# Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards

## Phase IV: Expectations for monitoring and environmental requirements at the post-consent phase.

Natural England.

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## Version History

| Document Version | Date Published | Summary of Changes |
|---|---|---|
| 1.0 | July 2022 | Document published |

# 1 Contents

# 2 Abbreviations

| | |
|---|---|
| ADD | Acoustic Deterrent Device |
| AEoI | Adverse Effect on Integrity |
| ASRU | Animals in Science Regulation Unit |
| BACI | Before-After-Control-Impact survey design |
| BAG | Before-After-Gradient survey design |
| BEIS | The Department for Business, Energy and Industrial Strategy |
| BMP | Benthic Monitoring Plan |
| CEFAS | Centre for Environment, Fisheries and Aquaculture Science |
| COWRIE | Collaborative Offshore Wind Research into the Environment |
| CRM | Collision Risk Modelling |
| DAERA | Department for Agriculture, Environment and Rural Affairs (Northern Ireland) |
| DAS | Digital Aerial Survey |
| DCO | Development Consent Order |
| DEFRA | Department for Environment, Food and Rural Affairs |
| dML | Deemed Marine Licence |
| EAH | East Anglia Hub |
| eDNA | Environmental DNA |
| EDR | Effective Deterrent Radius |
| EIA | Environmental Impact Assessment |
| EMF | Electromagnetic field |
| EOWDC | European Offshore Wind Deployment Centre |
| EPS | European Protected Species |
| ES | Environmental Statement |
| FFC | Flamborough and Filey Coast |
| GPS | Geographic Positioning System |
| GW | Giga Watt |

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| HDD | Horizontal Directional Drilling |
| HRA | Habitats Regulations Assessment |
| IHLS | International Herring Larval Survey |
| IHO | International Hydrographic Organisation |
| INNS | Invasive Non-Native Species |
| IPMP | In Principle Monitoring Plan |
| JNCC | Joint Nature Conservation Committee |
| kHz | Kilohertz |
| LiDAR | Light Detection and Ranging |
| MCAA | Marine & Coastal Access Act, 2009 |
| MCZ | Marine Conservation Zone |
| MDE | Marine Data Exchange |
| MEDIN | Marine Environmental Data and Information Network |
| MEEB | Measures of Equivalent Environmental Benefit |
| MESH | Mapping European Marine Habitats |
| MLA | Marine Licence Application |
| MMMP | Marine Mammal Mitigation Plan |
| MMMZ | Marine Mammal Mitigation Zone |
| MMO | Marine Management Organisation |
| MMObs | Marine Mammal Observers |
| MNR | Marine Noise Registry |
| MPA | Marine Protected Area |
| MUSE | Multi Sensor wildlife detection system |
| NAF | Nocturnal Activity Factors |
| NAS | Noise Abatement System |
| NE | Natural England |
| NIS | Non-Indigenous Species |

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| NMBAQC | National Marine Biological Analytical Quality Control |
| NPL | National Physical Laboratory |
| NRW | Natural Resources Wales |
| OMP | Ornithological Monitoring Plan |
| OPRED | Offshore Petroleum Regulator for Environment and Decommissioning |
| ORJIP | Offshore Renewables Joint Industry Programme |
| OSPAR | The Convention for the Protection of the Marine Environment of the North-East Atlantic (Oslo & Paris Convention) |
| OWEAP | Offshore Wind Enabling Actions Programme |
| OWEC | Offshore Wind Evidence and Change programme |
| OWF | Offshore Wind Farm |
| OWSMRF | Offshore Wind Strategic Monitoring and Research Forum |
| PAM | Passive Acoustic Monitoring |
| PCM | Post-Consent Monitoring |
| POSEIDON | Planning Offshore Wind Strategic Environmental Impact Decisions |
| PSA | Particle Size Analysis |
| PTS | Permanent Threshold Shift |
| QF | Qualifying Feature |
| QuMR | Improving quantification of mortality rates associated with displacement within the assessment process (ORJIP study) |
| RIAA | Report to Inform Appropriate Assessment |
| RIB | Rigid Inflatable Boat |
| ROV | Remotely Operated Vessels |
| SAC | Special Area of Conservation |
| SBMon | Review of current and planned monitoring of seabird behaviour across operational wind farms (ORJIP study) |
| SCANS | Small Cetaceans in European Atlantic waters and the North Sea |
| SIP | Site Integrity Plan |
| SMRU | Sea Mammal Research Unit |

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| SNCB | Statutory Nature Conservation Body |
| SPA | Special Protection Area |
| SPI | Sediment Profile Imagery |
| SPR | Scottish Power Renewables |
| SSSI | Site of Special Scientific Interest |
| TADS | Thermal Animal Detection System |
| UXO | Unexploded Ordnance |
| VMS | Vessel Monitoring System |
| WoRMS | World Register of Marine Species |
| ZSL | Zoological Society London |

# 3 Introduction

As the offshore wind sector grows in response to ambitious Government targets[1], it is crucial that there are clear expectations and advice for the use of data and evidence at the post-consent phase to support the production and implementation of effective monitoring plans.

Understanding the real-world effects of offshore wind farm (OWF) construction and operation upon ecological receptors is an important aspect of post-consent monitoring (PCM). Monitoring plans can help to validate predictions and assumptions made within applications, whilst also helping to detect unforeseen effects and address areas of uncertainty. Effective PCM also provides a feedback loop of information which can then be used to inform whether further monitoring should occur or if additional mitigation, compensation or restoration measures are required.

Natural England (NE) have produced a series of documents to provide best practice advice for the use of environmental data and evidence standards for offshore wind development in English inshore and offshore waters.[2] This project is in collaboration with the Department for Environment, Food and Rural Affairs (DEFRA), as part of the Offshore Wind Enabling Actions Programme (OWEAP). For the purposes of this document, best practice is defined as the accepted approach and an expected standard to achieve, with additional recommendations also provided.

This advice does not extend to the waters of Devolved Administrations where advice is provided by the relevant Statutory Nature Conservation Body (SNCB). The relevant SNCB should be consulted on matters which fall outside of English waters.

This document is the fourth and final document in the series of best practice advice[3] and provides advice and principles for monitoring at the post-consent phase. Specific advice is provided for the key ecological receptors for OWF – at time of writing these are primarily seabirds, marine mammals, seabed habitats and species, and fish.

Additional post-consent monitoring may be required for offshore wind projects, such as for marine and coastal archaeology, shipping and navigation or commercial fisheries. These topics are not considered within this document.

This advice is not intended to act as a prescriptive plan for how to produce and implement post-consent monitoring plans, but instead provide best practice advice and principles for consideration to help guide detailed discussions when developing post-consent monitoring

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[1] Up to 50 Giga Watt (GW) of offshore wind by 2030, including up to 5 GW generated by floating offshore wind. For more information please see: https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy#renewables

[2] See the following link for more information: [redacted]

[3] The first document provides best practice advice for the collection and use of data and evidence for pre-application baseline characterisation surveys (Parker *et al.* 2022a). The second in the series provides expectations for pre-application engagement and the evidence plan process (Parker *et al.* 2022b). The third document addresses data and evidence expectations at application (Parker *et al.* 2022c). [redacted]

Requests for access to the SharePoint site where the advice is stored should be sent to the following email address: neoffshorewindstrategicsolutions@naturalengland.org.uk (please allow up to 3 working days for requests to be approved).

plans. The advice will also be of use when agreeing In Principle Monitoring Plans (IPMPs) at the examination phase. The receptor-specific sections are aimed to provide advice for designing the relevant PCM plans, whilst leaving sufficient room for discussion about innovation and new ideas. Monitoring plan proposals should be discussed with Natural England, or relevant SNCB, and be fully justified with robust reasoning and supporting evidence.

Advice is also provided on post-consent requirements, such as marine licence applications for Unexploded Ordnance (UXO) clearance and European Protected Species (EPS) licence applications, as well as requirements for the production of Site Integrity Plans (SIPs) and Marine Mammal Mitigation Plans (MMMPs). Advice on these topics are discussed in the relevant receptor sections. Advice is also provided on the production of draft decommissioning plans (Section 9).

This advice document should be considered 'live' and will be periodically updated to reflect evolving best practice in Environmental Impact Assessment (EIA), planning reforms or other relevant changes coming out of the Environment Act[4] and in response to Government policy and initiatives, such as the recent British Energy Security Strategy[5] and 'Project Speed'.[6]

## 3.1 Emerging changes to the planning system

The advice provided within this document (and others in the series) represents the most current advice for offshore wind projects.

Natural England are aware of multiple cross-Government policy statements, reform projects and strategies, such as the British Energy Security Strategy or Defra's review to 'refocus' HRA processes. The proposed reforms could result in changes to the planning system and supporting environmental legislation, with implications for future offshore wind projects.

Natural England understands that the proposed changes to the planning system and supporting legislation are unlikely to be enacted for current projects, but may be applicable for future leasing rounds, although this is yet to be confirmed. This document, and others in the series, will be updated in light of changes to the planning and regulatory system when available.

## 3.2 How to use this document

Review of this document is intended to be the first step for prospective OWF projects when considering environmental monitoring plans and should be used as a framework for subsequent discussions at the post-consent phase. Guiding principles and recommendations for PCM are provided below.

This document should also be used to inform marine licence applications for UXO clearance and EPS licences, as well as other marine mammal considerations, such as SIPs and MMMPs. The scientific names for each species considered within this document are provided within Annex I.

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[4] https://www.legislation.gov.uk/ukpga/2021/30/contents/enacted and https://www.gov.uk/government/publications/environment-bill-2020

[5] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

[6] https://www.gov.uk/government/news/pm-a-new-deal-for-britain

The advice below is non-binding and is provided without prejudice to the consideration of any statutory consultation response which may be made by Natural England in due course. The final advice on any monitoring proposals from Natural England is reserved and will be made on a project-specific basis, based on the information then available.

**Discretionary Advice Service**

Natural England provides a chargeable Discretionary Advice Service to provide upfront advice on planning proposals. Developers can request bespoke advice on all aspects of monitoring programmes or other requirements at the post-consent stage on a project-specific basis: https://www.gov.uk/guidance/developers-get-environmental-advice-on-your-planning-proposals

# 4 Post-consent monitoring

Monitoring of the marine environment and ecological receptors is an important process for offshore wind projects at the post-consent phase. Monitoring is required in order to address areas of uncertainty, test hypotheses and to validate predictions made within project Environmental Statements (ES). Monitoring is also required to inform on the requirement for subsequent remedial measures.

The requirement for monitoring at the post-consent phase is secured by conditions on the Development Consent Order (DCO) and associated deemed Marine Licences (dMLs) obtained at the consent stage. The legislative basis for PCM is primarily driven by Habitats Regulations Assessment (HRA) and EIA requirements but may also be required under the Marine and Coastal Access Act (2009), which relates to Marine Conservation Zones (MCZs) (MMO, 2014).

Receptor-specific monitoring plans are agreed between the applicant and the Marine Management Organisation (MMO), as the regulator, in consultation with the relevant SNCB(s). IPMPs outline the monitoring proposals and provide the framework for receptor-specific monitoring plan discussions at the post-consent phase (see Section 4.1).

As set out by MMO (2014), monitoring requirements are largely driven to:

- Reduce uncertainty or validate predictions made within the ES and EIA / HRA assessments;
- Detect unforeseen impacts;
- Inform adaptive management; and
- Provide evidence on the effectiveness of mitigation measures to ensure compliance with measures identified in assessments to mitigate significant impacts.

The MMO (2014) informative report pre-dates any delivery of any compensatory measures by offshore wind farms in English waters, which are therefore not addressed within the report. For the purposes of this document, ‘compensatory measures’ is used to refer to both compensatory measures under the Habitat Regulations and Measures of Equivalent Environmental Benefit (MEEB) under The Marine and Coastal Access Act, 2009 (MCAA) (Defra, 2021).

Evaluating the success of compensation measures is an important consideration for current projects and is likely to become more relevant as more OWFs are constructed, thereby contributing to greater in-combination and cumulative effects. Moreover, considering the stipulation for strategic compensation for projects within the recent British Energy Security Strategy[7], this is likely to be a future area of consideration.

Therefore, it is also advised that PCM may also be required to:

- Provide evidence to assess the significance of adverse effects, evaluate the success of compensation measures and to help inform whether further remedial measures are required.

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[7] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

Typical monitoring plans consist of a proposed series of surveys, and subsequent reports, at the pre-construction and post-construction phases. Due to the long timescales for the construction of some projects, monitoring may also be required during the construction phase. Comparing pre-construction and post-construction monitoring could enable the detection of impacts resulting from construction activities and subsequent recovery. However, any monitoring plans will need to be tailored to the specific receptor and predicted impact to determine the most appropriate method and timeframe for evaluating effects.

Monitoring will also be required at the decommissioning phase to monitor the effects of decommissioning activities and removing infrastructure, as well as validating predictions of recovery. Refer to Section 9 for more information on decommissioning.

## 4.1 In Principle Monitoring Plans

IPMPs are agreed during the examination stage before consent for the project is granted and act as a pre-cursor for monitoring plans at the post-consent phase. IPMPs should set out the principle purpose(s) for the proposed monitoring, as well as an outline plan for topics and receptors to be monitored. IPMPs should provide a starting point for further discussions at the post-consent phase.

Draft IPMPs are produced in consultation with the relevant regulator(s) and SNCB(s) to set out the basis for delivering the outline monitoring measures as required by the conditions contained within the dMLs. Draft IPMPs are further developed during the examination phase and are referred to within the draft DCO.

Once finalised and agreed, IPMPs provide the basis for receptor-specific monitoring plans at the post-consent phase, when finer details are agreed regarding monitoring survey timings, locations and methodologies. IPMPs provide a framework to guide the applicant on the future expectations for monitoring and to help reduce ambiguity for the drafting of DCO and dML conditions.

An effective IPMP can provide many benefits to the applicant, such as addressing issues which otherwise need to be considered at the post-consent phase, as well as providing confidence to the regulator and relevant SNCBs that areas of uncertainty will be addressed during the post-consent phase. However, the effectiveness of IPMPs can vary significantly across projects.

The below section provides advice as to what information IPMPs should provide as well as recommendations for how to maximise the usefulness of the process.

### 4.1.1 Natural England’s recommendations

Natural England recommend that an effective IPMP should:

- Provide a brief background/overview of the proposed OWF project at the start of the document, which will be updated as the project design is refined, to ensure that the monitoring remains fit for purpose. IPMPs should also provide an outline timetable for the expected delivery of works and monitoring programmes;

- Clearly set out the uncertainties, residual concerns, and evidence gaps of the EIA, HRA and MCZ Assessment (if applicable), raised as part of the consenting process;

- Provide clearly defined monitoring aims and objectives that will be addressed/tested by the monitoring programme at the post-consent phase, and hypotheses for monitoring should also be provided where applicable. Specific uncertainties and assumptions projects intend to target through the proposed monitoring should be clearly stated. Research aims and hypotheses should be reviewed at the post-consent stage, prior to the monitoring being undertaken, to ensure that they are robust and fit for purpose;

- Outline monitoring proposals which are most likely to provide the required evidence to better understand uncertainties, fill evidence gaps or test hypotheses, rather than broad monitoring for the sake of undertaking monitoring (MMO, 2014). Where possible, this should include information on the number, timing and duration of surveys, which will then be used to inform receptor-specific monitoring plans which are agreed at the post-consent phase. IPMPs should use the results of monitoring programmes by other projects to learn lessons and improve effectiveness;

- Provide sufficient information and detail to inform the production of receptor-specific monitoring plans and to clearly define the framework for further discussions. The IPMP should clarify the principle purpose(s) for monitoring on a receptor-specific basis[8] and provide an indication of what and where monitoring programmes will focus upon and what this should achieve;

- Provide clearly presented information, such as a table to summarise the proposed in-principle monitoring for each topic or ecological receptor. IPMPs should clearly state the ‘headline reasons for monitoring’ and ‘monitoring proposal’, and how these relate to the defined monitoring objectives / hypotheses;

- Provide predicted timescales for recovery of receptors after an impact has occurred and clarity on how decisions will be made during the post-consent phase, including the conclusion of monitoring. For example, clearly defined criteria for when post-construction monitoring will be undertaken and when monitoring will be deemed to have met the objectives of monitoring programme or when further monitoring will be required. IPMPs should also outline the circumstances upon which monitoring plans will be amended and highlight the role of any working groups for decision making;

- Provide an outline of what actions could be undertaken in the event that monitoring reveals that impacts are of a greater significance than predicted within the application or if additional concerns are highlighted. This may include requirements for further monitoring, or the implementation of additional mitigation measures required to reduce impacts, including further restoration measures where relevant;

- Allow for some flexibility to agree changes to the IPMP as monitoring plans evolve and detailed design information becomes available. For example, new or emerging technology may become available at the point of implementation, such as new tags or tracking devices, which enables new data to be collected; and

- Identify potential routes to achieving strategic level monitoring in collaboration with other projects or with strategic research groups, such as the Offshore Renewables Joint Industry Programme (ORJIP) or the Offshore Wind Strategic Monitoring and Research Forum (OWSMRF), in order to address monitoring objectives, areas of uncertainty or evidence gaps. This is particularly important for monitoring priorities

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[8] Examples of primary purpose(s) for monitoring may include (but not limited to): impact validation, addressing evidence gaps, understanding the extent of recovery and to inform on the requirement of further management or remedial measures.

which require greater scale and scope than is achievable by individual projects alone.

Natural England can provide bespoke project-specific advice on the production of draft IPMPs on a case-by-case basis.

## 4.2 Advice relating to post-consent monitoring

The MMO undertook an informative review of all post-consent monitoring that had occurred to date in English waters (MMO, 2014). This review provides the context for PCM at offshore wind farms as well as providing recommendations for the design and implementation of monitoring plans (MMO, 2014).

Whilst the MMO review (2014) pre-dates post-consent monitoring that has since occurred at offshore wind farms in English waters, the regulatory context, principles and recommendations provided remain applicable and relevant to current projects at the post-consent phase. It is therefore advised that this document is referred to and the associated principles and recommendations are followed as a matter of best practice.

The process and structure of the planning system, including post-consent monitoring, is currently under review by Government, Defra, Natural England and other bodies (see Section 3.1). Options for how PCM can be improved to increase our understanding of the marine environment, the effects of offshore wind development and provide information-rich data over relevant spatial and temporal scales are being considered, such as the promotion of strategic or collaborative monitoring (see Section 4.4).

The following section provides Natural England’s advice and recommendations for the production and delivery of receptor-specific monitoring plans at the post-consent phase.

### 4.2.1 Natural England’s recommendations

Natural England’s recommendations relating to the design and delivery of post-consent monitoring plans are set out below.

- **Early and continued engagement with SNCBs** – engagement with the relevant SNCB(s) is recommended at the earliest possible opportunity to agree the focus of monitoring plans and to allow for continual engagement as plans evolve.

- **Clear aims, objectives and hypotheses** – post-consent monitoring plans should be targeted and have clear aims and hypotheses (Chambers *et al.* 2012; MMO, 2014; Lindeboom *et al.* 2015). Monitoring should be proportionate to the level of risk to biological receptors and should not be delivered for the sake of monitoring, but instead focus on sensitive receptors and be driven by a clear understanding of what the monitoring is seeking to address (MMO, 2014). This helps to collect data that is information rich, as well as data rich (Wilding *et al.* 2017). Early engagement with NE or relevant SNCB is recommended to help agree monitoring plans.

- **Detection of unforeseen impacts** – post-consent monitoring should be targeted, with clear monitoring aims and objectives. Whilst PCM plans should not be designed to detect unforeseen impacts, the analysis of the results of PCM may identify unforeseen impacts which arise during offshore wind farm development across relevant spatial and temporal scales (MMO, 2014). If detected, unforeseen effects can be investigated through adaptive monitoring (see Section 4.3). Participation in collaborative or strategic-level monitoring projects may be also appropriate for identifying long term and lasting effects to marine receptors as a result of offshore wind development.

- **Statistical power** – the ability of a survey to collect a sufficiently large amount of data to make robust statistical inferences about changes is known as its power (Maclean *et al*. 2006). Where possible, power analyses should be undertaken before monitoring commences to inform the design of PCM to ensure sufficient statistical power in subsequent analyses to detect meaningful changes (Bennet *et al.* 2016). Projects should also aim to reduce dependence within or between sampling units and plan the statistical tests and/or modelling approach so that the nature and quantity of data collected is suited to conduct the required tests/modelling (Bennet *et al.* 2016; Noble-James *et al.* 2018). Early engagement with Natural England is recommended when considering the statistical power of analyses and how this is used to inform survey design, or if power analyses indicate that the expected statistical power may not be sufficient to draw meaningful conclusions.

- **Uncertainty and significance** – as set out within MMO (2014), uncertainty and significance are two important considerations when designing and implementing PCM plans. Uncertainty reflects the extent of error or assumptions that were made when predicting impacts. There is a greater need to monitor topics if there is higher uncertainty regarding the effects of an impact or resulting recovery of receptors. The significance of an impact is another important consideration for PCM and helps to inform whether further management or remedial measures are required (MMO, 2014).

- **Sufficient duration** – PCM should be of a suitable duration to capture lags in impacts to receptors being detected as some impacts may only be detectable after a duration of time, depending on the receptor and the monitoring objectives. In addition, PCM may be required to monitor the recovery of receptors after an impact has occurred (e.g. impacts from construction) or a compensation measure has been put in place. Monitoring plans should be designed to incorporate long term or lasting impacts to validate predictions made within the ES and to improve our understanding of long-term effects and recovery of marine receptors. Monitoring plans should also have a clearly defined criteria for when and how decisions will be made on the conclusion of monitoring during the post-consent phase, for example when monitoring will be deemed to have met the objectives of the monitoring programme. Refer to the adaptive management approach principle below (Section 4.3).

