods.

If the UK could start over, they would use the same standards and guidance across all monitoring programmes from the start. They would also sort out the lack of join-up between industries and the government and would try to avoid the diminishing of funds. Instead of creating separate programmes for individual licences, sectors or policy questions, data should be collected according to the principle of 'collect once, use many times.' This would allow monitoring results to support offshore wind development, fisheries management, marine protected areas and broader assessments of environmental change across the North Sea.

Ireland

The lack of international harmonisation is somewhat of an obstacle, but at the same time, because Ireland is still implementing offshore wind monitoring, they can use the work that has already been done on the North Sea and implement the methods that will work for Ireland. Ireland is trying to prevent to re-invent the wheel, by strategically learning from other countries.

For Ireland, harmonisation at the indicator, methods and data format level would be most important. To them, it is less clear that harmonisation is needed at the decision-making or governance level, because governance structures differ between countries. If countries use the same indicators and look at the same pressures, then methods and data formats become key for comparability across regions. At the same time, local differences are likely to remain because of different environments.

A challenge is understanding who is doing what and establishing contact with the people actually performing monitoring activities. Communication between stakeholders can be limited.

An approach that works well in Ireland, is that the Marine Ecosystems and Ornithology Working Group brings together all relevant stakeholders, improving communication between them. Other engagement activities such as webinars have also helped.

A quick win for harmonisation would be to use the standard methods used to feed into OSPAR and ICES for all monitoring, since these are already used by all NSEC countries that deliver data to OSPAR and ICES. Additionally, standardisation of new emerging methods like eDNA is also valuable. If Ireland could start over, they would involve ecologists from the very beginning.

Denmark

A lack of international harmonisation can be a problem, especially with a growing interest in using neighbouring countries' data. The lack of access to data from other countries is an increasing problem.

As for the level at which harmonisation is desirable, Denmark believes it should follow a hierarchy: first harmonize methodology and the data/storage/data formats, because these are the prerequisites for comparability, and only then build further up towards higher-level items such as governance and decision-making.

Potential bottlenecks for harmonizing monitoring are primarily data sharing constraints, differences in how data are stored, and compromises made at the national level. Implementation becomes difficult unless the responsible authorities coordinate and roll it out properly. As for what should not be harmonized, the emphasis is less on forbidding local differences and more on not compromising national time series, since continuity is crucial for detecting long-term changes (such as climate change).

What works well in Denmark's approach is the two-year survey setup for offshore wind baseline monitoring and a focus on hazardous substances in sediments.
For first steps and quick wins, Denmark suggests starting with harmonized (or at least comparable) guidelines, ensure responsible authorities are committed to implementing them, and begin by identifying mismatches between existing methodologies. New programmes are easier to harmonize than long-running ones. Full harmonization across countries is seen as a large long-term project (potentially a decade or more) requiring authorities to be on board.

New monitoring methods such as eDNA are welcome, as long as new methods don't mean that old time series are not preserved. If Denmark could start over, they would coordinate earlier, allocate more resources from the start (both staffing and budget for expertise/consultancies), and begin with standardization in collaboration with other countries to avoid avoidable delays and extra costs.

France

With the current lack of harmonisation, France finds it difficult to compare results across countries, which limits research and cross-analyses. To them, harmonisation is desirable especially for data formats, to improve comparability. Once data formats are harmonized, methods and data processing can also be harmonized. The main bottleneck for this is costs, operational constraints (for example due to differences in equipment), and acceptance issues, for example from wind farm developers. If a wind farm already has monitoring methods agreed in its permit, changing methods for harmonization can lead to additional costs and require renegotiation of stakeholder expectations.

France thinks local differences should not be harmonized, when ecosystems differ a lot and might require different methods (for example for benthic habitats). Something that works well in France is monitoring different components simultaneously.

A first step in harmonization could be megafauna monitoring, as these methods are relatively well-known and are already quite similar between countries. Fish stock evaluation and sediment and water quality are likely also similar already, whereas plankton monitoring is very inconsistent between countries and would require more time to harmonize. Harmonization of new emerging methods would also be useful.

If France were to start over, they would talk more with experts about data collection and storage in the beginning, to prevent becoming overwhelmed by the volume of data, as they are now. They would also take seasonal difficulties, for example data collection in wintertime, into account.

Belgium

The lack of international harmonisation is regarded as an obstacle. Harmonisation is mostly wanted through long-term research, with clear research questions. Ideally, every country takes up their own research questions, which can be combined into one 'research agenda'. This would require sufficient funding for all countries. It would also be beneficial if countries would share their different monitoring methods and programmes with one another.