- **Strategy for consequence** – a key role of post-consent monitoring is to validate the predictions of the ES, HRA, EIA or MCZ Assessment (Section 4). Monitoring plans should therefore have a clear strategy for subsequent remedial action if the monitoring shows that the original conclusions are incorrect, such as the significance of an impact upon a receptor or the timeframe for its recovery (MMO, 2014). Thresholds can be used to set acceptable levels of change for some environmental indicators, which if exceeded, can trigger additional monitoring or the implementation of mitigation or management measures to avoid adverse effects (Bennet *et al.* 2016; Wilding *et al.* 2017).

- **Sharing of data** – in order to maximise the usefulness of post-consent monitoring, data and reports should be made publicly available and provided to the relevant data repositories, such as the Marine Data Exchange (MDE) and the Marine Environmental Data and Information Network (MEDIN). All reports should be supported by the source/raw data and provide a description of the collection methodology and protocols followed (MMO, 2014). Metadata and environmental metadata should also be made publicly available (Chambers *et al.* 2012). Natural England advise that PCM data should be shared within the relevant data repositories as a matter of best practice. This could be secured as a licence condition for projects.

- **Maximise use of baseline characterisation data and existing data** – where possible, data collected at the pre-application phase should be used to supplement post-consent monitoring data. The results of baseline characterisation surveys may also be useful to inform the design of post-consent monitoring plans (e.g. the key areas or receptors for monitoring to focus upon). There may also be suitable existing datasets which can be used to provide context or supplement site-specific monitoring data. However, the validity and suitability of existing datasets must be carefully considered if used beyond providing a historical context for subsequent monitoring data (Noble-James *et al.* 2018). Parker *et al.* (2022a) provides advice and principles for the use of existing data to inform baseline characterisation surveys.

- **Comparable and standardised data** – data should be collected and presented in a consistent format which, where possible, enables effective comparisons with other datasets and other monitoring programmes. Consistent data standards may also allow for backwards/forwards compatibility of monitoring methods over time. Data collection should follow the MEDIN data standards and guidelines as a matter of best practice.[9] A consistent naming convention should also be followed. Species should be recorded using the World Register of Marine Species (WoRMS)[10] list of accepted scientific names and biotopes should be recorded using the EUNIS classification system (EEA, 2019). A consistent and comparable approach also enables effective cumulative and in-combination assessments and improves the functionality of data repositories.

- **Follow industry standards, methodologies and protocols** – monitoring programmes should follow the current industry standards, methodologies and protocols as a matter of best practice. This may apply to data collection, handling or analysis (Chambers *et al.* 2012). Receptor-specific advice is provided within the relevant sections below. Whilst this document will be periodically updated to reflect evolving best practice for industry standards and survey methodologies, Natural England would welcome the opportunity to discuss proposals to use the latest industry monitoring methods, standards or protocols.

- **Novel and emerging monitoring methods –** Natural England acknowledges the role of offshore wind farm developers in exploring and testing new monitoring methods. Natural England supports innovation and welcomes the exploration of novel and emerging monitoring methods, such as environmental DNA (eDNA), or passive monitoring methods. Although there can be challenges presented by the relative novelty of some techniques in early stages, collaborative working can unlock many wider benefits if planned carefully. Early engagement with Natural England is recommended if novel approaches are proposed.

- **Strategic / joined up approach –** a strategic, collaborative or joined up approach can deliver monitoring programmes of a greater scale and scope, thereby providing a greater understanding of ecological impacts, sensitivity or recovery (see Section 4.4). Natural England strongly supports strategic or collaborative monitoring proposals and can provide bespoke advice on a case-by-case basis.

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[9] [redacted]

[redacted]

## 4.3 Adaptive monitoring and discharge of conditions

Adaptive monitoring is the process of evaluating data collected to date, to help inform the duration and/or design of further monitoring (Bennet *et al.* 2016). It can also be used to assess whether monitoring should continue or if the relevant licence conditions can be discharged (MMO, 2014). Adaptive monitoring can also inform on the requirement for further mitigation, compensation or restoration measures.

Adaptive monitoring is of particular importance for where there is scientific uncertainty regarding lasting impacts or recovery of receptors (Bennet *et al.* 2016) or where monitoring is seeking to validate predictions of the ES, EIA, HRA or MCZ Assessment.

Adaptive monitoring is relevant during the post-construction phase where monitoring is investigating changes to the natural environment and ecological receptors over an undefined timescale, such as until a receptor recovers.

Licence conditions should incorporate flexibility over the duration of monitoring plans, to allow the results of monitoring surveys to inform the requirement for future surveys or the implementation of management measures (MMO, 2014). This helps to ensure monitoring programmes are delivering the agreed aims and objectives set out by the monitoring plans and ensure monitoring is proportionate to the level of data required.

For example, if the ES predicted a full recovery of an MPA feature within a certain timeframe, monitoring may be required until full recovery has occurred and can be agreed between the applicant, SNCB and MMO as the relevant regulator. Conversely, if a receptor has demonstrated the predicted level of recovery, and if agreed by all parties, the requirement for additional post-construction surveys may be discharged early.

In addition, another aspect of adaptive monitoring is the flexibility of the monitoring plan. Due to the long timeframe between projects obtaining consent and completing PCM surveys after construction, monitoring plans need to capture the scope for changes to the methodology or focus of surveys over time. This may be due to new evidence or understanding of impacts to marine receptors, or due to new technology becoming available which enables more ambitious studies. For example, seabird tagging projects should allow for flexibility in methods as new tracking devices become available. Natural England can provide advice on a case-by-case basis.

## 4.4 Collaborative / strategic monitoring

Delivering monitoring projects collaboratively could have many benefits for the collection of post-consent monitoring data and can help to answer key evidence gaps or research priorities.

Collaborative monitoring could include joint monitoring programmes across zones or regions where projects pool resources to achieve monitoring aims, or where key research questions are divided between projects within a zone or region to allow sufficient time and resources to be dedicated to each question. Collaborative monitoring could also comprise individual offshore wind projects contributing data, money or resources to a strategic research project led by another organisation, such as by ORJIP or ORSMRF, to address shared research questions or evidence gaps.

Working collaboratively allows for the pooling of resources and/or division of labour, which enables monitoring programmes to be of a greater scale and scope than possible on a project-specific basis. This enables data collection to produce useful and information-rich data over sufficient spatial and temporal scales to enhance our understanding of the marine environment and the effect of offshore wind development upon ecological receptors (Wilding *et al.* 2017). In addition, collaborative monitoring could be undertaken over larger spatial and temporal scales than project-specific monitoring plans, which could enable the detection of wider community changes, unforeseen or long-term effects, and allow for greater statistical power in subsequent analyses.

Some projects have worked collaboratively to address key shared questions of mutual interest at the post-consent phase (e.g. see Section 6.3.1). If implemented effectively, this allows for the division of labour and allows multiple projects to undertake more insightful monitoring programmes than possible on an individual project-level.

Whilst there is widespread agreement of the benefits of collaborative monitoring across sector groups, a framework is required to facilitate strategic monitoring programmes at the government level. Facilitating strategic monitoring is a key objective of Natural England's Approach to Offshore Wind[11] (Natural England, 2021) and Natural England supports the implementation of strategic monitoring as a mechanism to address key evidence gaps and to deliver monitoring projects at scale.

Natural England are also leading the Planning Offshore Wind Strategic Environmental Impact Decisions (POSEIDON) project. This is a multi-year project, funded through the Crown Estate's Offshore Wind Evidence and Change (OWEC) programme, which is seeking to address strategic data collection for offshore wind projects. The outputs of the POSEIDON project will be incorporated into this advice when available.

Projects should consider whether data collection for some aspects of post-consent monitoring could be undertaken collaboratively with other regional projects in order to answer specific monitoring aims and priorities.

Natural England strongly supports the implementation of collaborative monitoring programmes across projects, zones or regions, and can provide advice on a case-by-case basis.

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# 5 Seabirds

This section provides advice for monitoring programmes for seabirds at the post-consent phase. This includes key considerations for seabird monitoring (Section 5.1) and specific advice on key monitoring requirements for seabirds at the post-consent phase.

Primarily the seabirds section covers disturbance and displacement, collision, and apportioning as the key areas of uncertainty in ornithological assessments at present, along with monitoring at the colony. At the end of each section, relevant case studies and guidance have been referenced.

Advances in technology, and our understanding of the evidence base, are moving at a pace in the field of marine ornithology. The advice below should be considered a signpost to current key areas of PCM for seabirds. A major change in offshore wind PCM for seabirds has been the move towards objective/hypothesis-based monitoring, seeking to address the key uncertainties/evidence gaps identified in the DCO process, and away from ‘generic’ 3 years pre- and 3 years post-construction surveys.

The development of each wind farm Ornithological Monitoring Plan (OMP) requires early and substantive engagement with Natural England to ensure it addresses the key questions. This advice does not detract from that need.

## 5.1 Key considerations for post-consent monitoring of seabirds

Section 4.2 provides high level principles for designing and implementing PCM for all receptors and are relevant at any scale. In the case of seabirds, there is a clear and urgent need to move towards strategic, joined up projects, that enable longer term/larger scale monitoring that employ methodological and sampling regimes required to answer key questions with suitable statistical power (Section 4.4).

Whether it is a wind farm or strategic level project, there is a best practice process common to all monitoring requirements for seabirds. The key considerations for this process are set out here:

- **Identifying monitoring objectives and testable hypotheses** – data gathering should be planned and conducted with specific objectives in mind. The specific objectives should be shaped by the high-level monitoring requirements which will typically be to: i) validate predictions made in an EIA or HRA, ii) detect any unforeseen impacts, or iii) ensure compliance with measures identified in assessments to mitigate (or compensate) significant impacts. The focus should in most cases be to address predicted impacts which have i) the greatest uncertainty – i.e. the greatest extent of error or assumptions that were made in calculating the impact and/or ii) the greatest significance – the extent to which the identified impact is deemed significant.

  Ideally, once the specific objective(s) have been identified, these should, where appropriate, be used to generate hypotheses that can be tested with appropriately collected data, such as those collected through Digital Aerial Survey (DAS) methods. Natural England should be consulted at the earliest opportunity to advise on the identification of objectives and hypotheses to be tested as part of PCM.

- **Identify appropriate data** – only once clearly defined objectives and/or hypotheses are established is it possible to identify the data sets required to address these hypotheses and plan a monitoring strategy with confidence that the resultant data will serve to test those hypotheses and meet those objectives.

- **Identify data requirements and plan analyses –** having established the specific objectives and, where appropriate, the hypotheses to be tested, and the data required, consideration should be given at the earliest opportunity to: i) the pros and cons of the various analytical approaches that might be applied to the data, and ii) the survey methodology necessary to gather the data.

- **Power analysis and survey design –** the ability of a survey design to collect a sufficiently large amount of data to make robust statistical inferences about changes is known as its power (Maclean *et al.* 2006). For example, the power to detect change from survey data alone is related to the spatial extent and coverage, number of independent samples, temporal extent and frequency of surveys (see Maclean *et al.,* 2006; 2007; 2012; Pérez Lapeña *et al*. 2010). It is recommended that 'power analyses' of existing appropriate datasets, for example those collected as part of baseline characterisation, should, whenever possible, be undertaken to inform details of sampling design, such as the total extent of area to be surveyed, number and spacing of independent samples (transects, transect segments or grid nodes). Power analyses also ensure that such designs maximise the probability of detecting the changes in the parameter being explored (e.g. abundance and distribution) that might reasonably be anticipated in respect of the species of particular interest.

  It is recommended that Natural England is consulted at an early stage to discuss the suitability of using existing datasets for power analyses. Typically, power is expressed as the probability of detecting a change of x % at a probability of y. Power (and precision) are dependent on sampling sufficiency; designs should therefore consider and describe the expected resulting precision and power when deciding how many independent sample units to record and the level and distribution of coverage needed. Webb *et al.* (2014) provide some examples of power analyses applied to sampling of focal bird species within a marine SPA.

- **Novel approaches to ornithological monitoring** – Natural England recognises the value and opportunities in trialling new technologies and supports the exploration of novel and emerging monitoring methods that can help to improve our understanding of the effects of offshore wind farm development and operation upon seabird receptors. For example, passive monitoring methods, such as cameras on turbines, have the potential to provide new datasets for monitoring actual collisions of seabirds with turbines as well as providing data on seabird flight heights or avoidance behaviours, and are increasingly deployed. Although there can be challenges presented by the relative novelty of some techniques in early stages, collaborative working can unlock many wider benefits if planned carefully; this necessitates early engagement to discuss flexibility and contingency in the approach.

- **Reporting** – Natural England advises that full analyses of PCM data should be conducted after each year of post consent monitoring and presented in each annual report. This allows an informed assessment to be made of the robustness of the data, the survey plan that generated the data, and of the analytical approach which might subsequently be applied to the completed dataset. Gaps and limitations can be identified. This information can be used to modify the approach to surveys and/or analytical approach, in a timely fashion. Otherwise, there is a considerable risk that a PCM programme spanning many years, and conducted at considerable expense, will prove ultimately not to have been fit for the purpose of meeting the specific objectives or testing specific hypotheses of the PCM (Wilding *et al.* 2017).

- **Collaborative monitoring** – as highlighted within Section 4.4, Natural England strongly supports collaborative approaches to marine monitoring and can provide advice on a case-by-case basis. Projects should consider whether ornithological monitoring objectives can be best delivered collaboratively across projects, zones or regions, or through participation in strategic monitoring projects (e.g. led by ORJIP or OSMRF). By working collaboratively, monitoring projects can be of a greater scope and scale to produce statistically robust and information-rich data over sufficient spatial and temporal scales to draw meaningful conclusions and address key evidence gaps (Wilding *et al.* 2017). The wording of DCO and dML conditions should be carefully considered to help facilitate collaborative and/or strategic approaches for seabird PCM to be undertaken.

## 5.2 Disturbance, displacement and distributional changes

The construction, operation, maintenance and decommissioning of offshore wind farms can lead to the disturbance and/or avoidance by seabirds and therefore changes to their use of sea areas in and around developments i.e. displacement. This has the potential to lead to impacts on individual survival or productivity and so impacts on population-level demographic rates. Furthermore, the degree of avoidance of wind farms by seabirds is an important behavioural consideration when predicting mortality arising from collision (see Section 5.3). Consequently, monitoring of changes to the distribution of seabirds is often a key element of post-consent monitoring.

### 5.2.1 Digital aerial surveys

In the Phase I advice document (Parker *et al.* 2022a), it was advised that all seabird baseline characterisation surveys should use DAS methodology as standard. In this document, therefore, we present advice only in respect to the use of DAS within PCM, reflecting the fact that best practice should ensure, where appropriate, consistency in methodology so that data are comparable over time. However, many of the principles set out below are equally relevant to other methodologies, such as visual aerial surveys or boat-based surveys, where they have been agreed on a project-specific basis.

#### 5.2.1.1 Plan analyses of data

Within the context of PCM, analyses of DAS is typically conducted to quantify changes between different phases of wind farm development (i.e., pre-, during, and post-construction) in the abundance of a species using certain sea areas e.g. within a wind farm array and within certain buffers around it.

Abundance and density estimates used to assess change can be generated through either a design-based or model-based analysis of the survey data (Buckland *et al.* 2012). The merits and limitations of both approaches are presented in the Phase III advice (Parker *et al.* 2022c). The application of model-based approaches, such as density surface modelling techniques, may improve the power to detect change (Maclean *et al.*, 2006; 2007; 2012). Early engagement with NE is recommended to discuss whether a model-based approach is suitable on a project-specific level.

Model-based analyses extrapolate from the surveyed plots or transects to the entire survey area by fitting a model with bird density data and predictive covariates (such as bathymetry or sea surface temperature). This approach relies upon the sourcing and inclusion of suitable covariates (at an appropriate spatial and temporal resolution) (see Section 5.2.1.5). Thus, defining the suite of environmental covariates that may be necessary to construct a model that adequately captures the variation in bird distribution in space and time is a critical early step in the planning of analyses and data collection.

PCM reports should clearly state the spatial model used to generate abundance and density estimates or distribution maps, including justification for the selected modelling method. All models have some limitations and assumptions which should be clearly stated within reports. If a model-based analysis is used, model diagnostics should be provided to demonstrate how well the model fits the data. Wherever possible, output files from the modelling package used should be made available. Maps of species' distributions produced from raw data, and design-based estimates should also be provided as a matter of best practice to allow for comparison with modelled distributions.

#### 5.2.1.2 Survey area

The extent of the area to be surveyed is a critical factor in determining whether the full magnitude and spatial extent of any impact of wind farm construction and operation on the distribution of birds can be quantified and detected against a background of other environmental factors that may also influence the birds' distribution.

Current best practice dictates that a Before-After-Gradient (BAG) approach (Ellis & Schneider (1997), and see discussion in Jackson & Whitfield, 2011) should be employed in PCM studies of displacement and distributional changes.

In the Phase I and Phase III advice (Parker *et al.* 2022a; 2022c), the joint SNCB interim displacement advice note (Joint SNCBs, 2017) and its update (Joint SNCBs, 2022), various buffer distances have been recommended for use in baseline characterisation surveys e.g. 2 km for most seabirds, at least 4 km for seaducks and divers, and at least 10 km where an array is within 10 km of an SPA designated for non-breeding red-throated diver (Joint SNCBs, 2022).[12] These values are indicative of the distance around an array over which a reduction in density of each species might be expected, based on empirical evidence. However, if survey areas for PCM are limited to these distances there is a risk that it will not be possible to detect the limit to the extent of the sea area over which a negative effect on bird density occurs. This risk arises if no sea areas beyond the anticipated zone of influence around an array are captured such that the survey data contain no contextual information on background "natural" changes to bird abundance and distribution over time against which any effect of the wind farm must be detected.

Thus, the specific objectives of PCM may require larger distances are surveyed than the buffers used in baseline characterisation. The spatial extent of PCM DAS surveys should be determined by the species which is anticipated to respond negatively over the greatest distance from the array. Existing site-specific survey data such as that gathered during baseline characterisation may be useful in identifying the location and nature of favoured habitat to which displaced individuals may relocate.

It is recommended that Natural England are consulted for project-specific advice on the appropriate buffer size.

#### 5.2.1.3 Timing of surveys

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[12] https://data.jncc.gov.uk/data/9aecb87c-80c5-4cfb-9102-39f0228dcc9a/interim-sncb-advice-rtd-displacement-buffer.pdf

The specific objectives of DAS should be shaped by the hypothesis identified concerning key impacts of greatest significance and/or uncertainty to be tested, which should in turn dictate the months/seasons in which DAS must be focussed to meet those specific objectives. The number and spacing of the years in which such surveys should be conducted during the lifetime of a wind farm should be discussed with Natural England and subject to adaptive management as required (see Section 4.3).

Natural England should be consulted at the earliest opportunity to discuss the suitability of the pre-existing monitoring data for this purpose in terms of aspects such as age of data, survey extent, frequency, coverage and resolution.

All data within a given season (e.g. a breeding season for a species) should come from consecutive surveys across all of that season in each year of monitoring. Combining multiple incomplete datasets from different years to provide “complete” coverage of a season should be avoided wherever possible.

Depending upon the objectives of PCM, DAS may be better conducted at intervals through the lifetime of the wind farm rather than in consecutive years.

#### 5.2.1.4 Power analysis and survey design

Power analyses of baseline characterisation data should be conducted whenever possible at the earliest opportunity to ensure that the methodologies are appropriate for detecting change of a given magnitude (MMO, 2014). Furthermore, pre-construction monitoring data collected over the initial period following consent should ideally be used to conduct an updated power analysis to confirm or, if necessary, modify the monitoring design.

To date, the majority of PCM DAS have involved an even spread of survey coverage across the entirety of the area surveyed i.e. even transect spacing or an evenly spaced grid. However, because displacement effects typically manifest themselves as a gradient of effect that diminishes with increasing distance from an array, this approach may not be best suited to quantifying the extent of the effect when the % reduction in density over much of that gradient is anticipated to be less than 50%. To reliably quantify such gradients, and the limits to them, it may be necessary to adopt a survey design that incorporates an element of stratification e.g. survey coverage that increases with increasing distance from the array and towards the anticipated limit to the zone of influence for the species of interest.

If power analyses conducted in the initial stages of planning PCM DAS indicate very limited or no power to detect changes in abundance of the anticipated magnitude, Natural England should be consulted at the earliest stage to discuss alternative monitoring approaches.

#### 5.2.1.5 Identification and collection of additional information to inform analyses

The application of density surface modelling techniques to DAS data enables environmental correlating factors to be accounted for. Changes in bird densities that might be a result of the construction or operation of the wind farm may be better evaluated taking account of the influence of other factors on their distribution. If, as recommended, use of such a model-based approach to analyses of DAS data is anticipated, the other likely key drivers of bird displacement/distribution should be identified at the earliest opportunity i.e. when planning PCM.

Existing data sources for static covariates should be identified. MMO (2014) noted that the inclusion of temporally varying covariates rather than solely static covariates (ideally environmental data that is collected synoptically to the timing of the bird surveys) would greatly help in evaluating wind farm effects on bird distribution. Plans should be put in place as part of PCM to obtain such data either from third parties who may be conducting surveys of such environmental factors synoptically with planned bird surveys, or by undertaking bespoke surveys to gather the necessary data.

The possibility of capitalising on (and/or adapting) surveys planned for other aspects of PCM, such as monitoring of other ecological receptors, to yield supporting data for inclusion within model-based analyses of bird distribution should be investigated.

#### 5.2.1.6 Reporting

As noted above (Section 5.1) full analyses should be presented in reports, which may be required annually. Following analysis of the data, each successive monitoring report should clearly present the estimate (with associated measures of uncertainty) of the number of individuals of each key species displaced and of the spatial extent over which the abundance/density of birds has been significantly reduced in comparison with baseline, pre-construction conditions. Because a declining gradient in the magnitude of the % reduction in abundance/density with increasing distance from an array is likely (with any increases over time likely to occur in sea areas further removed from an array), abundance/density estimates and changes in those over time should be presented in concentric buffer strips around an array. Gradients in % displacement are unlikely to apply uniformly in all directions around an array so, where possible, information should be presented which describes the spatial variation around the array in the maximum distance at which statistically significant reductions in abundance/density over time are detected.

In cases in which PCM has had a specific objective of validating predictions in the ES of the numbers or % of individuals likely to be displaced and of the distance/area over which that effect occurs, PCM reports should present those numbers from the ES alongside the updated estimates derived from analyses of the PCM DAS data as a matter of best practice, so that the validity or otherwise of those original values is clear.

#### 5.2.1.7 Limitations of DAS and tracking studies

Digital aerial surveys are a critical source of information in understanding changes to the distribution of birds and in quantifying displacement effects. However, DAS cannot discriminate between birds from different populations or source colonies and so cannot determine the extent to which changes to the usage of space by individuals from different populations or colonies following wind farm development differs between them or indeed between individuals from within a given population or colony. Tracking studies of carefully selected individuals from specific populations/colonies allow such information to be gathered. This can often be an important element of PCM to validate predicted displacement impacts*.* See Section 5.4.1 on tracking, in the apportioning section for more detail.

### 5.2.2 Individual fitness and population-level consequences associated with disturbance/displacement

In line with SNCB guidance (Joint SNCBs, 2017) predicted mortality is typically generated from displacement matrices, presenting the % of birds displaced on one axis and the % mortality on the other. The magnitude of displacement is increasingly evidence-based, largely as a consequence of evidence gathered during PCM. However, in stark contrast, the mortality value selected is invariably not informed by direct empirical evidence but by expert judgement. This therefore remains a glaring gap in understanding and a significant area of uncertainty in all impact assessments of population level impact in which mortality through displacement is an element.

Given that exploration of the individual fitness and population-level consequences associated with displacement has not previously been a part of PCM, but arguably should be, plans to conduct monitoring to address this issue should be discussed with Natural England at the earliest opportunity.

### 5.2.3 Useful sources of information

A Collaborative Offshore Wind Research into the Environment (COWRIE) funded project provided a review of DAS techniques and initial protocols with respect to technical issues and survey design and analysis (Thaxter & Burton, 2009). MMO (2014) noted that due to the developments in aerial survey methods that have taken place since the COWRIE review, further consideration of best practice in relation to use of these methods would be timely. That remains true today.

The joint SNCB interim displacement advice note (Joint SNCBs, 2017), and its update (Joint SNCBs, 2022), provide useful information on approaches to displacement impact assessment. Searle *et al.* (2018) is a useful reference regarding the development and application of the SeaBORD modelling tool[13] to assessment of displacement and barrier impacts (albeit based on seabird tracking data rather than DAS data).

Recent PCM reports in which DAS have been used in exploring displacement and distributional changes include reports for Lincs (HiDef & Bio Consult SH, 2017), Burbo Bank extension (HiDef, 2020) and London Array (APEM, 2021) offshore wind farms. Natural England does not necessarily fully endorse all the methodological details of the surveys or analyses employed in these studies or their conclusions.

Finally, the ORJIP research project on ‘Improving quantification of mortality rates associated with displacement within the assessment process’ (QuMR)[14] seeks to critically review the rates used to determine the mortality of birds displaced by offshore wind farms in the United Kingdom and is currently ongoing.

## 5.3 Collision mortality and avoidance behaviour

Offshore wind farms may present a risk of collision to seabirds and other migratory species which use the marine environment. This is a particular concern for species that do not avoid wind farms and spend time flying at altitudes swept by turbine blades. Birds may also be at greater risk when wind farms are located close to breeding colonies or where they intersect migratory flyways. Collision mortality may impact survival rates and, in the breeding season, could also influence productivity if chick rearing adults are killed.

Our current understanding of collision risk at offshore wind farms is largely based on theory rather than empirical data. Collision Risk Models (CRM) that are used to predict collision mortality associated with a project rely on the use of specific wind farm and bird parameters. However, there is considerable uncertainty associated with many of these parameters due to difficulties gathering empirical data on collisions and avoidance behaviour and the inherent spatial and temporal variability associated with different sites, seasons, and environmental conditions.

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[13] https://data.marine.gov.scot/dataset/finding-out-fate-displaced-birds

[14] [redacted].

## 5.3.1 Avoidance behaviour, collision monitoring and estimation of rates

Avoidance behaviour may be exhibited at different spatial scales depending on the sensitivity of a species or an individual. Birds may totally avoid an OWF (macro-avoidance), which has implications for displacement (see Section 5.2). Alternatively, they may enter a wind farm but avoid flying close to turbines (meso-avoidance) or avoid collisions through last second manoeuvres within close proximity to the rotor swept area (micro-avoidance). Together, these components comprise the overall avoidance response and determine the collision risk, though this is not directly comparable to the avoidance rates adopted in CRM which also incorporate potential sources of error in different parameters (Band, 2012).

An improved understanding of changes in flight characteristics and area use by collision sensitive species following the construction of an OWF could help improve the accuracy of assessments (e.g. by defining more appropriate CRM parameters that may better reflect risk when a wind farm is built) and inform future planning and OWF design (e.g. by identifying areas within arrays where birds are at greater risk of collision). Detailed data on the movements of individual birds within an OWF array can be collected using a variety of methods including GPS tracking, visual tracking studies, rangefinder 3D tracks, radar tracks and combined radar-camera systems. Ideally, such studies should have suitable pre-construction baseline data against which the post-construction data can be compared to clearly identify behavioural changes. However, where such data is unavailable, alternative methods can be employed to assess variations in behaviour by exploring variations in area use with distance to the array, individual turbines or rotor swept areas or comparing observed tracks against simulated tracks.

Studies relating to within-wind farm avoidance behaviour also closely link with the pressing requirement to quantify the numbers of birds that collide with, and are killed by, the fixed and moving parts of wind turbines within an array. This is a particularly important source of uncertainty in OWF impact assessments but is technically challenging to address. As a result, evidence of seabird collisions with offshore structures is currently very sparse and a limited number of studies have provided data on collisions and associated avoidance behaviour. This is largely because carcass collection methods, with associated corrections, developed and applied onshore (see Huso *et al*. 2017), are not applicable at-sea where carcasses do not remain in-situ and searches cannot be completed reliably. Thus, collisions must be measured directly through visual observations or the use of other appropriate sensor technologies.

In addition to detecting and quantifying the number of collisions, studies must also consider the flux (rate of passage of birds through the turbine array per hour) to enable the estimation of a collision rate. This demands the use of suitable, often concurrent, monitoring methods to directly quantify passage rates (e.g. through radar monitoring or vantage point surveys) or to estimate the densities of birds flying through the project area (e.g. from digital aerial surveys) which can then be translated to a flux. An understanding of collision rates is key to the estimation of avoidance rates and validation of CRM predictions.

### 5.3.1.1 Identifying monitoring objectives and testing hypotheses

Monitoring of avoidance behaviour should as a minimum seek to quantify three-dimensional space use by relevant collision sensitive species within the OWF area and a relevant buffer prior to and following construction. Where possible, consideration should be given to monitoring during construction to provide information on how behaviour might change in relation to degrees of site development.

Dedicated collision monitoring methods should ensure that collision rates are produced that are comparable with EIA and HRA assessment estimates. This will allow direct comparison with predictions presented within the ES and will allow the calculation of avoidance rates using a standardised approach.

Monitoring should be carefully planned and implemented to address specific questions. These questions may arise from uncertainty in project-level assessments for species deemed at high risk of significant impacts from collisions, or wider uncertainty relating to cumulative and in-combination impact estimates. Examples of potential monitoring goals could therefore include:

- validation of specific project-level collision mortality estimates;
- validation of avoidance rates applied within CRM;
- investigation of within, and between, project variability in species-specific avoidance behaviour and collision risk;
- investigation of the effects of environmental factors on collision risk (e.g. wind conditions and visibility); and
- investigation of other factors that could influence avoidance behaviour and collision risk (e.g. turbine density and lighting) and identification of potential mitigation measures.

Natural England should be consulted at the earliest opportunity to advise on the identification of objectives and hypotheses relating to avoidance behaviour and collision monitoring to be tested as part of PCM.

#### 5.3.1.2 Plan analyses of data

The analysis of behavioural data should provide either an understanding of changes in the relative use of an OWF and relevant buffer by relevant collision sensitive species prior to and after construction, or with distance to the array, individual turbines and their rotor swept area. Changes in the proportions of birds flying at different heights within an OWF, the proportions of birds entering the OWF footprint, and the time spent within the footprint prior to and after construction should be estimated as a minimum where pre-construction data has been collected. In all cases, the variation in the proportions of birds flying at different heights and distances relative to the rotor swept areas of the built OWF array should be estimated to allow investigation of potential changes in behaviour with the proximity to a potential risk.

This information can be used to underpin assessment of variability in potential within-wind farm avoidance response rates. Analyses should also consider information on the operational status of individual turbines and environmental conditions at the specific time of individual records. Behavioural state analyses could also be employed where suitable tracking data are collected to evaluate how the use of the OWF area has changed following construction (e.g. proportions of time spent foraging, resting or commuting in the area).

The analysis of collision data should, as a minimum, provide species- and turbine-specific collision rates and, where possible, a measure of associated variability over a defined period. This should be derived from observed numbers of collisions and a measure of local flux of the focal species. Depending on the monitoring objectives, and scope of the study, the analyses may then need to be expanded to investigate spatial and temporal variability in collision rates using appropriate parametric and non-parametric statistical tools.

Where more strategic studies are considered, across multiple projects, monitoring approaches should be proportionate to the size of the project but should ideally use the same methods to ensure data are compatible during analyses. Further model covariates could also be explored to examine the effects of project-specific factors on overall or mean collision rates. For example, the size of the array, size of the turbines, rotor tip clearance, distance between turbines, proximity to breeding colonies and variability in environmental conditions could be explored as potential drivers of variations in collision rates.

#### 5.3.1.3 Consider target species and seasonality

The target species of any investigation should be clearly defined and should reflect those species where significant impacts or uncertainty in assessments have been identified during EIA or HRA, as set out within the IPMP. Survey methods can then be tailored to these specific species. For example, large species (e.g. gannet) may accommodate larger telemetry packages incorporating more sensors. Large species may also be easily detected and identified using radar and camera systems. Smaller species may only accommodate limited telemetry packages, if at all, and the use of more sensitive radar, camera or impact detection tools may be required to ensure sufficient detection and identification rates.

Further, where species are known to spend some time in flight outside daylight hours the need for night-vision/low-light or thermal cameras may become a more important consideration. The appearance and ecology of the target species may also be important in determining the scope of additional data that is collected during monitoring. For example, some species of seabird may be easier to age than others or may have more readily identifiable behavioural traits which could provide further insights into the avoidance behaviour and occurrence of collisions. Where possible, studies should investigate potential variability in results between immatures and adults.

Whilst data collection methods should aim to provide specific information on target species, it is likely that broad-scale monitoring would also generate useful data (e.g. passage rates) on other species at risk of collision. Where information on non-target species is generated, these data should also be reported as standard, though any analysis is expected to be limited.

The timing of data collection should also be carefully considered in relation to the scope of the study. For example, where a target species is only present at a specific time of year (e.g. on migration or during breeding) monitoring should concentrate on this period alone. Where a species may be present throughout the year, but is more abundant during one period, consideration should be given to whether more effort should be focused on collecting data at that time, or when the species is less abundant and thus any effects could be more difficult to detect. This should also be balanced by the perceived importance of effects at different times of the year (e.g. collision impacts on breeding birds may also directly impact chick survival and colony productivity during the breeding season).

#### 5.3.1.4 Selection and application of monitoring methods

This is an area of technological development that is moving at pace. A range of monitoring techniques have been suggested and trialled for collision detection and investigation of avoidance behaviour. Desholm *et al.* (2006), Collier *et al.* (2011; 2012), Dirksen (2017) and Molis *et al.* (2019) provide useful reviews of some of the potential technologies that could be adopted to monitor collisions and associated avoidance rates. Most recently ORJIP has commissioned a project to fully review all systems available to monitor collisions at offshore wind farm sites (SBMon), and report on their suitability and application.[15] The report will be linked here when available.

Techniques often involve the use of bespoke camera or video packages (including thermal or night vision cameras for nocturnal monitoring) or multi-sensor bird detection systems employing auditory and impact or vibration sensors. Alternatively, surveyors equipped with binoculars, scopes, or rangefinders could be stationed on turbines to monitor collisions or tracking (GPS, visual or radar) data can be used to follow the path of birds through a wind farm and provide information on behavioural responses and potential collisions. However, each of these methods have limitations, whether associated with taxonomic identification, the physical limitations of the marine environment (e.g. weather conditions and salt corrosion), engineering and logistical limitations relating to installation on turbines, health and safety concerns (for staff on turbines) or costs (Collier *et al.* 2011). Careful consideration should be given to the selection of the most appropriate monitoring solution to adequately address the monitoring objectives.

#### 5.3.1.5 Determine effort and duration of the study required to ensure an adequate chance of quantifying avoidance behaviour or detecting collisions (or lack thereof)

An understanding of the monitoring effort required to detect species-specific collisions or to quantify avoidance behaviour is critical when designing a PCM study. A simple assessment of the potential population size, or flux, of the target species in the study area, derived from at-sea surveys at relevant times of year, could be used to help inform an analysis of sample size requirements to characterise behaviour for a given confidence level (e.g. 95%) and confidence interval (e.g. 5%). However, consideration should be given to the potential reductions in the use of the site following construction of the OWF. Alternatively, where tracking studies are planned, an analysis of simulated tracking data could be used to provide an indication of the numbers of individual birds and duration of tracking required to confidently describe the 95% area use by a population within a specific area (see Thaxter *et al.* 2017).

For collision monitoring, as a minimum requirement, the predicted numbers of collisions per annum for each focal species from the ES should be used to estimate how many collisions might be expected to be recorded per turbine, per annum. Power analyses can be used to determine the number of turbine and temporal coverage required to measure collisions with confidence. The ORJIP project ‘SBMon’ has a work package to conduct simulation-based power analysis to estimate sampling effort required to ground truth collision risk models, though this project will not provide definitive guidance but rather an evaluation of methods. The report will be linked here when available.

There is a further need to consider potential changes that might occur due to habituation which could result in an increased number of birds using a site (for example reef effects possibly leading to better foraging conditions and increased foraging behaviour which could lead to increased risk). Some studies should seek to monitor collisions at intervals over the lifetime of a wind farm to examine this.

#### 5.3.1.6 Estimation of avoidance rates used in collision risk modelling

Collision rate estimates should also be used in the calculation of avoidance rates, to which CRM is highly sensitive. Here, the difference between the CRM predicted numbers of

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[15] [redacted]

collision, in the absence of avoidance behaviour, and the observed numbers of collision can be used to calculate an avoidance rate (Cook *et al.* 2014):

$$Avoidance\ Rate = 1 - \left(\frac{Observed\ Collision\ Rate}{Collision\ Rate\ Predicted\ in\ Absence\ of\ Avoidance}\right)$$

The collision rate predicted in the absence of avoidance is a function of the flux rate (birds passing through the rotor swept area a wind farm over a given time period) and probability of a bird passing through the turbine swept area and colliding with a blade (probability of collision). Thus, where possible, the results of collision monitoring should be used to derive site and species-specific avoidance rates or should be used in combination with existing studies (SNCB Avoidance Rates review, pending) to add to the current evidence base. However, it should be noted that, without further correction, the resultant avoidance rates will be representative of within-wind farm avoidance and will not account for any macro-avoidance or attraction exhibited by a species. Thus, a detailed understanding of avoidance behaviour at different scales is also required to ensure this can be accounted for during assessments (see Section 5.3.2 below).

#### 5.3.1.7 Useful sources of information

The ORJIP bird collision avoidance study at Thanet Offshore Wind Farm (2014-2017) represents one of the most extensive studies investigating collision risk and avoidance behaviour to date (Skov *et al.* 2018). Here, a multi-sensor monitoring system was deployed that included the use of visual observers on two turbines using rangefinders (230 days), and a Thermal Animal Detection System (TADS) coupled with radar technology. Despite this effort, the study only recorded a total of six collisions between July 2014 and April 2016.

Within their review of monitoring systems and techniques for investigating bird collisions and avoidance behaviour, Molis *et al.* (2019) provide an overview of the development of the Multi Sensor wildlife detection system (MUSE) used at Thanet OWF for the ORJIP project. Molis *et al.* (2019) also provide recommendations for future studies and suggest, as a minimum, that one multisensory system should be installed in each corner of an array and in the centre of the wind farm. However, they note that ideally all wind turbines should be equipped with monitoring systems and multiple arrays should be monitored simultaneously.

A more recent study, at the Vattenfall European Offshore Wind Deployment Centre (EOWDC), Aberdeen, has also employed MUSE to track birds through the site (comprised of 11 wind turbines) to evaluate collision risk and avoidance behaviour for several key species. The study took place between 2020 and 2021 with the results still under analysis. An initial report (Vattenfall, 2021) provides an overview of the project and initial results, though no collisions have been reported to date. Natural England also notes that a further large-scale study, at Neart na Gaoithe Offshore Wind Farm, Scotland, will also look to examine collision risk and avoidance behaviour when commissioned, though the exact details of the study are not currently available.

There has also been a single example of the use of visual tracking to investigate collision risk and avoidance behaviour at an offshore wind farm which provides an example of an alternative approach during post-consent monitoring to validate collision risk modelling. Harwood *et al.* (2018a) tracked breeding Sandwich tern within a 4 km buffer around Sheringham Shoal Offshore Wind Farm (88 wind turbines) from a fast Rigid Inflatable Boat (RIB) before, during, and after construction between 2009 and 2015. Although no collisions were recorded, the study provided valuable insights into variations in avoidance behaviour.

## 5.3.2 Validation of additional CRM parameters

The predicted numbers of collisions estimated during CRM is sensitive to several parameters and assumptions used in the CRM process (Cook *et al.* 2014). Several key bird parameters can strongly influence the results: flight height, flight speed and nocturnal activity factor. Post-consent monitoring can improve our understanding of these parameters and validate those values used in CRM and so validate predicted impacts used to inform impact assessments.

### 5.3.2.1 Flight height distributions and flight speeds

Data on the height at which collision sensitive birds fly informs both direct collision risk assessments and may feed into generic flight height distributions, such as those described by Johnston *et al.* (2014). Data on flight height distributions can also be used to explore seasonal and spatial variability and potential changes in behaviour in response to the construction and operation of an OWF. Thaxter *et al.* (2015a) provided a review of methods that could be used for collecting flight height data. Flight speeds are also an important parameter in collision risk modelling. The Band model (Band, 2012), and subsequent stochastic iterations of the model, effectively use flight speed twice, once in the estimation of flux and again in the estimation of the probability of collision. Within PCM, the objectives of flight speed monitoring should be to provide confidence in the values adopted within CRM and an understanding of variability at relevant spatial and temporal scales. As with flight height monitoring, such information could improve our understanding of changes in behaviour and risk of collision associated with the construction of an OWF.

Flight heights were traditionally estimated by surveyors during boat-based surveys by placing observed birds in relatively coarse flight height categories, often simply related to the potential collision risk height associated with the rotor swept area of a specific turbine model. In some cases, flight heights were refined to smaller categories and the accuracy and precision of observers can be relatively good, though surveyors may end up biasing flight height distributions downwards (Harwood *et al.* 2018b). However, estimates remain subjective and boat surveys are still limited to daylight hours and by weather. Technological advancements have allowed for more precise estimates of flight heights. For example, handheld optical laser rangefinders have been used effectively from boats (Harwood *et al.* 2018b) and were employed during post-consent monitoring for Sheringham Shoal. Rangefinders were also used extensively during the ORJIP project at Thanet Offshore Wind Farm (Skov *et al.* 2018). Here they were used to provide both flight heights and speeds of birds from three-dimensional fixes. However, there may be potential biases associated with the use of rangefinders due to equipment limitations (e.g. range) and selection of particular birds by operators. Nevertheless, where boat-based surveys are employed for any bespoke studies, rangefinders should be used to collect flight height measurements as best-practice.

Radar may also be used to generate flight heights but generally requires some form of independent species identification (Hüppop *et al.* 2006). Telemetry is also increasingly being used to estimate the altitude of birds using either GPS where altitude is recorded directly, or by combining positional telemetry with altimeters (pressure sensors). GPS tags were used to collect flight height data for lesser black-backed gulls at Orford Ness, and GPS tags with altimeters have been used to investigate flight heights of gannets at Bass Rock (Cleasby *et al.* 2015). However, the precision and accuracy of flight heights will vary between different types of tag and consideration should be given to ensuring data are processed appropriately and the data produced will be fit-for-purpose (see Cleasby *et al.* 2015; Ross-Smith *et al.* 2016). Further, GPS tracking is likely to be limited to the breeding season, when birds are central-place foragers and tags can readily be retrieved. Indeed, our understanding of movement and flight behaviour in the non-breeding season is lacking because of these limitations and studies which can provide data outside of the breeding season are likely to be particularly useful. DAS providers have also explored photogrammetric methods for deriving flight heights of birds based on the relatively size of the bird and application of trigonometry and bespoke data processing algorithms.