To Belgium, the largest bottleneck for harmonisation is laws and governance for EIAs in different countries. A practical solution for that would be the Belgian WinMon.BE model. What works well in the Belgian approach is the combination between monitoring and the search for mechanical explanations, and the fact that their approach is based on the interactions between components.

Low-hanging fruit for harmonisation would be the research agenda, as mentioned above: a regional research programme that can fill in knowledge gaps and can be implemented relatively fast (within 5 years), for example through an initiative like GNSBI.

Harmonisation for emerging methods is a good idea, but these methods first need to be worked out further.

If Belgium were to start over, they would formulate their research questions more clearly. Rather than monitoring from data collection protocols, they would monitor from unexpected impacts and concrete hypotheses.

The Netherlands

The Netherlands has a relatively detailed and intensive monitoring network, with monitoring requirements that are sometimes more stringent than those in neighbouring countries. Harmonisation should therefore improve comparability and efficiency without reducing the quality, detail or value of existing national programmes.

International harmonisation can involve shared resources, coordinated sampling, common methods, indicators and data standards. Complete uniformity is not necessary, as different methods can be acceptable if they produce comparable results. Harmonising policies and monitoring requirements are more challenging because countries have different political, legal and scientific contexts.

The main barriers are limited funding and capacity, differences in existing monitoring networks, varying interpretations of European legislation, regional ecological conditions and the risk of disrupting long-term time series. Local differences in species, habitats and environmental conditions should be retained where they are ecologically relevant. Established datasets should therefore be protected, and new methods should initially be applied in parallel with existing methods to identify potential trend breaks and assess comparability.

Harmonisation could be achieved by:

- coordinating existing surveys, vessels, sampling locations and satellite observations;
- establishing common minimum requirements for indicators, methods, quality assurance, data formats and metadata;
- improving cross-border use of tracking data by expanding receiver networks along coastlines and in border areas;
- expanding shared automated systems, including FerryBox installations on research, commercial and ferry vessels;
- improving monitoring of primary production, zooplankton and small pelagic fish, which are essential for understanding North Sea food-web dynamics;
- developing an interconnected European data infrastructure based on national repositories, shared catalogues, APIs and standardised metadata;
- developing a coordinated monitoring framework for offshore wind development across the North Sea.

Large-scale aerial bird surveys are a strong element of the Dutch monitoring approach and provide valuable information on the distribution of species relevant to offshore wind development. Existing survey flights could potentially be used for additional monitoring purposes. In the longer term, drones, automated image recognition and AI could improve efficiency and reduce reliance on ships, aircraft and manual data processing. These technologies are already being explored for applications such as plankton imagery, bird detection and marine mammal acoustic monitoring. However, emerging methods, including eDNA, remote sensing and advanced sensor systems, should first be validated before being widely adopted.

If the Netherlands were to start over, they would want clearer European requirements for assessing ecological carrying capacity and cumulative effects. Moreover, a fully integrated international authority for harmonised North Sea monitoring would be desirable. The priority, however, should be to continuously improve monitoring, while managing methodological changes through well-designed transition periods. Monitoring networks should also be robustly designed, using statistical expertise to ensure sufficient sampling coverage and reliable results.

Norway

No information was provided regarding this topic.

OSPAR

The lack of international harmonisation remains an obstacle, despite improvements through OSPAR assessment harmonisation. Methods and consistency in monitoring still differ between countries.

Harmonisation would be most desirable in space and time of monitoring, as well as methods. The largest bottleneck for harmonisation would be institutional barriers, both in policies as well as in politics. This can also go down to the personal or cultural level, such as a key figure within an organisation not wanting to change a method they have been using for decades. Another bottleneck is the lack of lawful requirements for countries, which forces them to use the same monitoring from the top-down. A last bottleneck is the difference in funds and time, as some countries have a lot more financial space than others.

OSPAR would be a good platform to realize harmonization between countries, as for the data they collect, they have already managed harmonization between countries. Because of this, OSPAR believes most of the 'low hanging fruit' in terms of harmonisation, have already been done. Harmonisation should focus on better communication and discussion between data collecting experts, data assessing experts, and policymakers. Monitoring methods for unique local habitats do not need to be harmonized. Emerging methods like eDNA provide opportunities for harmonisation from the start.

If OSPAR could start over, they would shape monitoring for biodiversity and for European Policies like the MSFD, in the same way as European fishery policies: through binding legislation and a coordinated, joint effort, so that it is truly more comparable and efficient.

IV

Appendix: Full transcripts

Is supplied seperately.