More recently, the potential for ‘Light Detection and Ranging’ (LiDAR) to be used to collect data on flight height distributions and the proportion of birds at collision risk height has been investigated (Cook *et al.* 2018). This is a promising approach, with initial studies indicating a high degree of accuracy. One key consideration is the need for LiDAR to be accompanied by digital imagery to confirm the presence of a bird and identify it to species level, as well as how birds are then matched to flight heights. However, Natural England consider this to be a useful method which, if it could be deployed appropriately, would be able to produce a large database of observations that could potentially be used to derive a standardised set of flight height data. The use of LiDAR for collecting flight height data has been proposed as part of the OMP for Hornsea Project One, and Sofia OWF are employing this method during their pre-construction DAS.

Similar technologies and methods to those described for flight height monitoring can also be employed to estimate flight speeds of seabirds if a time and distance between positional fixes is produced. Thus, radar, GPS or visual tracking, rangefinders (where three-dimensional fixes are produced) and, assuming a single bird can accurately be assigned a position in more than one image or set of point laser returns, potentially photogrammetric or LiDAR techniques could be employed.

Considerations for the collection of flight height and speed data should focus on the accuracy and precision of different methods, representative sample size requirements to characterise individual or population level variability, and spatio-temporal coverage for relevant species. Technical challenges or limitations should also be considered such as whether an aircraft outfitted with LiDAR equipment can be flown at altitudes required to safely clear OWF whilst providing standard camera survey data at the same time. Where tracking methods are employed, the trade-off between numbers of birds tracked, duration of tracking and intervals between needs to be carefully considered. In relation to flight speeds, studies need to consider whether the time between fixes will adequately capture flight speeds during specific behaviours (e.g. foraging), where birds may circle at speed and not move large distances over ground. Moreover, variation in flight heights and speeds with different behavioural states should be investigated, and the time spent by individuals exhibiting those behaviours within the study area should also be quantified where possible. This will provide a better understanding of area utilisation and associated collision risk.

Analysis of flight height data should look to provide species-specific flight height distributions and an associated measure of variability. These can be produced by examining the frequency of observations at different heights or fitting distributions or models to the observation data, with bootstrapping providing a method for estimating coefficients of variation and confidence intervals. Similarly, flight speed data should produce a mean and associated measures of variance and precision. Such analyses can be carried out using pooled data, or data could be subset at different temporal and spatial scales to quantify potential variation over time. This would allow comparisons within and outside an OWF and potentially with distance from individual wind turbines to aid understanding of avoidance behaviour. Where tracking approaches are utilised, analyses should take into account the potential for auto-correlation between fixes (e.g. by examining auto-correlation functions) and, where necessary, data should be thinned appropriately and/or resampled to address potential issue that arise from records not being independent from each other.

### 5.3.2.2 Nocturnal Activity Factors

Nocturnal activity factors (see Garthe and Hüppop, 2004) are used in the calculation of flux within the Band CRM (Band, 2012), and subsequent stochastic iteration of the model. Thus, changes in the specification of this parameter could significantly impact collision estimates and it is important that we have confidence in the values, and variability, adopted. Whilst it is likely that environmental factors may have an effect on nocturnal activity (e.g. due to the amount of ambient light or length of days), it is unclear whether lighting of OWFs, and simple provision of offshore structures, could influence the nocturnal activity of collision sensitive species. Where nocturnal activity is monitored, environmental variables should be recorded at relevant spatial and temporal resolution and the potential effect of OWFs investigated where suitable before and after data is produced.

Studies aiming to quantify nocturnal activity need to be able to record species-specific bird movements across the entire diurnal cycle. It may be possible to quantify nocturnal activity using physical observations of birds at-sea by employing night vision or thermal imaging cameras when light levels preclude unaided observations. However, the ability to detect and identify birds using such technology at night may be severely restricted and provide data that may be highly biased. Nevertheless, remote collision monitoring system often employ some form of thermal or night vision camera to ensure coverage at night (e.g. Skov *et al.* 2018; Vattenfall, 2021) and, where species can be confidently identified, such information could be invaluable to our understanding of variation in collision risk and avoidance rates. Similarly, radar can be used to identify bird movements but could suffer from species identification issues at night unless other systems are employed (e.g. linked camera systems with thermal or night vision capabilities) at the same time.

Auditory monitoring methods could also be employed but are likely to be restricted in terms of spatial coverage, with birds needing to pass within detection distance of a receiver to produce a record. Again, it may be possible to deploy such systems on multiple OWF turbines to assess potential changes in detection rates at different times of day and night to provide data on nocturnal activity at specific OWFs.

Tracking data could provide the best understanding of individual variability in nocturnal activity and provide added value in that they could also provide data on flight height, flight speed and be results could be used to infer behavioural states. However, the use of GPS tags is likely to be limited to species that can carry tags without welfare issues and generally to the breeding season, when tags can be deployed and retrieved with relative ease at breeding colonies. Understanding potential seasonal variations in nocturnal activity is again important when parameterising CRM to provide confidence in the collision estimates. Thus, additional tracking studies that provide data for the non-breeding season may be of value. Smaller, lighter geolocator tags, that can have a longer battery life and be fitted with additional immersion/saltwater switch or depth sensors could be employed to help build up an understanding of the amount of time birds spend sitting and flying at night (e.g. Garthe *et al.* 2012). GPS tagging is also not guaranteed to provide data relating to specific OWFs and, when using such data, an assumption may be required that OWFs do not influence nocturnal activity of collision sensitive species. Furness *et al.* (2018) used data from various gannet tracking studies, at multiple colonies in different countries, to provide refined estimates of nocturnal activity during the breeding season and non-breeding season (fewer observations) and information derived from this has now been incorporated into the Phase III best practice advice (Parker *et al.* 2022c).

When planning nocturnal activity studies, care should be taken when defining day and night periods and concurrent ambient light levels should be recorded where possible to help understand potential variations and subtleties in behaviour. Sample size requirements should be estimated to ensure representative samples, at either the individual or population level, are likely to be achievable using the selected method and to ensure there is sufficient spatial and temporal coverage. Further, analyses should be planned to ensure appropriate measures of activity are clearly defined and can be detected with confidence.

## 5.4 Connectivity / apportioning

Often a key area of uncertainty in colony-specific impact assessments is the way in which an overall level of predicted mortality via e.g. displacement or collision arising from a given development should be attributed across more than one colony/population, from which affected birds may originate in one or more seasons. Consequently, post-consent monitoring of relative degrees of connectivity between a development area and various possible source populations at different times of year is a key consideration.

### 5.4.1 GPS tracking studies

Tracking studies using GPS tags provide empirical data on the proportion of birds within a particular development area that originate from each connected breeding colony. As with other types of studies, the specific details will vary with species, population and the objectives of the monitoring, and early engagement with Natural England will help to ensure the correct technology and methodology is used.

A few examples of the use of tracking to inform connectivity include the use of GPS tags to investigate foraging behaviour of Sandwich terns breeding on the North Norfolk Coast and their interaction with Dudgeon and other offshore wind farms in the area (Collier *et al.* 2019) and tracking of lesser black-backed gulls to assess connectivity with the Walney Extension and Burbo Bank Extension offshore wind farms during four breeding seasons. In addition, as part of a strategic monitoring programme for the Hornsea Zone to understand connectivity between the Hornsea Zone and Flamborough and Filey Coast (FFC) SPA, tracking will be undertaken for kittiwake and gannet.

#### 5.4.1.1 Identify the question to be answered / objective to meet / hypothesis to test with tracking surveys

Tracking can be used to address displacement/disturbance, energetic consequences/barrier effects and apportioning, but the data requirements to explore these differ.

Best practice requires that PCM is conducted to answer clearly identified questions, meet clear objectives and potentially test a clear hypothesis (which can be tested). It is crucial that clear objectives and hypotheses are set before a tracking study can be suitably designed.

#### 5.4.1.2 Type and number of individuals to be tracked

Given that the high-level monitoring objective of PCM is to validate predictions made within the EIA and/or HRA, and to measure the effectiveness of measures identified within these assessments to mitigate (and compensate) for significant effects, PCM will typically be targeted towards those species where impacts are predicted. However, the practical feasibility of capturing and placing tags on birds must also be considered, given that tags are typically placed on birds at their breeding colony, making tracking studies more feasible for certain species, such as gannet, kittiwake and other gulls, than for other species such as auks. Similarly, breeding adults and fledglings are more easily tagged and therefore tracked than immatures/juveniles and non-breeding birds which are likely not present at the breeding colony and would need to be captured at sea. Therefore, tracking studies, including those related to PCM, are generally targeted towards breeding birds. Subsequently, there remains a significant evidence gap relating to movement ecology of non-breeding and juvenile seabirds (Carneiro *et al.* 2020).

As applies to other types of studies, consideration should be given to the number of birds that need to be tagged and tracked in order to provide a representative sample, with an assessment made using either site-specific data or based on existing studies of the same or similar species. Thaxter *et al.* (2017) found a sample size of 24 birds was sufficient to characterise offshore area use of lesser black-backed gulls from Orford Ness and suggested that tracking fewer birds for longer was more important than tracking more birds for less time. However they also acknowledged that different populations of species may show different patterns in area use and the sample size required will depend on study-specific aspects and should be determine on an individual basis. Soames *et al.* (2013) investigated the number of shags and kittiwakes were needed to predict 95% of the area of active use and outlined a method that can be used to inform future studies to determine the number of devices needed to estimate area use of seabirds.

As with the number of birds tracked, how long they should be tracked for (both within and across years) will depend on the specific population and the hypothesised drivers of population change; if the aim is to compare pre-construction, construction and operational phases, it is likely that the tracking study will need to cover all these phases. Thaxter *et al.* (2015b; 2017) noted that the foraging behaviour of many seabird species can vary considerably across pre-breeding, breeding and post-breeding seasons and tracking of birds during only one of these phases may not sufficiently characterise the species' area use.

Thaxter *et al.* (2015b) investigated movements of lesser black-backed gulls from the Alde-Ore Special Protection Area prior to construction of (but after consent was granted for) Galloper OWF, in order to investigate interactions between this species and offshore wind farm areas. Subsequently, post-consent monitoring for Galloper OWF included GPS tracking of lesser black-backed gulls from this SPA, allowing for comparative analyses of the foraging trips, wind farm connectivity and area use before and after construction of the windfarm (Green *et al*., in prep).

#### 5.4.1.3 Origins of the individuals to be tracked / where they should be captured

The location(s) from which individuals should be tracked will depend on the question being asked. This may just be a single population predicted to be significantly impacted or it may require tracking of birds from more than one origin if: i) impacts are predicted on more than one population/colony, and/or ii) there is a need to reduce uncertainty about assumed apportionment values. If the breeding season is the primary period of interest, then it will be those colonies which are expected to have connectivity based on either generic or site-specific foraging ranges. If the non-breeding season is the primary period of interest, there will need to be consideration of factors that may determine what, if anything, is possible, such as the availability of suitable tag types, sample sizes needed and how many possible source populations.

#### 5.4.1.4 Determine the season(s) in which tracking is required

In general, breeding season studies are more practicable, since tags are typically fitted to birds when they are easily accessible at breeding colonies. Depending on the type of tag used, limitations on battery life may limit the period during which birds can be tracked. However, lower precision tags that require less power, such as geolocators, can be used to track seabirds throughout the year, providing data on movements during the non-breeding season. Even within a breeding season, foraging behaviour of seabirds can vary, in response to changes in local prey availability and the increasing nutritional needs of growing chicks. The season(s) during which birds should be tracked will depend on the species and the specific question(s) being asked, and early engagement with Natural England is advised in order to ensure tracking studies are designed to fulfil the specific monitoring objectives.

#### 5.4.1.5 Other considerations, including tag type

If tracking is being used to answer questions related to other parameters such as displacement or collision risk, tags that provide additional information related to behaviour such as avoidance, flight height and flight speeds, should be considered. These include tags with pressure sensors (altimeters) and accelerometers. Consideration must also be given to the spatial resolution of location fixes required in order to fulfil the specific objectives of the study. Since tags have a maximum allowable weight in proportion to the birds they are being placed on (<3%), there are limitations with what type of tag can be used with smaller species such as terns, however advancements in tagging technology mean that this is likely to change in the future. The suitability of alternative tracking devices given the objectives of the PCM should be discussed, and the most suitable type agreed, with SNCBs in advance of any tracking devices being purchased or deployed.

### 5.4.2 Other techniques relevant to connectivity / apportioning

Other techniques can be used to determine the origin of birds found at sea within or close to development areas. These include photography, catching birds at sea, analysis of stable isotopes, colour ringing data and dietary studies.

The use of photographic sampling from vessels of opportunity was proposed as part of the OMP for Dogger Bank A & B, whereby photographs of kittiwake, gannet, razorbill and guillemot at sea will provide data on age class and origin of individuals, with a comparison between birds at sea vs. FFC SPA, including the proportion of bridled vs. non-bridled guillemots, indicating the degree of connectivity between the two sites. This has been proposed alongside catching birds at sea to collect wing measurement data, which will be used to allocate kittiwakes to colonies at different latitudes, and primary feather samples for stable isotope analysis.

Lastly, diet studies (discussed further in Section 5.5.1) can also be used to identify foraging ranges and hotspots, and the degree of overlap with offshore wind areas.

## 5.5 Colony-based studies

One of the issues of greatest concern regarding predicted impacts of offshore wind farms is the impact that they may have on breeding seabird populations. While the effects may be manifest remote from the colony e.g. collision mortality events, increased energy expenditure and trip times because of displacement and/or barrier effects, many of the impacts are felt at the colony. Typically, consent decisions rest upon predicted levels of change to the survival and or productivity of the impacted population and so changes to its predicted future size with and without the proposed development. Consequently, colony-based studies can play an important role within PCM in establishing evidence of the changes that occur in species' ecology, key demographic rates and abundance and how those compare with predictions or assumptions within environmental statements.

### 5.5.1 Selection of colonies and monitoring requirements

Colony-based studies enable the measurement of impacts of a particular offshore wind farm on nearby seabird colonies, and thus validate the predictions of impacts to particular species made during the HRA and EIA. It also ensures compliance with the measures identified during these assessments to mitigate and/or compensate for any significant impacts. Lastly, there is the opportunity to identify any unforeseen impacts that were not taken into consideration during the impact assessment, but which can inform future developments.

The key demographic parameters monitored at a colony-level and required for EIA and HRA assessments are numbers (abundance), the number of births (breeding success or productivity) and the number of deaths (survival). Existing demographic monitoring studies of key species at FFC SPA include productivity monitoring, adult survival rates and whole-colony counts. Contribution to this monitoring has been proposed as part of the OMP for Hornsea Project Two, with a focus on gannet and kittiwake.

Other studies may involve looking at diet, behaviour (e.g. nest attendance) and the use of tracking technology to study seabird movements and foraging ranges (see Section 5.4.1). Diet studies, which are important in understanding the drivers of inter-annual variation in breeding success and/or changes in breeding numbers, are generally limited to the period when seabirds are breeding, since this is when they are accessible on or near land. Several methods are available and the most appropriate will depend on a number of factors including species, but include: analysis of stomach sampling/regurgitations, excrement and pellets, observations/photography at the colony and biochemical methods such as stable isotope analysis of feathers.

Dogger Bank C have proposed as part of their OMP to use two of these methods to provide further data on the diet of seabirds at FFC, by facilitating analyses of existing samples of regurgitates from kittiwakes, gannets and auks, and through the use of photography of prey carried by guillemots, razorbills and puffins.

# 6 Marine mammals

This section provides advice for monitoring programmes of marine mammals at the post-consent phase, covering both key considerations and specific advice. This chapter also provides advice on other considerations and legislative requirements relating to marine mammals for projects at the post-consent phase (Section 6.6).

## 6.1 Key considerations for post-consent monitoring of marine mammals

Section 4.2 provides high level principles for designing and implementing PCM for all receptors. However, the monitoring of marine mammals differs materially from monitoring of other receptor groups with more established monitoring methods (such as seabirds or seabed habitats). The advice provided within this section is specifically for PCM of marine mammals.

- **Clearly defined aims and hypotheses** – as outlined within Section 4.2, the aims of monitoring should be clearly defined at the start of discussions with Natural England (ideally pre-submission). These aims/principles should then be clearly set out in the IPMP, along with thought-out monitoring option(s) to address the aims and hypotheses. The aims and options in the IPMP should be used as a framework for detailed discussions at the post-consent phase (see Section 4.1). Monitoring of marine mammals at the post-consent phase should be targeted and hypothesis-driven in order to fill evidence gaps or validate predictions of the ES and produce information-rich data (Wilding *et al.* 2017). Monitoring for the sake of undertaking monitoring should be avoided (MMO, 2014).

- **Sufficient size and scope** – all marine mammal monitoring programmes should consider whether the planned monitoring is of sufficient size and scope and contain sufficient power to produce statistically-robust and meaningful data. Due to the challenges of monitoring marine mammals, monitoring projects should be carefully considered as to whether they can sufficiently answer monitoring hypotheses, address key evidence gaps or areas of uncertainty. Whilst some monitoring aims and hypotheses may be successfully addressed by a project alone, others may require collaboration across projects or participation in wider studies or research programmes (see below);

- **Early and continued engagement with Natural England** – engagement with Natural England, or relevant SNCB(s), is recommended at the earliest possible opportunity to agree the focus and detail of monitoring plans. Continued engagement is recommended as monitoring plans evolve. Natural England can provide project-specific advice on a case-by-case basis.

- **Novel approaches to marine mammal monitoring** – Natural England recognises the value and opportunities in trialling new technologies and supports the exploration of novel and emerging monitoring methods that can help to improve our understanding of the effects of offshore wind farm development and operation upon marine mammal receptors. For example, passive monitoring methods, such as Passive Acoustic Monitoring (PAM) stations, have the potential to provide new datasets for monitoring changes to marine mammal distributions or behaviour, and are increasingly deployed. Although there can be challenges presented by the relative novelty of some techniques in early stages, collaborative working can unlock many wider benefits if planned carefully; this necessitates early engagement to discuss flexibility and contingency in the approach.

- **Collaborative / strategic monitoring projects** – due to the nature of marine mammals it can be challenging for projects alone to collect statistically robust datasets, particularly in regard to marine mammal abundance and distribution. For example, project-specific DAS are unlikely to provide sufficient data for meaningful conclusions to be drawn regarding impacts to marine mammals at the reference population level.

  Whilst project-specific monitoring can provide useful and meaningful data on some aspects of uncertainty contained with applications, for other monitoring priorities and evidence gaps, projects should consider whether the aims of monitoring are best delivered by working collaboratively across projects within relevant zones or regions, or through participation in strategic monitoring projects. Collaborative / strategic monitoring can help to deliver monitoring projects of sufficient scale and scope to deliver the aims of monitoring, test hypotheses and address areas of uncertainty (see Section 4.4). An excellent example of collaborative marine mammal monitoring by the East Anglia Zone projects is provided within Section 6.3.1.

  Natural England strongly supports collaborative approaches to marine monitoring and can provide advice on a case-by-case basis. Early engagement with Natural England, or other relevant SNCB, is recommended if projects are considering participating in collaborative or strategic-level monitoring projects. If a collaborative or strategic project is being considered, then it may be advisable to have a steering/working group to ensure co-ordination, like the Regional Advisory Groups in Scottish waters.

## 6.2 Underwater noise

Underwater noise is one of the key pressures to marine mammals during offshore wind development and has the potential to cause behavioural impacts, such as disturbance and displacement, as well as physiological impacts including loss of hearing, injury or death (Weilgart, 2007; Erbe, 2012). The extent and magnitude of the impact from underwater noise is based upon the level of underwater noise predicted, as informed by underwater noise modelling.

Monitoring programmes should therefore seek to validate predictions made in the ES, such as the predicted levels of underwater noise produced by piling activities during construction or during the operational phase. However, other monitoring objectives, such as understanding the effect of underwater noise upon the distribution or behaviour of marine mammals, may be best undertaken through collaborative approaches (see Section 6.3.1).

### 6.2.1 Validation of predicted underwater noise levels from piling

Underwater noise modelling is an important component of offshore wind farm DCO applications where piling, or part-piling, is required in the marine environment. Modelling is used to provide quantitative predictions of underwater noise propagation in order to predict impact ranges and behavioural effects upon marine mammals. Therefore, the predicted noise levels produced by piling, as set out within the ES, are an important parameter which should be validated by monitoring during construction.

Best practice for offshore wind projects undertaking piling activities is to monitor underwater noise levels at various distances from the noise source, following the National Physical Laboratory (NPL) Good Practice Guidance Note no. 133 (Robinson *et al.* 2014).[16] This monitoring is typically undertaken for the first four installed piles to allow for a report to be provided to the MMO to highlight if measured noise levels exceed those predicted within the ES.

Natural England advise that measuring noise levels for piles across the most representative substrates of a project area would provide useful and meaningful data for how noise levels change across substrate types. For example, whether noise levels generated by piling is greater in coarser or more consolidated sediment types. This could be undertaken in addition to the monitoring of the first four piles, as these first four piles are not necessarily representative of the worst-case in terms of underwater noise levels (or environmental factors which may influence noise levels e.g. depth, sediment type). Understanding of the influence of sediment type on noise emissions could help to refine the predictive noise modelling in ESs. There can be a mismatch between the locations modelled in the ES, and the locations monitored, which limits understanding of how accurate the modelled predictions are.

Currently, this data is submitted to the MMO but may not be shared or made publicly available. Natural England recommends that this information from all projects is hosted in a single central location, such as the Marine Noise Registry (MNR), and used to improve knowledge of underwater noise impacts generated by piling and to inform future applications. Sharing of underwater noise monitoring data (and associated metadata on data collection and subsequent modelling) also allows for independent third-party evaluation. This follows the recommendations as set out within MMO (2014) which states that data should be presented or made available to allow third party, independent evaluation. An example of a registry that has achieved this is MarinEARS for German waters.[17]

### 6.2.2 Validation of underwater noise generated by operational turbines

Offshore wind turbines generate continuous underwater noise during their operation and so contribute to elevated noise levels in and around the wind farm through the development's lifecycle. Whilst the noise produced by operational turbines is predicted to be low level in ESs, it is audible in terms of frequency and sound level to marine mammals. As marine mammals use sound for foraging, navigation and communication, there is potential for underwater noise generated at the operational phase to affect marine mammal behaviour by impairing hearing or masking communication between individuals (Erbe *et al.* 2016).

There are gaps in the data on operational noise levels from turbines representative of those being built at present. Specifically, with regards to fixed-bottom turbines, the existing operational noise monitoring data are limited in terms of number of locations, the size of the turbines, and the water depths installed. In current ESs, significant extrapolation is being undertaken from this limited evidence base to 'scale up' potential impact zones to the increasing size of wind turbine generators proposed for current OWF projects. It is acknowledged that the shift from using gear boxes to direct drive technology is expected to reduce the sound level during operation (Stöber & Thomsen, 2021). Nevertheless, Natural England advises that monitoring of the operational noise of fixed-bottom wind turbines is required in order to validate this, and other assumptions made in the underwater noise modelling for ESs for OWFs.

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[16] [redacted]

[redacted]

There is also a paucity of data on the operational noise sources, nature (impulsive and/or continuous) and levels of floating offshore wind turbines. Whilst this industry is in an emerging phase, it is particularly important to undertake valuable post-consent monitoring, in order to add to the evidence base and pave the way for future projects, for which our understanding of underwater noise levels is less well understood.

Monitoring of underwater noise levels generated by wind turbines during the operational phase can be undertaken using hydrophones. Monitoring of this type can be undertaken by individual projects to validate predictions within the ES by recording noise levels before and after construction, following the NPL guidelines (Robinson *et al.* 2014).

## 6.3 Validating predictions of changes in the behaviour of marine mammals

Offshore wind construction, operation, maintenance and decommissioning activities have the potential to affect the behaviour of marine mammals through disturbance. Behavioural changes can lead to monitorable effects, such as changes in spatial distribution or proportion of time spent in different behavioural states, e.g. feeding or resting. (Bailey *et al.* 2014).

Such changes may affect marine mammal foraging success and lead to increased stress levels and reduced fecundity. They could also affect reproductive success, if animals are displaced from key areas for reproduction e.g. breeding, calving or nursing areas or undergo a reduction in these key behaviours. The consequences of changes to behaviour are poorly understood, and therefore may be investigated through post-consent monitoring (Thompson *et al.* 2010; Forney *et al.* 2017).

For fixed offshore windfarms, ESs routinely predict that the construction phase will have the greatest impact to marine mammals. Accordingly, uncertainties in the assessment of construction impacts have typically been the focus of PCM for marine mammals, and so they are the focus of this section. However, the option to address uncertainties of impacts during other phases should not be discounted e.g. operational noise, impacts to seal haul outs at cable landfall, or changes to prey distribution due to presence of structures.

### 6.3.1 Validation of predicted displacement of cetaceans and distribution changes as a result of construction activities

Marine construction activities, such as piling and presence of construction and maintenance vessels, may result in displacement effects and changes to the distribution of cetaceans within and adjacent to the project area (Todd *et al.* 2020; Benhemma-Le Gall *et al.,* 2021). Predicting the potential impact of this is a key component of project DCO applications and therefore may be subject to post-consent monitoring.

It is acknowledged that there are challenges to designing a project to monitor changes to cetacean distributions as a result of offshore wind development on a project-specific basis. However, it is possible to design research projects of sufficient size and scope to provide meaningful and statistically robust results by working collaboratively across developments or in conjunction with academia.

Natural England’s experience is that project-specific DAS or boat-based surveys are unlikely to provide sufficient data for meaningful conclusions to be drawn regarding impacts to cetaceans (or seals) at the reference population level. Typically, marine mammals are seen in too few numbers, and/or with too high spatial and/or temporal variability, to be able to detect any changes in the impact areas. This is an example of where power analysis would be required to determine the likelihood of detecting a change using the proposed survey design.

PAM methods, such as F/C-PODs, can provide meaningful marine mammal vocalisation data to improve our understanding of the distribution of cetaceans and their response to offshore wind activities, address uncertainties and fill evidence gaps (Dähne *et al.* 2013; Nuuttila *et al.* 2013; Robbins *et al.* 2016; Todd *et al.* 2020). PAM can also be used to determine changes in presence or rate of feeding behaviour through monitoring of acoustic patterns associated with feeding behaviour, such as inter-click intervals, for example as undertaken by Benhemma-Le Gall *et al.* (2021). However, it is vital that PAM stations are deployed over sufficient spatial and temporal scales, as evidenced by Thompson *et al.* (2010), and summarised below.

Thompson *et al.* (2010) provides an example of investigating the response of cetaceans to the construction of two turbines in Scottish waters. This project used T-PODs (an early version of C- and F-PODs) to monitor cetacean vocalisations at the turbine location and an adjacent control site over multiple years, following the Before-After-Control-Impact (BACI) monitoring sampling approach. The project demonstrated the effectiveness of using passive acoustic techniques to monitor marine mammal distributions and provided some useful insights. However, due to dolphins being recorded at low abundances, the datasets lacked the statistical power required to draw meaningful conclusions. Therefore, Thompson *et al.* (2010) highlights the need for monitoring projects to be designed with sufficient scale and scope to deliver data of sufficient power for further analysis, especially given the inherent challenges involved in surveying marine mammals. This recommendation is supported by Natural England.

Thompson *et al.* (2010) provides a useful list of recommendations for future monitoring which should be considered if planning a study addressing changes to marine mammal distribution as a result of offshore wind development. Recommendations include considering other anthropogenic noise sources in order to determine an effective baseline against which to measure offshore wind impacts alone. Recommendations are also made to combine acoustic monitoring techniques with other methods and the suggested use of a gradient-based BAG sampling design, instead of a BACI-style approach, which avoids having to predetermine the location of impact and control sites at the large and uncertain spatial scales of impact (Thompson *et al.* 2010).

An excellent example of a collaborative marine mammal monitoring programme in English waters is the approach taken by Scottish Power Renewables (SPR) for projects within the East Anglia Hub (EAH) offshore wind zone.[18]

The programme is using C/F-POD[19] hydrophones to passively monitor marine mammal vocalisations underwater in order to investigate the broad-scale spatial-temporal variability and distribution of harbour porpoise across the East Anglia region as a result of construction and operational activities from multiple offshore wind farms. The project includes multiple static PAM stations per project phase and will seek to estimate dose-response function(s) to validate/refine predictions of the magnitude and extent of porpoise responses to construction activities and associated noise sources, such as to Acoustic Deterrent Devices (ADDs).

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[18] The East Anglia Hub (EAH) consists of East Anglia ONE North, East Anglia TWO and East Anglia THREE offshore wind farms. See [redacted]

It is hoped that working collaboratively across the East Anglia projects, the programme should facilitate the collection of datasets of sufficient scale and scope to provide statistically robust data, with sufficient power, to allow for meaningful conclusions to be drawn.

The EAH monitoring programme is an excellent example of collaboration for marine mammal monitoring. Natural England fully supports monitoring programmes that take a similar approach of working collaboratively across individual projects and would welcome the opportunity to discuss collaborative monitoring projects further with any developer.

Note that cetaceans are currently not subject to tagging projects in UK waters as the process is extremely difficult and there are concerns regarding animal welfare, public perception and logistics.

### 6.3.2 Validation of predicted displacement of seals and distributional changes

Seal movements and changes to their distribution and behaviour as a result of offshore wind development can be investigated using tagging or telemetry monitoring methods. Seal tag data can be used to address many different uncertainties and evidence gaps for understanding the effect of offshore wind development and operation on seal populations.

Seal tagging or telemetry data can be used to investigate the effect of offshore wind construction and operation upon seal distributions, including displacement or attraction effects. Tagging data can identify fleeing behaviour of seals as a response to underwater noise, which can help validate predictions of how many individuals will experience auditory injury as a result of construction activities (Thompson *et al.* 2013; Hastie *et al.* 2015). Seal tag data can also be used to monitor other changes in behaviour, for example, changes in behavioural state within the zone of effect from impact sources, which can be scaled up to inform overall changes in energy budgets included in population modelling.

Although not a direct requirement of PCM, an additional advantage of this kind of data collection is that it can be utilised by multiple projects, not just those relating to a monitoring plan, thus increasing the value of the data. For example, seal tagging data can be used to monitor movements and foraging behaviour at-sea and from haul-out locations. These data can then be used to produce at-sea distribution maps, which in turn can be used to determine abundance estimates within specified areas to inform future ecological assessments (Sharples *et al.* 2012; Russell *et al.* 2017; Carter *et al.* 2020).

Monitoring programmes seeking to tag seals will require a licence from the Animals in Science Regulation Unit (ASRU), which is a component of the Home Office, under the Animals (Scientific Procedures) Act, 1986.[20] Guidance for applying for a ASRU licence is provided within the following link: https://www.gov.uk/guidance/research-and-testing-using-animals.

There are several UK organisations that have experience of tagging of seals, including the Sea Mammal Research Unit (SMRU)[21] and Zoological Society London (ZSL)[22]. It is recommended that any projects interested in tagging seals as part of their monitoring programme seek advice from (and potentially collaborate with) one of these organisations to understand the feasibility and usefulness of any proposed projects.

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[20] https://www.gov.uk/guidance/research-and-testing-using-animals

[redacted]

Tagging projects have provided useful information on the movement of seals in the North Sea, Irish Sea and around Scotland (e.g. Carter *et al.* 2020). It is noted however that, for some areas, the tagging data available is quite dated and could benefit from new tagging efforts. There are also areas which are comparatively poor in terms tagging effort and data, such as southwest England, which is utilised by designated grey seal populations from Lundy Island, and the Isles of Scilly.

The Crown Estate announced a new floating wind leasing round which will be located in the English and Welsh waters of the Celtic Sea.[23] Therefore, future project monitoring plans may choose to investigate the movement and distribution of seals in the southwest of England and Wales to address evidence gaps and validate predictions made within ESs.

## 6.4 Impact pathways associated with floating offshore wind

The design of floating offshore wind farms differs materially from fixed offshore wind farms in various ways, such as the use of chains or tethers to attach turbines to the seabed or the use of free-floating ‘dynamic’ cables. Accordingly, some of the environmental considerations and impact pathways for floating wind also differ (Jonkman & Matha, 2011; Maxwell *et al.* 2022).

Given the lack of evidence currently available to support impact assessments for floating wind farms, a key evidence priority for PCM would be to understand the impact of floating offshore wind construction, operation, maintenance and decommissioning activities upon marine mammal receptors, to validate predictions made within the ES. Better understanding of the key differences in environmental effects between fixed and floating wind infrastructure would address evidence gaps and areas of uncertainty, and benefit future developments.

As floating wind is an emerging sector in English waters, it is vital that appropriate and robust monitoring is put in place at this early stage, to allow for the development of the evidence base to support the continued growth of this sector. It is acknowledged that priorities for monitoring are likely to evolve as knowledge of ecological impacts produced by floating offshore wind farms improves and more data are collected. This document will be periodically updated to reflect current uncertainties and evidence gaps.

### 6.4.1 Impact pathways relating to underwater noise

In addition to the sources of underwater noise discussed in Section 6.2, another potential source of underwater noise specific to floating offshore wind turbines is the impulsive ‘snapping’ noise detected by monitoring at the Hywind DEMO site during the operational phase (Martin *et al.* 2011). This operational noise source is thought to be generated by cables and turbine tethers ‘snapping’ in underwater currents. However, there are limited data on this operational underwater noise from other projects and the subsequent impacts to marine mammals are yet to be quantified or fully understood (Martin *et al.* 2011; Burns *et al.* 2022). Floating offshore wind farms may therefore seek to quantify this effect and validate predictions through PCM programmes until a sufficient evidence base has been collected.

There is a current OWEAP-funded evidence project, led by the Centre for Environment, Fisheries and Aquaculture Science (Cefas), which seeks to assess underwater noise risk impacts of floating offshore wind turbines upon marine receptors, including marine mammals. The outputs of this project will be incorporated into this document when available.

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[23] [redacted]

### 6.4.2 Novel pathways relating to dynamic cables

A key difference in the design of floating offshore wind farms, rather than fixed, is the use of 'dynamic' cables which are suspended in the water column. These can include the inter-array and export cables as well as the tethers which anchor the turbines to the seabed.

The use of free-floating dynamic export cables raises questions over the potential for impacts to marine mammals due to electromagnetic field (EMF) effects (Maxwell *et al.* 2022). EMF is generally screened out for fixed turbines because the cables are buried within sediment, which greatly reduces the EMF that marine mammals may be exposed to. However, dynamic cables introduce EMF into the water column, increasing exposure and therefore the potential for impact (Hutchinson *et al.* 2020; Maxwell *et al.* 2022). Therefore, PCM may be required to validate assumptions/predictions made in the ES until a sufficient evidence base has been collected.

Free-floating export cables, along with anchor chains or tethers, pose another new potential impact pathway to marine mammals through primary or secondary entanglement. Primary entanglement would comprise animals that are entangled in the export cables or the anchor chains and tethers that secure the turbines. Secondary entanglement would comprise marine mammal entanglement in other materials, such as fishing gear or marine litter, that has become entangled on floating offshore wind infrastructure (Maxwell *et al.* 2022). The extent and magnitude of impacts are thought to be low but are currently unknown. It may be possible to collect data on entanglement risk (or lack of) through routine offshore wind farm monitoring during the operational phase, which could then be used to address this evidence gap and validate predictions of the ES. If this impact is proposed to be monitored through routine monitoring, then information on the specifics of the monitoring (e.g. method, frequency) should be included in the ES. If the routine monitoring is deemed insufficient, then specific post-consent monitoring of this risk may be required to build a sufficient evidence base on this potential impact pathway.

Natural England can provide site-specific, bespoke advice on the design of post-consent monitoring plans to address key evidence gaps for floating offshore wind farms on a case-by-case basis.

## 6.5 Validating the effectiveness of mitigation measures

As well as validating impacts and effects upon marine mammals as a result of offshore wind farm construction and operation, post-consent monitoring can also be used to evaluate the effectiveness of mitigation measures, validate predictions made regarding them within project ESs and inform on their future use, thereby addressing key evidence gaps.

Mitigation for marine mammals during piling construction may comprise:

- A pre-piling search for marine mammals, visually using Marine Mammal Observers (MMObs) and/or acoustically using PAM;
- Deployment and activation of an ADD for a pre-determined period of time;
- Soft start and ramp up of piling hammer energies and strike rate before reaching operational levels; and
- Use of noise abatement systems (NAS).

PCM could be targeted towards validating the effectiveness of any of these measures in reducing the risk of impact to marine mammals.

Any monitoring undertaken to validate the effectiveness of mitigation measures should be outlined in the Monitoring Plan. It is Natural England's view that searches undertaken under the MMMP do not comprise PCM unless sufficient justification is provided on how they will address assumptions in the ES. The purpose of the MMMP is outlined in Section 6.6.1.

### 6.5.1 Effectiveness of ADDs

Acoustic deterrent devices (ADDs) are used to displace marine mammals from an area prior to the commencement of noisy activities, such as impact piling, to mitigate for any potential risk of injury or mortality.

ADDs emit loud underwater noise and have been shown to displace seals, low frequency and high frequency cetaceans from the impact ranges within which instantaneous injury or mortality may occur. They are activated for a defined period of time (often <1 hour) before the noisy activity, such as piling, commences. This allows individuals to leave the impact area before auditory injuries, such as Permanent Threshold Shift (PTS), or direct mortality can occur (Dähne *et al.* 2017; Thompson *et al.* 2020; Todd *et al.* 2021).

All ADD use should be recorded by the mitigation team. In addition, the team should record any detections of marine mammals in the mitigation zone during ADD deployment, including the behaviour of any individuals. This is standard reporting undertaken as part of the MMMP and is not typically presented as PCM.

Due to the methodology of ADDs, their use intrinsically results in the disturbance and direct displacement of marine mammals, which could result in negative effects, albeit presumed to be of a lesser magnitude of the impact if no mitigation is deployed (Dähne *et al.* 2017; Brandt *et al.* 2018). However, there are suggestions that ADD use may result in effects over a greater radius than piling activities alone (Dähne *et al.* 2017). Therefore, the sound levels produced by ADDs should be verified to optimise their use to ensure they are effective whilst also minimising disturbance (Thompson *et al.* 2020).

Sparling *et al.* (2015) provides a review of the use of ADDs to mitigate for pile driving at offshore wind farms. This report, along with recent reports on ADD usage and effectiveness (e.g. Marine Scotland, 2021; McGarry *et al.* 2020) highlight current uncertainties and evidence gaps in our understanding of ADDs and their effects upon marine mammals.

Additional monitoring to validate mitigation measures may be required depending on the assumptions of the ES, for example through tag data or observational data. As part of this, PAM could be used to monitor actual noise levels emitted by ADDs at varying distances from the source, following NPL guidance (Robinson *et al.* 2014), in order to better understand and predict noise transmission, and correlate received noise levels with observed behavioural responses in marine mammals.

The monitoring of ADD effectiveness and different deployment setups could help to validate predictions made in project ESs and address key uncertainties in the MMMP. Monitoring programmes of this nature could be undertaken by individual projects. However, monitoring programmes must be carefully designed to ensure they will provide meaningful data. Natural England can provide bespoke, project-specific advice for projects considering monitoring projects relating to the use of ADDs as a mitigation measure.

### 6.5.2 Effectiveness of noise abatement systems

Another way in which impacts from underwater noise can be mitigated is through noise abatement systems (NAS), which reduce the level of sound released into the water column. There are several different types of NAS (as reviewed by Verfuss *et al.* 2019). Although NAS have not yet been used in English waters to mitigate piling noise, certain types (namely bubble curtains) have been used for UXO disposal and, more widely, NAS has been used for OWF in European waters. Developers in UK waters are increasingly including NAS as a potential method to reduce underwater noise. Given the lack of usage of NAS thus far, there are data gaps on these systems and their efficacy in UK waters, which should be addressed through monitoring.

Bubble curtains are a mitigation measure that can be deployed, in certain environmental conditions, to reduce the propagation of underwater noise. Bubble curtains work by releasing a stream of air bubbles around the noise source which acts as an absorbing barrier to the emitted sound, thereby reducing the noise levels at-source. This reduction in the noise level at-source can reduce the received levels to marine mammals at distance from the source.

Whilst overall sound level reductions are beneficial, it is also important to consider the specific frequencies over which a reduction in sound is predicted. This should be considered in the context of both the peak frequencies of the sound source, and the hearing sensitivity of the key marine mammal receptors in the area. Bubble curtains have been shown to be effective at higher frequencies (1-10 kHz; Verfuss *et al.,* 2019), reducing the probability of an impact to marine mammals sensitive to this frequency range e.g. harbour porpoise.

The use of bubble curtains has been shown to reduce the likelihood of behavioural changes that would lead to displacement effects and effective habitat loss for harbour porpoise (Lucke *et al.* 2011; Dähne *et al.* 2017). However, there are limitations to the water depths in which bubble curtains have been shown to be effective, and current speed can hamper hose deployment.

If bubble curtains, or other NAS, are proposed as a mitigation measure within a project application and associated draft Marine Mammal Mitigation Plan (see Section 6.6.1), an estimate of the reduction of source sound levels and subsequent sound levels at varying distances from the noise source will be provided in the ES. These should be verified through PCM. The effectiveness of NAS to reduce source sound levels can be difficult to quantify and will vary depending on a number of factors. For example, with regards to bubble curtains, this may include the bubble size, bubble rising speed and environmental conditions, such as depth or current strength (Rustemeier *et al.* 2012; Lippert *et al.* 2013). For piling, the pile size and type and proposed hammer energy are important considerations when determining the likely level of noise reduction, whilst for UXO clearance programmes, key factors include the UXO size and disposal method. Attenuation will also be influenced by environmental conditions and how the NAS affects the characteristics of the sound e.g. the frequency spectrum.

Post-consent monitoring programmes should seek to address uncertainties and validate the predicted reduction in underwater noise levels achieved by bubble curtain or other NAS deployment during the construction phase. This can be achieved by using PAM to record actual noise levels at set distances and depths from the noise source. Monitored noise levels from abated activities could be compared to unabated activities, e.g. those predicted using industry-standard methods such as the Soloway and Dahl (2014) semi-empirical equation (for UXO) or piling models. There may be value in undertaking unabated activities for the purposes of gathering monitoring data for comparison to those collected from abated activities, to answer the question of how much reduction in noise is offered by the NAS.

However, Natural England advise that monitoring of underwater noise without NAS applied should only occur in low-risk areas, such as outside of designated site boundaries, and should be agreed with Natural England and MMO on a case-by-case basis.

Acoustic monitoring projects should monitor noise levels at near- and far-field distances from the noise source and follow the relevant NPL guidance (Robinson *et al.* 2014).

Furthermore, monitoring of marine mammal responses to noise impacts, both with and without NAS, could provide vital data to evaluate the success of the mitigation measure and demonstrate anticipated reduction in impacts (e.g. displacement) over varying distances. This would help to validate key predictions within the ES and address evidence gaps in our understanding.

## 6.6 Other considerations at the post-consent phase

There are additional requirements, beyond monitoring, that are required for marine mammals at the post-consent phase. These are addressed below.

### 6.6.1 Marine mammal mitigation plans

A Marine Mammal Mitigation Plan[24] (MMMP) is required for activities that may result in injurious or lethal effects in marine mammals. The MMMP details the mitigation measures that are required to reduce the risk of injury or lethal effects to negligible levels.

Thus far, MMMPs have been produced for activities related to offshore wind that may cause injury or lethal effects from underwater noise. Specifically, MMMPs are likely to be required for piling and UXO works. It is anticipated that MMMPs will also be required for decommissioning OWFs, but these can be produced closer to the time of decommissioning when specific activities and methods are better understood (see Section 9). The need for additional MMMPs to cover other activities should be determined on a case-by-case basis.

A draft MMMP is submitted at the application stage to inform ecological assessments of residual impact significance at examination. Draft MMMPs should provide enough information to demonstrate the potential impact can be mitigated sufficiently, with the finer details agreed at the post-consent phase. It is noted that the draft MMMP may cover both UXO clearance and piling activity, although the final MMMPs should comprise separate documents. MMMPs are agreed and finalised with the regulator (MMO), in consultation with the appropriate SNCB(s), at the post-consent phase prior to construction activities beginning.

The MMMP should comprise a ‘one-stop shop’ that clearly defines all the proposed marine mammal mitigation measures that will be implemented during the proposed activity, details of communication channels between the mitigation team and vessel crew, and all monitoring requirements. As a minimum, the mitigation measures in the MMMP must follow the JNCC mitigation guidelines for geophysical surveys[25], impact piling[26] and explosive[27] use, where relevant, and also any updates on best practice from the SNCBs that have been published or identified through consultation.

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[24] Also known as Marine Mammal Mitigation Protocols.

[25] https://hub.jncc.gov.uk/assets/e2a46de5-43d4-43f0-b296-c62134397ce4

[26] https://hub.jncc.gov.uk/assets/31662b6a-19ed-4918-9fab-8fbcff752046

[27] https://hub.jncc.gov.uk/assets/24cc180d-4030-49dd-8977-a04ebe0d7aca

Mitigation zones should be informed by the project-specific underwater noise modelling with minimum zones for certain activities outlined by JNCC's mitigation guidelines.[28]

The predicted impact range of PTS in marine mammal hearing from piling and UXO noise sources should be used to determine the appropriate duration of ADD activation. ADDs should be activated for sufficient time to deter marine mammals from the full extent of the PTS zone, taking into account the species-specific fleeing speeds (McGarry *et al.* 2020). Early engagement with the regulator and SNCB is recommended when considering PTS metrics, impact ranges and ADD duration.

Though the aim of the mitigation measures is not to reduce disturbance, there may be measures included in the MMMP which also reduce disturbance, such as the deployment of NAS.

Guidance on suitable marine mammal mitigation measures is provided by the JNCC at the following link: https://jncc.gov.uk/our-work/marine-mammals-and-noise-mitigation/

#### 6.6.1.1 Information required to inform a MMMP

Where a MMMP is required, the following information should be submitted as a matter of best practice:

- Description of the project and the Maximum Design Scenario (MDS), outlining the worst-case scenario for each activity. For example, this may include the number and size of piles and proposed hammer energy, or the number and size of UXOs required for clearance;
- Relevant results from the project's underwater noise modelling, in relation to anticipated impact zones;
- Clearly defined Marine Mammal Mitigation Zone (MMMZ), supported by justification and evidence;
- Clear description and methodology for all mitigation measures that will be implemented, including the protocol for night-time works;
- Roles for Marine Mammal Observers (MMObs) and PAM operators, and a description of the PAM equipment to be used with evidence that it can detect focal species;
- Predicted effectiveness of applied mitigation measures and a description of the expected significance of residual effects once mitigation measures are applied;
- Description of how the relevant licence conditions will be met by the MMMP; and
- Procedure for reporting and a clearly defined communication protocol is also required.

### 6.6.2 Marine Mammal Site Integrity Plans

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[28] https://jncc.gov.uk/our-work/marine-mammals-and-noise-mitigation/

#### 6.6.2.1 The SIP process

Site Integrity Plans (SIPs) are a tool to support the HRA. The production of a SIP is required if a development cannot exclude the potential for an Adverse Effect on Integrity (AEoI) upon an SAC in-combination with other plans or projects, at the Examination phase. The uncertainty over excluding AEoI typically arises due to the uncertainties in project specifics such as pile type, hammer profile, and piling schedule, in addition to uncertainty over these parameters in other projects.

SIPs are a mechanism for revisiting the in-combination assessment in the HRA post-consent, prior to the commencement of the noisy activity prior to it commencing to ensure no AEoI to designated features of a SAC from in-combination impacts. SIPs are commonly used to assess activities that produce underwater noise that may result in significant disturbance to SACs designated for harbour porpoise.

The SIP needs to take into consideration all other sectors and activities that could contribute to underwater noise disturbance, such as UXO clearance, piling, oil and gas exploration and geophysical surveys.

When compiling a SIP for the harbour porpoise SACs, a project should refer to the SNCB guidance on assessing significant noise disturbance in harbour porpoise SACs (JNCC *et al.* 2020).[29] This document details the thresholds and assessment method for determining the potential for an AEoI due to significant disturbance.

A draft SIP should be submitted at the examination stage to the regulator (MMO) for approval, in consultation with the relevant SNCB, to provide confidence that the development activities will not result in AEoI of the relevant harbour porpoise SAC(s) in-combination with other plans or projects. Multiple SIPs from different developments and the scheduling of noisy activities must be effectively managed by the regulator to ensure no AEoI of the SAC in question.

#### 6.6.2.2 Advice on compiling SIPs for harbour porpoise SACs in English waters

There are two SACs designated for harbour porpoise in English waters, the Southern North Sea SAC and Bristol Channel Approaches SAC. These sites share Conservation Objectives including the objective that there is ‘no significant disturbance of the species.’[30]

Natural England, JNCC and DAERA[31] have provided joint advice for assessing and preventing significance of noise disturbance against the conservation objectives of harbour porpoise SACs (JNCC *et al.,* 2020).[32] The advice provided within this document should be followed as a matter of best practice when assessing noise disturbance to harbour porpoise SACs.

The guidance advises that ‘noise disturbance within an SAC from a plan/project, individually or in combination, is considered to be significant if it excludes harbour porpoises from more than:

1. 20% of the relevant area of the site in any given day, or
2. an average of 10% of the relevant area of the site over a season.’

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[29] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/889842/SACNoiseGuidanceJune2020.pdf

[30] Conservation Objectives for the Southern North Sea SAC can be found at the following link: https://jncc.gov.uk/our-work/southern-north-sea-mpa/#conservation-advice

[31] Department for Agriculture, Environment and Rural Affairs (Northern Ireland)

[32] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/889842/SACNoiseGuidanceJune2020.pdf

Due to the level of activity in the vicinity of the Southern North SAC, there is a very real possibility that these thresholds could be exceeded thereby causing an adverse effect on the integrity of the designated site. Therefore, mitigation measures are required to ensure that underwater noise from projects in-combination does not result in these thresholds being exceeded. The SIP can be used to secure mitigation measures that will ensure the avoidance of AEoI on harbour porpoise SACs. This can be used alongside specific conditions on Marine Licences e.g. regarding engagement between developers and industries.

Projects should use the assessment method set out in JNCC *et al.* (2020) to determine the potential for their project in-combination with other plans and projects to exceed the thresholds. We acknowledge that many projects may have undertaken their own project-specific modelling to determine potential impact ranges. However, for the purpose of the SIP, there is a need to have a standardised impact range that can be applied to each type of impulsive noisy activity. Accordingly, the SNCBs have set out a series of Effective Deterrent Ranges (EDRs) in the joint SNCB guidance note on assessing the significance of noise disturbance to SACs designated for harbour porpoise (JNCC *et al.* 2020). These EDRs should be applied to all projects included in the SIP. Advice on the use of EDRs is presented in the guidance document.

For unmitigated driving of monopiles and UXO clearance, the EDR is 26 km. This means that any development undertaking these activities within 26 km of a SAC designated for harbour porpoise has the potential to contribute to underwater noise disturbance of the site. The requirement for an individual development to have SIP will depend on whether the project, in-combination with other plans and projects also occurring within or adjacent to the SIP, has the potential to contribute to significant noise disturbance and so an AEoI on the site.

The Crown Estate announced the intention for a new floating wind leasing round of up to 4 GW in the Celtic Sea, situated in English and Welsh waters.[33] The British Energy Security Strategy has now increased the ambition to up to 5 GW of floating wind by 2030.[34] As the Bristol Channel Approaches SAC is in the new floating wind lease area, SIPs may be required for offshore wind projects in the Celtic Sea to assess the potential for AEoI on the Bristol Channel Approaches SAC in-combination and ensure appropriate management measures are put in place.

The requirement for a SIP will be assessed on a project-specific basis but it is unlikely that it will be needed if a project's impact zone does not overlap a SAC designated for harbour porpoise.

Early engagement with Natural England and the regulator (MMO) is recommended for projects that may result in disturbance to SACs designated for harbour porpoise.

#### 6.6.2.3 Information required for a SIP

The final SIP should be produced no earlier than nine months and no later than six months prior to the noisy activity commencing, as at this stage the final project design details and other project parameters should be known, plus that of other projects that may act in-combination.

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[33] [redacted]

[34] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

In order for a SIP to be agreed by the regulator, the following information is required:

- Clearly stated activities the SIP is applicable for;
- Description of the project and the MDS, setting out the worst-case scenario, for each activity;
- Figure showing the project activities and where other noisy activities will occur in relation to the SAC in question, with relevant distances and percentage overlap with the relevant seasonal portion of the SAC;
- Spatial and temporal worst-case scenario considered in the HRA for the project in-combination with other projects expected to affect the same SAC;
- Clearly stated mitigation measures that will be implemented (with reference to the MMMP); and
- Residual impacts, across relevant spatial and temporal scales of the project in-combination with other plans or projects, once mitigation has been applied.

An effective SIP should provide the regulator (MMO), in consultation with the relevant SNCBs, with confidence that an AEoI on the site will not occur by a development, in-combination with other projects, once the appropriate mitigation measures are applied.

### 6.6.3 European Protected Species application

European Protected Species (EPS) are protected under the 'Conservation of Habitats and Species Regulations 2017' and the 'Conservation of Offshore Marine Habitats and Species Regulations 2017', collectively known as the Habitat Regulations.[35] [36]

All cetaceans (whales, dolphins and porpoise) are listed in Annex IV(a) of the Habitats Directive and are therefore EPS.[37] Note that non-cetacean marine species are also listed in Annex IV(a), including leatherback turtle, loggerhead turtle, Kemp's Ridley turtle, green turtle and Atlantic sturgeon. Although these species are not discussed further within this section, these species are subject to the same EPS regulations and the advice provided within this section remains applicable.

It is an offence under the legislation to capture, kill, disturb, or injure any individual of an EPS throughout their natural range.[38] JNCC, Countryside Council for Wales (now Natural Resources Wales (NRW)) and Natural England have published guidance on assessing the potential for an offence to EPS to occur.[39] Projects should follow the advice provided within this guidance document as a matter of best practice when determining whether a licence is required to undertake an activity i.e. if the activity is likely to result in an offence to EPS under the legislation.

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[35] The Conservation of Offshore Marine Habitats and Species Regulations 2017 are applicable in offshore waters between 12 to 200 NM.

[36] https://www.gov.uk/government/publications/protected-marine-species/cetaceans-dolphins-porpoises-and-whales

[37] https://www.gov.uk/government/publications/list-of-annex-iv-a-species

[38] https://www.gov.uk/government/publications/european-protected-species-apply-for-a-mitigation-licence

[39] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/850708/Draft_Guidance_on_the_Protection_of_Marine_European_Protected_Species_from_Injurt_and_Disturbance.pdf
NB: The criteria used to predict auditory injury to marine mammals referred to in this document (Southall *et al.* 2007) have since been updated and thresholds presented in Southall *et al*. (2019) should be used instead.

In order for an EPS licence to be granted, applications must pass the three tests as set out by the Habitats Regulations.[40] These are outlined below:

1. The licence application must relate to one of the certain purposes referred to in the legislation;
2. There must be no satisfactory alternative; and
3. The action authorised must not be detrimental to the maintenance of the population of the species concerned at a favourable conservation status in their natural range.

## 6.6.4 Marine licence for UXO clearance

Unexploded ordnance are distributed on the seabed throughout English waters, particularly within the North Sea, and can range in size and weight from 100 g up to over 700 kg (OSC, 2021). The disposal of UXOs can produce significant underwater noise, which has the potential to disturb, injure or kill marine mammals and other fauna (e.g. fish) within a certain impact radius (Robinson *et al.* 2020). The scale of potential impacts of clearing UXOs will depend upon the disposal method, the size of the UXO and its location.

Pre-construction surveys are required to identify possible UXOs within the wind farm array and export cable corridor for clearance. However, it is likely that all projects will need to undertake UXO clearance campaigns prior to construction commencing due to health and safety concerns and to protect infrastructure. UXO clearance works require a marine licence from the MMO.[41]

Natural England advise that the UXO clearance activities should not be included in the list of activities on the dML/DCO for an offshore wind farm. A marine licence for UXO activity should be applied for during the post-consent phase when more information about the number and size of UXOs needing to be cleared is available from the pre-construction surveys.

A detailed impact assessment and mitigation plan should be submitted as part of any licence application (Joint interim Government position statement, 2021). Marine licence applications for UXO clearance will require an EPS licence and MMMP, and may also require a SIP to be produced to support the application.

Early engagement with the relevant regulator and Natural England (or other relevant SNCB) is recommended when considering the clearance of UXOs.

### 6.6.4.1 Monitoring of UXO clearances

Monitoring of UXO clearance campaigns may be required to validate predictions of the marine licence application and key areas of uncertainty regarding effects upon marine mammals.

As stated by the joint interim Government position statement[42], applications should provide a robust environmental monitoring plan to validate the predictions made within the application and to inform future use. Monitoring should take place whether the clearance procedure is

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[40] https://www.legislation.gov.uk/uksi/2017/1012/regulation/44/made

[41] https://www.gov.uk/guidance/make-a-marine-licence-application

[42] https://www.gov.uk/government/publications/marine-environment-unexploded-ordnance-clearance-joint-interim-position-statement

via high order detonation or a low noise alternative (Joint interim Government position statement, 2021).

The monitoring plan should primarily focus on the underwater noise generated by UXO disposal, in line with the National Physical Laboratory noise monitoring protocol (NPL, 2020)[43]. However, monitoring of other parameters may also be required, e.g. surveying of UXO crater sizes and depths if seabed impacts are a concern (see Section 7.3.1).

#### 6.6.4.2 Information required to inform a UXO disposal application

UXO disposal Marine Licence Applications (MLAs) are submitted to the regulator (MMO) for approval, in consultation with the relevant SNCB, and must provide sufficient information to inform ecological assessment and to determine whether a marine licence can be granted.

This section should be read in conjunction with Sections 7.3.1 and 8.5.1 which provide advice on information requirements to inform UXO disposal applications for benthic receptors and fish respectively.

As a minimum, UXO disposal applications should include the following:

- Project description and MDS outlining the worst-case scenario for assessment. A ‘realistic worst-case scenario’ can also be presented for context;
- Expected number of UXOs for clearance;
- UXO location and size;
- Proposed clearance method(s), including options other than detonation;
- Timings for clearance. If UXO clearance is proposed to be undertaken in stages, e.g. inshore and offshore, or array and export cable corridor, this should be clearly stated;
- Estimation of underwater noise levels generated by UXO clearance, supported by strong evidence, justification and/or modelling;
- Mitigation measures required to mitigate for impacts to marine mammals.[44] This may take the form of a MMMP;
- Presence of sensitive species and supporting habitats;
- Overlap with MPAs designated for marine mammals;
- Assessment of significance of impact to each marine mammal receptor, supported by robust justification (EIA). Ecological assessments should provide an assessment of significance of residual impact after mitigation measures have been applied; and
- If within an SAC, a Report to Inform Appropriate Assessment (RIAA) should be submitted to provide information to inform ecological assessments of significance upon designated SAC marine mammal populations (HRA). Sufficient information should be provided to determine whether the project is likely to have an adverse

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[43] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/955204/NPL_2020_-_Protocol_for_In-Situ_Underwater_Measurement_of_Explosive_Ordnance_Disposal_for_UXO.pdf

[44] See: https://hub.jncc.gov.uk/assets/24cc180d-4030-49dd-8977-a04ebe0d7aca

effect on the integrity of an SAC alone or in-combination with other plans and projects.

In addition, MLAs also may require the following supporting documents:

- SIP for SACs (Section 6.6.2); and
- EPS licence application (Section 6.6.3).

Early engagement with the relevant regulator and SNCB is recommended when considering the clearance of UXOs, especially if novel approaches are proposed.

# 7 Seabed habitats and species

Seabed habitats and species, also known as benthic receptors, can be affected by the construction, operation & maintenance, and decommissioning of an offshore wind farm and associated infrastructure. Benthic receptors can constitute marine habitats and biotopes, infaunal and epifaunal species and communities and designated features of the MPA network.

Monitoring at the post-consent phase can be used to test hypotheses, fill evidence gaps and detect and evaluate changes to the marine environment caused by offshore wind farm development. This can include targeted monitoring to validate the predicted impacts and the recovery of receptors, as set out within the application, and to inform on the requirement for subsequent remedial measures. Impact validation monitoring is required if a project is expected to affect designated MPA feature to validate predictions of whether an adverse effect will occur or not and the magnitude of any impact. The results of benthic monitoring may also detect unforeseen impacts and wider ecosystem changes, which could then be investigated through adaptive monitoring (see Section 4.3).

It is crucial that monitoring programmes are well-designed to ensure collected data has sufficient power and is statistically robust to allow meaningful conclusions to be drawn (Noble-James *et al.* 2018). Monitoring should be targeted and not undertaken for the sake of monitoring.

Applicants agree a Benthic Monitoring Plan (BMP) with the MMO and the relevant SNCB(s) (Natural England in English waters) after projects have obtained consent. IPMPs provide the broad framework for discussing and agreeing BMPs (see Section 4.1), with finer details, such as the number and location of samples, agreed at the post-consent phase.

This section provides key considerations for the design and implementation of benthic PCM plans, and also considers monitoring of intertidal habitats and species which could be affected at the cable landfall.

Early engagement is recommended for projects considering the production of BMPs.

## 7.1 Key considerations for benthic post-consent monitoring

This section outlines key considerations for the design and implementation of benthic monitoring plans at the post-consent phase. This builds upon Section 4.2 which provides recommendations and advice for PCM of all ecological receptors.

Key considerations for PCM of benthic receptors:

- **Clearly defined aims and hypotheses** – as outlined within Section 4.2, the aim of benthic monitoring should be clearly defined at the start of discussions to agree the BMP. Benthic monitoring at the post-consent phase should be targeted and hypothesis-driven in order to produce information-rich data, fill evidence gaps, validate predictions of the ES including predicted effects upon designated features and to trigger additional management measures (if required) to achieve an appropriate level of recovery (Wilding *et al.* 2017). The IPMP should be used as a starting point and framework for benthic monitoring at the post-consent phase (see Section 4.1). Refer to Section 7.1.1.1 for more information on defining the aims of benthic monitoring plans.

- **Designated sites and protected features** – offshore wind development has the potential to affect protected sites designated for marine and intertidal features, namely SACs, MCZs and SSSIs.[45] Some habitats and species are also afforded protection through other means, such as those listed under Schedule 5 of the Wildlife & Countryside Act[46] or OSPAR-designated species and habitats.[47] Monitoring within protected sites is required if a project is expected to affect an MPA or designated feature. Monitoring should seek to validate the predicted effects upon a designated feature to determine if an adverse effect occurs and may also monitor the subsequent recovery of designated features over a defined timeline in order to inform the requirement for remedial measures.

- **Use of historical and existing datasets** – some areas may have been sampled previously and have existing datasets available which could supplement site-specific monitoring surveys. However, the validity and suitability of existing datasets must be carefully considered if used beyond providing a historical context for subsequent monitoring data (Noble-James *et al.* 2018). Parker *et al.* (2022a) provides advice and principles for the use of existing data to inform baseline characterisation surveys, but the advice provided is also applicable for considering the use of existing datasets to inform post-consent monitoring.

- **Sampling design and the selection of appropriate ecological indicators** – the design of benthic sampling should be carefully considered in light of the aim and objectives of monitoring and the specific hypotheses or research questions the monitoring is seeking to address. The optimal approach will be highly dependent upon the questions that monitoring is seeking to answer. Indicators and metrics should be used to measure change and reach meaningful conclusions regarding the state of marine environments or the significance of effects. The selection of the most appropriate indicators is essential to ensure that the data collected is suitable and will answer the specific monitoring hypotheses (Noble-James *et al.* 2018). Refer to Section 7.1.1 for more information.

- **Sufficient samples and replicate for robust statistical analysis –** the number of samples required is another key consideration that should be agreed in consultation with the relevant SNCB(s). The required number of samples should be carefully considered to ensure sufficient power and statistical significance in subsequent analyses to allow for meaningful conclusions to be drawn. The variability of benthic habitats will influence the number of samples required, with a greater number required to understand variable heterogenous environments than homogeneous areas (Ware & Kenny, 2011; Noble-James *et al.* 2018). Sampling-induced variability will be lowered by increasing the sample size (Lindeboom *et al.* 2015). Replicate samples may be required at each sampling station. Further information on the number of samples and the requirement for replicates is provided within Section 7.1.1.6.

- **Seasonal and temporal variations –** the temporal and seasonal variation of the target ecosystem, habitat or focal species for a survey should be carefully considered when designing a BMP. Many marine species exhibit seasonal variations in

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[45] Natural England advise that Marine Licence exemptions should not be granted for surveys occurring within designated site boundaries. Surveys within SSSIs require consent from Natural England. See: https://www.gov.uk/government/publications/request-permission-for-works-or-an-activity-on-an-sssi

[46] https://www.legislation.gov.uk/ukpga/1981/69/schedule/5

[redacted] [redacted]

abundance and biomass due to reproductive patterns and ephemeral cycles that can affect the results of surveys and should be acknowledged when analysing data. This includes macroalgae and seagrasses, which are best surveyed in the summer months where foliage growth is at its greatest, and some epifaunal communities such as bryozoans and hydroids which exhibit seasonal cycles due to epifaunal die-back over winter (Noble-James *et al.* 2018). Other species, such as the polychaete *Sabellaria spinulosa,* are highly ephemeral and will naturally change with the seasons. The timing of benthic surveys is an important consideration which should be taken into account when planning monitoring programmes. The timing of monitoring surveys should be consistent across monitoring years to ensure that data are comparable and to allow for robust statistical analysis (MMO, 2014). Any seasonal effects or limitations in the data should be fully explored within subsequent reports.

- **Timescales for monitoring –** monitoring requires repeat sampling to detect change over time in one or more indicators. The appropriate timescales for monitoring programmes will be highly dependent upon the question monitoring is seeking to address, the project, expected impacts and the effected receptors. As a result, benthic monitoring plans may consist of a range of different timescales depending on the specific question monitoring is seeking to address. For example, impact validation may focus on the immediate impacts of construction whilst other monitoring may seek to investigate longer term or lasting changes to the benthic environment as a result of offshore wind development or operation. Some effects to the wider seabed may not be detectable for several years after construction, so it is important than benthic monitoring is of a sufficient timescale to capture long-term impacts, such as changes in the composition of biological communities (Lindeboom *et al.* 2015; MMO, 2014). Monitoring the recovery of benthic habitats or features in order to validate predictions made in the ES may require monitoring during the post-construction phase until the pre-defined level of expected recovery or monitoring objectives have been achieved and agreed with the relevant regulator(s) and SNCB(s). Post consent monitoring can also be used to determine the requirement for and success of remedial measures.

- **Marine monitoring and data analysis protocols and standards –** there are numerous protocols and standards for benthic monitoring methods and data processing that should be followed as a matter of best practice. These include the protocols set out by the National Marine Biological Analytical Quality Control (NMBAQC) scheme, such as Mason (2016) for particle size analysis and Worsfold *et al.* (2010) for processing macrobenthic invertebrate samples. Recommended Operating Guidelines for marine monitoring methods are provided by Mapping European Seabed Habitats (MESH). Geophysical surveys should adhere to the International Hydrographic Organisation (IHO) standards for hydrographic surveys (S45 and S57).[48] Species should be recorded using the WoRMS list of accepted scientific names.[49] Biotopes should be recorded using the EUNIS classification system (EEA, 2019). Guidelines for the handling of benthic survey data are provided by MEDIN.[50]

  Further advice is provided on the use of benthic monitoring standards and protocols within Parker *et al.* (2022a). It is recommended that the advice provided within this document is followed as a matter of best practice.

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[48] [redacted]

[redacted]

- **Novel approaches to benthic sampling** – Natural England recognises the role of developers in trialling new technologies and supports the exploration of novel and emerging monitoring methods that can help to improve our understanding of the marine environment. For example, eDNA and meta-barcoding methods have the potential to provide new data for monitoring infaunal sediment communities obtained through grab or core samples (Tang *et al.* 2018). The exploration of novel and emerging monitoring methods is welcomed but early engagement with Natural England is recommended if novel approaches are considered.

- **Collaborative monitoring** – as highlighted within Section 4.4, Natural England strongly supports collaborative approaches to marine monitoring and can provide advice on a case-by-case basis. Projects should consider whether benthic monitoring objectives are best delivered collaboratively across projects, zones or regions, or through participation in strategic monitoring projects. By working collaboratively, benthic monitoring projects can be of a greater scope and scale (both in space and time) to produce statistically robust and information-rich data over sufficient spatial and temporal scales to draw meaningful conclusions and address key evidence gaps (Wilding *et al.* 2017). Collaborative monitoring approaches can also help detect in-combination and cumulative effects, changes to wider benthic communities or lasting effects caused by offshore wind development.

Natural England can provide bespoke advice on the production of benthic monitoring plans on a case-by-case basis.

## 7.1.1 Design of benthic monitoring plans

This section provides advice on the specific considerations for benthic post-consent monitoring. Early engagement with Natural England is recommended at the post-consent phase to enable the effective design of BMPs.

### 7.1.1.1 Monitoring aims and hypotheses

As stated within Section 7.1, it is crucial that the aims for post-consent benthic monitoring and the specific hypotheses that will be tested are clearly defined. Monitoring plans should avoid vague aims or hypotheses so that meaningful data can be collected (MMO, 2014). This is important to ensure that monitoring addresses specific evidence gaps or areas of uncertainty in order to draw meaningful conclusions and to avoid monitoring programmes that produce monitoring reports that are data-rich but information-poor (Wilding *et al.* 2017).

The IPMP should provide the broad aims of benthic post-consent monitoring, based on the key topics and areas of uncertainty discussed during the examination stage, which should form the basis for further discussions (see Section 4.1).

Protected sites and species/habitats of conservation importance may be focal receptors for post-consent monitoring if a project may affect a designated site feature. However, this is highly project specific, so early engagement with Natural England is recommended to discuss benthic monitoring proposals.

Draft BMPs should clearly define specific and testable hypotheses. Hypothesis testing is a method of statistical inference which allows for the comparison of datasets, e.g. sampling results from pre- and post-construction.

Where hypothesis-driven monitoring is undertaken, monitoring plans should clearly define the hypothesis ($H_1$), which states that there is a statistical relationship between the two datasets, and the null hypothesis ($H_0$) which states that there is no relationship between the datasets (Noble-James *et al.* 2018). Hypotheses should be biologically justified and relevant. Caution is advised when considering null hypotheses as ‘no evidence of an impact’ should not be interpreted as ‘evidence of no impact’ (Wilding *et al.* 2017).

Projects should consider the specific monitoring aims and confidence in the predicted direction of change to determine whether a directional or non-directional hypothesis is the most appropriate approach. Additional information on the selection of hypotheses is provided by Noble-James *et al.* (2018) and the advice provided within this document should be followed as a matter of best practice.

#### 7.1.1.2 Indicators and metrics

Indicators and metrics are the ecological parameters or units that will be measured to understand changes to the marine environment. Selecting the most appropriate indicators is an important step when designing benthic monitoring plans and the choice of metric will determine the methodology, spatio-temporal scales and the required confidence in subsequent assessments (Wilding *et al.* 2017). Metrics must be assessed at the spatial and temporal scales that are relevant to the question monitoring is seeking to address and effort should be made to select metrics of change that can be linked to ecosystem function or service provision (Wilding *et al.* 2017).

Indicators may relate to the state of the marine environment, such as community composition, structure and function of habitats, species richness and diversity multivariate indices or nutrient levels, or indicators of specific and measurable pressures, such as the levels of contaminants within sediments (OSPAR, 2012; Noble-James *et al.* 2018).

Marine ecosystems are highly complex, and the selection of indicators should be carefully considered, particularly for indicators which reflect environmental conditions. An inappropriate indicator may not reflect the true environmental condition or the effects of offshore wind development, which may then impair the success of monitoring programmes and prevent meaningful conclusions from being drawn (Noble-James *et al.* 2018). In addition, it can be challenging to select indicators that are independent of each other due to the complexity of the marine environment. Dependence within or between sampling units should be minimised wherever possible to enable robust statistical analysis (Noble-James *et al.* 2018).

Indicators should be selected in a logical and objective way to ensure that monitoring programmes will achieve the monitoring aims (Noble-James *et al.* 2018). Early engagement with Natural England is recommended to ensure that the most appropriate indicators are selected.

Projects should consider whether relevant ecosystem-scale data can be collected using multivariate indicators (Wilding *et al.* 2017). This can include indicators such as Margalef’s species richness, Pielou’s evenness, Simpson’s and Shannon-Wiener indices for diversity or taxonomic distinctiveness (Noble-James *et al.* 2018). Software packages are available for statistical analysis of multivariate indices, such as PRIMER[51] (Noble-James *et al.* 2018).

#### 7.1.1.3 Methods for benthic monitoring

There are many methods for monitoring the marine environment and benthic receptors. These include physical sampling, such as core, grab and trawl sampling, underwater

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[51] [redacted]

imagery, remote sensing, acoustic methods (e.g. side-scan sonar or multibeam echosounder) and novel approaches, such as DNA metabarcoding (Cefas 2002; Rees *et al.* 2009; Tang *et al.* 2018). For monitoring close to infrastructure, it may be appropriate for surveys to be undertaken by divers or by using Remotely Operated Vessels (ROVs) (e.g. Coates *et al.* 2011).

The most appropriate method will be highly dependent upon the specific monitoring aims and specific hypotheses the monitoring is seeking to test, the selected indicators or metrics that will be measured and the ecological receptor in question. Judd (2012) provides advice on the selection of monitoring methods for benthic studies.

Parker *et al.* (2022a) provides advice on the use of various marine survey methods for baseline characterisation surveys, including intertidal walk-over and core sampling, remote sensing, subtidal grabs, underwater imagery and epifaunal trawls. The advice provided within this document is applicable for benthic monitoring and should be followed as a matter of best practice.

#### 7.1.1.4 Sampling and survey design

The design of benthic monitoring plans is important to ensure robust data will be collected that addresses the aims of monitoring and test the defined hypotheses using the selected indicators. The approaches used will also be informed by the methods and results of baseline characterisation surveys (Noble-James *et al.* 2018).

Probabilistic sampling designs should be used where possible as they typically have reduced systematic error and are more statistically rigorous (Noble-James *et al.* 2018). Probabilistic sampling designs include systematic grid sampling, stratified random sampling and random sampling, all of which have benefits and limitations. These are explored further within Ware & Kenny (2011), Noble-James *et al.* (2018) and NRW (2019b). Transects can also be used to investigate changes to indicators across pressure or environmental gradients (Coates *et al.* 2014; Lindeboom *et al.* 2015).

The optimal approach will be highly dependent upon the questions that monitoring is seeking to answer, the selected survey methods and environmental indicators. The level of variation of receptors and heterogeneity of receptors will also influence the sampling design, with stratified designs more suitable in highly variable environments. The level of statistical power needed to quantify the likelihood that an impact of a given effect can be detected should be carefully considered (Lindeboom *et al.* 2015). Statistical power can be increased through additional sampling stations as well as additional replicates at each station.

Noble-James *et al.* (2018) provides thorough advice on the design of benthic monitoring programmes which should be followed as a matter of best practice. In addition, Parker *et al.* (2022a) provides advice on the use of different marine monitoring methods and associated standards and protocols.

Natural England can also provide project-specific bespoke advice on the selection of an appropriate survey design to ensure that robust data is collected that will address the aims of monitoring and test the selected hypotheses.

##### 7.1.1.4.1 Before-After-Control Impact monitoring

BACI monitoring is an approach that is commonly used for benthic monitoring at the post-consent phase. This approach monitors an ‘impact’ site and a ‘reference/control’ site before and after the impact occurs, in order to determine whether an effect has occurred at the ‘impact’ site as a result of the works (such as offshore wind farm construction activities) whilst allowing for the detection of natural change and variability. Due to the long construction times of offshore wind projects, it may also be appropriate to monitor during the construction phase.

The approach can be improved by also monitoring a ‘secondary impact’ site which is outside of the main area of impact but in a location where far-field effects may be observed, e.g. sediment plumes.

Suitable control sites should (adapted from Noble-James *et al.* 2018):

- be in relatively close proximity to the impact site, but not directly adjacent so that it is subject to ‘overspill’ or edge effects;
- located in areas with high data confidence, particularly in relation to the selected indicators or metrics;
- have comparable biotic and abiotic environmental conditions to those of the impact site; and
- have comparable levels of the same pressures faced by the ‘impact’ site, so that the difference between the control and impact sites may be detected using an appropriate indicator.

The BACI style approach is limited in some situations due to the assumption that control sites and impact sites are identical, apart from the impact of offshore wind development. The marine environment is highly complex and confounding variables may arise due to the differences between control and impact sites over spatial and temporal scales, despite best efforts to identify suitable locations and reduce variability (Noble-James *et al.* 2018; Methratta, 2020). This can limit the ability of BACI approaches to determine specific cause-effect relationships, especially within areas of high natural variability (Methratta, 2020).

However, BACI approaches are suitable in many cases, especially in relation to effects with limited spatial and temporal extent (Methratta, 2020). In addition, sampling-induced variability can be reduced by increasing the sample size (Lindeboom *et al.* 2015). The robustness of the BACI-approach can be further improved, and the effect of confounding variables minimised, by undertaking repeated sampling of the control and impact sites as close to simultaneously as possible. Additionally, selecting multiple control and/or impact sites further improves the validity of collected datasets and enables robust statistical analysis (Noble-James *et al.* 2018). Whilst the chosen survey design approach will depend on the monitoring aims, indicators and receptors in question, it is advised that the additional improvements are followed where possible if a BACI approach is used.

#### 7.1.1.4.2 Before-After-Gradient monitoring

An alternative to the BACI approach is Before-After-Gradient (BAG) monitoring. This approach involves sampling along a gradient with increasing distance from turbines, both within and outside of the wind farm boundary, before and after the impact occurs (Ellis & Schneider, 1997; Methratta, 2020).

The BAG approach does not require the identification of suitable control sites and allows for the detection of effects across a spatial scale. The BAG approach also allows distance to be accounted for as an independent variable for statistical analysis (Methratta, 2020). The BAG approach overcomes some of the limitations of BACI approaches and the appropriateness of BAG monitoring should be considered for benthic monitoring plans.

#### 7.1.1.5 Sample locations

The required spatial extent of samples should be considered in light of the specific questions and hypotheses BMPs are seeking to address and the selected survey design. The spatial extent of surveys may be restricted to specific areas or habitats, rather than the whole project area, depending upon the specific questions the monitoring is addressing.

If undertaking repeat benthic sampling near infrastructure, i.e. if following a BACI or BAG sampling design, it is important that sampling stations are carefully selected so that repeat sampling is possible once infrastructure has been installed (i.e. repeat sampling stations should not overlap with the positioning of infrastructure to enable post-construction sampling).

#### 7.1.1.6 Number of samples

The number of sampling stations required for benthic post-consent monitoring will be highly dependent upon the monitoring aims and the specific hypotheses the monitoring is seeking to test. The number of samples required will also be influenced by the size of the focal area for monitoring and the level of variability and heterogeneity within the focal area or habitat. A greater number of samples is required to take account of natural variation, reduce sampling variation, understand the effects of an activity and to establish causal relationships (Ware & Kenny, 2011; Noble-James *et al.* 2018).

The required number of samples to facilitate subsequent statistical analysis, with sufficient power, should be considered at the planning stage and should be an important tenet of draft BMPs to inform monitoring plans.

##### 7.1.1.6.1 Replicates

The collection of replicate samples is important for some survey methodologies, such as subtidal grabs or cores, in order to collect data that is statistically robust and to allow for subsequent statistical analysis. Replicates allow for the analysis of small-scale variation and variation within sampling stations, and also helps to reduce the effects of random variation (Noble-James *et al.* 2018).

Where replicate sampling is undertaken, a minimum of three replicates should be collected at each benthic sampling station. However, this will vary on a number of factors, such as the receptor, the selected indicators, and the level of power required for subsequent analysis, and up to five replicates may be required. A greater number of replicates is likely to be required within highly variable or heterogenic environments where the distribution of marine organisms is patchy or sparsely distributed (Noble-James *et al.* 2018).

It is recommended that replicates are collected at each sampling station as a matter of best practice. However, this can be discussed with Natural England if an alternative approach is deemed appropriate, depending on the specific aims of the monitoring programme.

## 7.2 Post-consent monitoring of benthic receptors

Benthic receptors are diverse and can be highly variable in type and across spatio-temporal scales. In addition, the expected effects of offshore wind farm development upon benthic receptors can be highly varied depending upon the design, timing and methodology deployed as well as the receptor sensitivity, resilience and recoverability. Therefore, benthic monitoring plans should be highly tailored depending upon the specific research questions or evidence gaps the monitoring is seeking to address.

This section provides advice for specific aspects of benthic monitoring.

### 7.2.1 Intertidal zone

The intertidal zone supports unique and important habitats and species that are confined to the area between the tidal ranges. This includes intertidal mud and sandflats, coarse sediment shores, seagrass beds and saltmarshes.

The foreshore also supports areas of intertidal rock. However, due to the challenges of installing cables in rocky substrate, risks to unburied cable infrastructure and potential impacts upon recreational activities, areas of intertidal rock are likely to be avoided at landfall. In addition, alternative methods for cable installation, such Horizontal Directional Drilling (HDD), may be employed to avoid areas of intertidal rock at landfall. Therefore, intertidal rock habitats are unlikely to be directly affected by offshore wind cable installation and maintenance, so are not considered further within this section.

Sand dunes may be affected by offshore wind development if cable landfall goes through a dune system. However, sand dunes occur above Mean High Water so are not considered to be an intertidal habitat and are therefore not considered further within this document. However, monitoring of sand dunes may be required if a cable landfall is expected to affect dune habitats, in which case, early engagement with Natural England is recommended.

The intertidal zone can have high ecosystem and biodiversity value and is often afforded protection by the MPA network, such as SACs, SPAs, MCZs, Sites of Special Scientific Interest (SSSIs) and Ramsar sites. Monitoring within the intertidal zone is likely to be required if a project is expected to affect a designated feature or intertidal species and habitats of conservation importance.

Important considerations for the intertidal zone include (NRW, 2019a):

- the extent of the feature;
- distribution of the feature;
- community composition;
- sediment composition and character;
- sediment movement and hydrodynamics; and
- topography.

Offshore wind farm development may affect the intertidal zone through the installation of cable infrastructure at the landfall location and subsequent cable remediation and maintenance works.

Cable installation and remedial works can result in significant disturbance to intertidal habitats through abrasion and penetration of the substrate, as well as direct loss of intertidal habitat as a result of infrastructure placement. The installation of infrastructure could also result in indirect effects to intertidal receptors, and ecologically linked habitats such as sand dunes, through changes to the local topography, sediment movement or hydrodynamics.

This section provides advice for design and implementation of monitoring within the intertidal zone. Monitoring at the post-consent phase may be required if the cable landfall is located within or adjacent to sensitive intertidal habitats. Monitoring may be required to validate predicted impacts or investigate uncertainties regarding the magnitude or extent of impact upon intertidal habitats, species or features, or regarding the recoverability after the impact has occurred (e.g. after the construction and cable remediation phases have concluded). Monitoring may also be required to determine the degree of recovery and to inform whether remedial actions are required.

#### 7.2.1.1 Advice for monitoring intertidal receptors

The focus of intertidal monitoring should be on where cable landfall works could affect species, habitats and biotopes of conservation importance, such as MPA designated features, or where habitats have high ecological value to other species groups, such as supporting habitats for SPA protected birds or nearshore SAC fish nursery habitats (MMO, 2014). Monitoring proposals should target the areas and attributes that support MPA protected species, e.g. benthic infauna for non-breeding waders.

The aims of monitoring must be clearly defined, and monitoring programmes should be designed to produce data to test specific hypotheses. The aims of post-consent monitoring will be informed by potential impacts or areas of uncertainty identified during the examination phase and as highlighted within the IPMP (see Section 4).

If monitoring of intertidal areas is undertaken due to concerns of effects upon important supporting habitats for designated species, monitoring proposals should target the relevant areas and attributes that support MPA protected species, e.g. benthic infauna for non-breeding waders.

Monitoring of intertidal sediments does not require offshore survey vessels and equipment and surveys can be undertaken on foot. Parker *et al.* (2022a) provides advice for intertidal baseline characterisation survey methodology, such as Phase I walkover surveys and Phase II core sampling, across the intertidal zone (Wyn *et al.* 2006; NRW, 2019a). These methods can be used to investigate a range of attributes, such as feature extent and distribution, habitat biotopes, community composition, diversity metrics (e.g. species richness, evenness and diversity) and sediment composition.

Remote sensing survey methods, such as aerial imagery and LiDAR, could also be used to investigate certain aspects of intertidal habitats, such as the extent of features (Piel & Populus, 2007; Piel *et al.* 2012). If remote sensing methods are used, ground-truthing methods may be required to validate the survey outputs (NRW, 2019a).

The survey design and required number of intertidal sampling locations will be highly dependent upon the specific aims of monitoring, the extent and complexity of the receptors, the local environmental conditions and the level of variability of habitats and biotopes (Ware & Kenny, 2011; MMO, 2014; NRW, 2019a). Sufficient samples should be collected to allow for subsequent statistical analysis and to allow for meaningful conclusions to be drawn.

An appropriate number of replicates should be taken at each sampling station to allow for robust statistical techniques to be used to analyse the monitoring data and to detect significant changes. The number of replicates required will be influenced by the monitoring aims and survey design, as well as the level of variability across the focus area. Up to five replicates may be required at each sampling station (JNCC, 2004a; NRW, 2019a).

The timing of intertidal monitoring should be carefully considered when planning post-consent monitoring due to the seasonal patterns of growth and dieback exhibited by marine organisms. Monitoring of intertidal sediments is generally recommended to occur between

April and July, but sampling may be possible until October (JNCC, 2004a). Depending upon the specific aims of monitoring programmes, it may be possible to undertake intertidal monitoring outside of this window (e.g. if concerned with changes to abiotic factors, e.g. topography or sediment composition), but early engagement with Natural England is recommended in such cases.

The state of the tide during intertidal surveys is another important consideration if the lower shore is a focal area for monitoring. If sampling is required within the lower shore, it is important that surveys coincide with low spring tides to enable the greatest possible area for surveying (NRW, 2019a).

The BACI-style approach may be appropriate for monitoring of intertidal receptors at the post-consent phase. The BACI approach consists of pre-construction baseline surveys, to set the baseline, and subsequent repeated surveys at the same impact and control locations to investigate the effects of the development (MMO, 2014; Noble-James *et al.* 2018). Alternatively, a BAG approach could be used for transect-based sampling within the intertidal zone to investigate gradient effects (Methratta, 2020) (see Section 7.1.1.4).

Both approaches may include pre- and post-construction surveys, post-cable remediation surveys or surveys during the operational phase, depending on the aims of the monitoring and the hypotheses being tested. It is important that surveys are conducted at the same sampling locations and during the same time of year, to ensure that the data are comparable and to allow for meaningful conclusions to be drawn.

The JNCC Common Standard Monitoring Guidance for littoral sediment habitats provides high level guidance for monitoring intertidal sediments (JNCC, 2004a). It is recommended that this document is referred to if monitoring of the intertidal zone may be required.

## 7.2.2 Sediment-dominated environments and sandbanks

Subtidal sediments dominate much of the seafloor across English waters with complex bedform features consisting of sandbanks, sandwaves, ripples and mega-ripples. These features are dynamic and naturally migrate as a result of hydrodynamic processes and sediment movement, in some cases up to tens of metre per year (Morelissen *et al.* 2003).

Due to the requirements for construction, fixed offshore wind farms are predominantly built within sediment-dominated environments. The construction of hard infrastructure within sedimentary environments introduces hard substrate into sedimentary environments which has the potential to change the local sediment and biological community composition of adjacent habitats (Coates *et al.* 2014).

Advice is provided within this section for subtidal sediments and monitoring of Annex I sandbank features.

### 7.2.2.1 Advice for monitoring of subtidal sediments

Subtidal sediments can support diverse and productive infaunal and epifaunal communities and may support algal communities in shallow waters with sufficient light penetration. Sediments can range from coarse cobbles and sand to fine mud and silt, each with unique communities.

The methods and survey design when undertaking monitoring of subtidal sediments will be highly dependent upon the receptor, specific monitoring aims and selected indicators that will be monitored. Some survey methods (e.g. cores) will only be possible in certain substrates, such as mud and sand. It may be appropriate to use complementary methods, such as drop-down video and grab samples, to create combined datasets (MMO, 2014).

Infaunal communities and sediment characteristics can be surveyed by taking physical samples, such as grabs and cores, whilst epifaunal communities are best surveyed by epifaunal trawls or underwater imagery (Cefas, 2002). Underwater imagery can consist of drop-down video, high resolution stills and sediment profiling imagery (SPI). Acoustic monitoring methods, such as side-scan sonar and multibeam echosounder, can provide data on a range of biotic and abiotic factors and can be used in highly turbid environments with poor visibility (Griffin *et al.* 2020). Additional advice on the selection and deployment of marine monitoring methods is provided by Parker *et al.* (2022a).

The most appropriate sampling design for subtidal sediment monitoring will be dependent upon the specific monitoring aims, selected indicators and monitoring methods and the complexity of the environment. Similarly, the location of sample stations will be influenced by the specific hypotheses being tested, variation in the surrounding environment and suitability of control sites (NRW, 2019b).

Suitable sampling designs for physical sampling or underwater imagery may include grid-based systematic sampling, random sampling or stratified random sampling using the BACI approach. Alternatively, a BAG approach could be used for transect-based sampling to investigate gradient effects from an impact (Ellis & Schneider, 1997; Methratta, 2020). More information on the selection of sampling designs can be obtained from Noble-James *et al.* (2018).

Biological communities are best surveyed during spring and summer months when the growth of marine organisms is at the greatest extent and before seasonal dieback occurs. JNCC (2004b) recommends an optimal window of between April to July for monitoring sediment biological communities, with some surveys occurring until October. However, the appropriate window for surveying marine sediments will be dependent upon the specific monitoring aims and the hypotheses that will be tested and it may be appropriate for some surveys to occur outside of this optimal survey window, especially if monitoring abiotic factors (such as the structure and function of habitats). The timing and methodology of surveys should be consistent across monitoring years (MMO, 2014).

Replicate samples are recommended when undertaking physical samples (e.g. cores and grabs) and it is considered best practice to obtain a sub-sample from each sampling location for sediment Particle Size Analysis (PSA). Sampling and analysis should be undertaken following the NMBAQC guidance provided by Mason (2016).

All data collection and subsequent analysis should adhere to the relevant standards, protocols or recommended operating guidelines (see Section 7.1.).

The JNCC Common Standard Monitoring Guidance for inshore sublittoral sediment habitats provides high level guidance for monitoring subtidal sediments and provides advice for monitoring individual attributes, such as the distribution of biotopes, species composition or local topography (JNCC, 2004b). In addition, Cefas (2002) provides advice for benthic surveys at aggregate extraction sites which is applicable for monitoring of subtidal sediments. It is recommended that these documents are referred to if monitoring of subtidal sediments is undertaken.

#### 7.2.2.2 Sandbanks

‘Sandbanks which are slightly covered by sea water all the time’ are an Annex I listed habitat under the Habitats Directive and are a designated feature of SACs across UK waters.[52] Post-consent monitoring is likely to be required if an impact is expected to occur within an SAC designated for Annex I subtidal sandbanks or if sandbanks are expected to be affected by offshore wind development. This can include indirect effects, such as altered hydrodynamics or sediment budgets, as well as direct effects.

Sandbanks can be categorised into four main subtypes (Davies *et al.* 2001):

1. gravelly and clean sands;
2. muddy sands;
3. seagrass beds; and
4. maerl beds (composed of free-living *Corallinaceae*).

Sandbanks have a high morphological diversity and are highly complex with different infaunal and epifaunal communities occurring at different depths and locations on the sandbanks, with distinct peak, flank and trough communities (Larsen *et al.* 2016; JNCC, 2017). Sandbanks can also support areas of highly ephemeral *Sabellaria spinulosa* reef although the distribution of reef naturally fluctuates over time (see Section 7.2.3). Abiotic factors, such as depth, slope angle and sediment composition and particle size, also have high variability (Larsen *et al.* 2016; Schratzberger & Larcombe, 2014).

The seasonality and timing of surveys monitoring sandbank features is an important consideration. Relatively shallow areas with sufficient light penetration will support diverse algal communities in the summer months whilst faunal communities also exhibit seasonal cycles of growth and dieback (Noble-James *et al.* 2018). Seasonal effects should be considered when planning surveys of sandbank biological communities, which should optimally occur during the summer months. It is also important that the timing of surveys remains consistent across monitoring years so that the data are comparable and robust statistical analysis is possible.

As well as the biological communities present, offshore wind development may also affect the structure and function of sandbank systems. A common Conservation Objective for subtidal sandbank SAC features is to maintain or restore the structure and function of the qualifying habitats.[53] Therefore, if impacts to the structure, form or function of sandbank features are a concern, geophysical survey methods, such as side-scan sonar or multibeam echosounder, may be required to monitor morphological or structural changes to sandbanks as a result of offshore wind development.

Subtidal sandbanks can be highly mobile or relatively static depending upon the local sediment budget and hydrodynamics (Morelissen *et al.* 2003; Leenders *et al.* 2021). Therefore, it can be challenging to survey the same sampling stations in repeat surveys within dynamic sandbank systems. Sampling stations should be as close to the previous samples as possible whilst retaining consistent biotic and abiotic factors. Natural England can provide advice on the selection of repeat sampling stations in dynamic environments.

The JNCC Marine Monitoring Handbook (Davies *et al.* 2001) provides advice as to the monitoring of Annex I subtidal sandbank features, including the key attributes, such as the extent, physical properties, structure and function, biotic composition and biological structure of the feature. Davies *et al.* (2001) also suggests suitable methods for monitoring each

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[52] https://sac.jncc.gov.uk/habitat/H1110/

[53] e.g. https://data.jncc.gov.uk/data/26659f8d-271e-403d-8a6b-300defcabcb1/DoggerBank-2-

[redacted]

attribute which can be used to inform monitoring plans. It is recommended that this document is referred to when considering monitoring of sandbank features.

#### 7.2.2.3 Sandwave clearance

Sandwave clearance works are often required at the pre-construction phase in order to allow the sufficient burial depth for inter-array and export cables. Clearance works may also be required for infrastructure installation within the array, such as turbine foundations. Sandwave clearance consists of ‘pre-sweeping’ or dredging sediment to remove morphological features such as sandwaves, ripples and mega ripples, as well as the subsequent deposition of material.

Monitoring may be required at the post-consent phase in order to validate predictions of the ES regarding impacts and to monitor the subsequent recovery of benthic receptors. This is especially important when sandwave clearance works are required within MPAs designated for benthic habitats, such as SACs and MCZs, and where sandwave clearance works may affect designated features.

Sandwave clearance is often licenced through dMLs as part of the DCO licence and may have specific conditions attached to the DCO relating to monitoring. However, it is advised that all projects where sandwave clearance works may affect a designated feature of the MPA network should undertake monitoring at the post-consent phase.

Monitoring may be undertaken, both before and after sandwave clearance works occur, using geophysical survey methods, such as multibeam echosounder or side-scan sonar, following the relevant method protocols and standards, such as the MESH Recommended Operating Guidelines (e.g. Henriques *et al.* 2013) and IHO standards for hydrographic surveys (S45 and S57).[54] Monitoring should be of sufficient spatial and temporal scale to allow the predicted recovery of benthic receptors or morphological features to be observed. The required timescales for post-construction monitoring may be longer in areas of reduced hydrodynamics and sediment movement.

### 7.2.3 Reefs

Reefs are formed by rocky material or biological concretions that rise from the seabed to create habitats of conservation importance within the marine and intertidal environment.[55]

Geogenic reefs include areas of intertidal, infralittoral and circalittoral rock, as well as subtidal stony reef which is characterised by substratum with a large proportion of cobbles and boulders that have been colonised by a range of flora and/or fauna (Irving, 2009). Geogenic reefs also include chalk reef which is especially sensitive to physical disturbance and will not recover if damaged (Roberts *et al.* 2010; Moffatt *et al.* 2019).

Biological reefs are produced by a range of organisms which create habitats for other species, and alter the surrounding environment and hydrodynamics, through forming dense aggregations (Langmead *et al.* 2008; Jenkins *et al.* 2018). Species that can create biogenic reef include *Sabellaria spinulosa, Sabellaria alveolata*, soft-corals, native oyster and blue mussels (Langmead *et al.* 2008; Lisco *et al.* 2021).

Reefs may be affected by offshore wind development activities, such as construction, cable installation and remediation, maintenance and decommissioning. Areas of reef can be

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[54] [redacted]

[55] https://sac.jncc.gov.uk/habitat/H1170/

affected by abrasion and penetration of the seabed, change of substrate type or direct habitat loss, or indirectly by changes to local hydrodynamics or sediment transport or by smothering effects caused by sediment plumes. Conversely, the presence of offshore wind farm infrastructure also have the potential to create artificial reefs or facilitate biogenic reef establishment through the provision of hard surfaces for organisms to attach to (Langhamer, 2012; Degraer *et al.* 2020). Monitoring may therefore be required to address specific research questions and evidence gaps, or to validate and test predictions made within project ESs, such as rates of recovery.

Biological reef can be highly ephemeral, and its distribution can vary in space and time, although some areas will consistently support reef habitats (Lisco *et al.* 2021). Some biogenic reef, such as *Sabellaria spinulosa* and *S. alveolata*, can rapidly alternate between phases of growth, stasis and destruction during different seasons (Jackson, 2008; Lisco *et al.* 2021). Therefore, monitoring may be required in order to determine the extent of reef features prior to construction so that options to microsite around areas of reef can be explored.

If biological reef is expected to be affected by offshore wind development, the timeline and extent of its recovery is likely to be a key prediction of ESs. In such situations, monitoring during the post-construction phase may focus upon the recovery of reef habitats across temporal scales (Cooper *et al.* 2007).

#### 7.2.3.1 Advice for monitoring reef features

Due to the hard-surfaces of reef features and their sensitivity to physical survey methods, underwater imagery, such as drop-down video and photography, and/or high-resolution side-scan sonar (400/500 kHz) are commonly used to survey reefs. The selection of survey stations or transects should be informed by the best available data, such as from baseline characterisation surveys (NRW, 2019c).

Parker *et al.* (2022a) provides advice as to the use of underwater survey techniques, including underwater imagery and geophysical methods, such as multibeam echosounder and side-scan sonar. It is recommended that the advice provided within this document is used to inform the selection of monitoring methods for PCM of benthic features.

Monitoring programmes should also have regard for the MESH Recommended Operating Guidelines[56] for underwater video and photographic imaging techniques (Coggan *et al.* 2007) and the National Marine Biological Analytical Quality Control (NMBAQC) protocols and methodologies for surveying and analysis of data (Hitchin *et al*. 2015; Turner *et al.* 2016). Geophysical surveys should also adhere to the IHO standards for hydrographic surveys (S45 and S57).[57]

Some species, such as *Sabellaria spinulosa*, commonly occur in highly turbid environments with high suspended sediment concentrations, such as the southern North Sea or Severn Estuary. However, the poor visibility within highly turbid environments makes underwater imagery survey methods challenging. In such situations, a combination of high resolution multibeam echosounder and side-scan sonar can help to monitor reef features and provide information on the extent, patchiness and elevation of *S. spinulosa* outcrops (Jenkins *et al.* 2018; Griffin *et al.* 2020). This information can be used to determine a number of factors such as effects from offshore wind development, recovery after impact has occurred or whether aggregations of *S. spinulosa* constitutes as Annex I reef habitat (Gubbay *et al.* 2007; Jenkins *et al.* 2018). Acoustic data can also be used to provide data on the number

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[56] [redacted]

[57] [redacted]

and diversity of associated species on reef habitats, providing an indication of community composition and reef health (Pearce *et al.* 2014).

The monitoring methodology approach as set out by Jenkins *et al.* (2018) could also be applied to the monitoring of blue mussel, northern horse mussel, maerl[58] and native oyster beds, as well as areas of seagrass.

For intertidal and infralittoral reefs, such as those created by *Sabellaria alveolata* or blue mussels, alternative remote sensing monitoring methods are possible, such as the use of satellite imagery or LiDAR (Noernberg *et al.* 2010).

It is important to consider the indicators that will be used to monitor reef features. Advice on the selection of ecological indicators is provided by Langmead *et al.* (2008). Although this report predates much of the offshore wind development in English waters, the report provides useful advice regarding the selection and assessment of reef health indicators which can be used to inform PCM plans.

Pearce *et al.* (2014) provides an example of post-consent monitoring of *Sabellaria spinulosa* reef at Thanet Offshore Wind Farm using a variety of methods, including acoustic surveys and drop-down video work, pre-construction and approximately 18 months after construction concluded. PCM was undertaken to investigate the effect of the wind farm construction and operation upon *Sabellaria spinulosa* reefs, including their extent, macrofaunal diversity and community composition. Acoustic monitoring methods, coupled with drop-down video methods, successfully provided data on the extent and diversity of reefs (Pearce *et al.* 2014). However, additional monitoring during the post-construction phase would be required in order to determine the full effect of the wind farm upon the benthic environment over longer timescales and to separate any effects of the wind farm from the natural variability in the system.

The JNCC Marine Monitoring Handbook (Davies *et al.* 2001) provides advice as to the monitoring of Annex I reef features, including the key attributes for the feature and suitable monitoring methods. This document should be referred to when considering monitoring of reef features.

### 7.2.4 Wider community effects and colonisation of infrastructure

The construction of offshore wind farms introduces hard surfaces into the marine environment, such as turbine foundations, scour protection and external cable protection. This changes the local hydrodynamics and provides marine organisms with novel habitats that would not naturally occur, such as splash and intertidal zones located within areas of deeper water, or hard surfaces within areas dominated by sedimentary environments (Degraer *et al.* 2020). This is particularly significant for fixed wind farms which are typically constructed within sedimentary areas.

The introduction of hard infrastructure into the marine environment can produce an ‘artificial reef’ effect through the colonisation of surfaces by both indigenous and non-indigenous biofouling and epifaunal communities (Degraer *et al.* 2020). Whilst an artificial reef effect may have benefits for some benthic receptors and higher trophic levels, the presence of hard infrastructure may also provide an opportunity for species not indigenous to sedimentary environments and Invasive Non-Native Species (INNS) to establish or expand their population (Kerckhof *et al.* 2011; De Mesel *et al.* 2015).

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[58] Mearl beds can be formed by two species: *Phymatolithon calcareum* and *Lithothamnion glaciale.*

The sequential colonisation of hard infrastructure can also result in lasting changes to the surrounding environment, such as the composition of adjacent infaunal and epifaunal communities, sediment organic matter content and abiotic factors, such as sediment particle size composition or physicochemical processes (Kerckhof *et al.* 2010; Coates *et al.* 2011; Coates *et al.* 2014; Lindeboom *et al.* 2015; Wilding *et al.* 2017).

Lasting changes to oceanographic processes and adjacent benthic communities have the potential to affect ecosystem functioning and the provision of ecosystem services (Wilding *et al.* 2017). Some changes may have positive effects whilst others will be detrimental to benthic receptors. However, the significance of these effects is currently unknown as causal relationships are hard to determine and some impacts may be currently unknown (Lindeboom *et al.* 2015).

Offshore wind development can change local ecosystem processes which can result in both positive and negative effects upon benthic habitats and species, and the effects are likely to be different for each receptor or species (Coates *et al.* 2014; Lindeboom *et al.* 2015). The long-term effects of offshore wind farms upon the surrounding marine environment, localised oceanographic processes and adjacent communities is poorly understood and is a key area of uncertainty which could be investigated through post-consent monitoring.

#### 7.2.4.1 Biofouling and epifaunal communities on infrastructure

Offshore wind infrastructure displays clear zonation of biofouling and epifaunal communities with the upper reaches dominated by mussels, macroalgae, and barnacles, which are replaced by filter-feeding arthropods and then anemones at greater depths (Kerckhof *et al.* 2010; De Mesel *et al.*, 2015; Degraer *et al.* 2020).

The colonisation and subsequent succession of biofouling and epifaunal communities is a topic that may be investigated through post-consent monitoring (MMO, 2014). The colonisation of offshore wind infrastructure differs from natural habitats in terms of orientation, depth range, structure, and surface texture, and may selectively increase certain epifaunal or biofouling species (Wilhelmsson & Malm, 2008; Krone *et al.* 2013). Depending on the monitoring aims and selected indicators, monitoring programmes may seek to test hypotheses relating to the course of succession or community stability (MMO, 2014).

Monitoring methods for surveying the colonisation of infrastructure include drop-down video, high resolution underwater photography and the collection of physical samples by divers. It is important that monitoring projects have sufficient timescales to enable the detection of long-term impacts and to allow for successional processes to be observed (MMO, 2014).

A BACI-approach is not generally appropriate for monitoring biofouling and epifaunal communities on infrastructure itself. This is because turbines, external cable protection and scour protection material are newly placed habitats which are materially different from the habitats upon which they are located (MMO, 2014).

The colonisation of infrastructure by biofouling and epifaunal communities upon fixed turbines has been the subject of previous monitoring plans (MMO, 2014). However, uncertainties remain regarding how these new communities may affect the surrounding environment under different ecological conditions or infrastructure designs, such as floating offshore wind (Maxwell *et al.* 2022).

Post-consent monitoring should be targeted and focus upon the predicted direct and indirect impacts of colonisation, such as their role in acting as vectors for the establishment and expansion of INNS, effects upon trophic interactions and mobile species and changes to the wider environment (MMO, 2014; Lindeboom *et al.* 2015). These topics are discussed in the subsequent sections.

### 7.2.4.2 Spread of non-native species

The introduction of hard infrastructure into a broadly sedimentary environment provides a new habitat for indigenous and non-indigenous species to colonise beyond their natural range. This may provide an opportunity for INNS and species not indigenous to sedimentary environments to establish within the new habitat or expand their range by using infrastructure as ‘stepping-stones’ (Wilhelmsson & Malm, 2008; Kerckhof *et al.* 2011; De Mesel *et al.* 2015; Wilding *et al.* 2017). In addition, the movement of construction and maintenance vessels to an area could result in the movement of indigenous and non-indigenous species to new areas (Wilding *et al.* 2017).

De Mesel *et al.* (2015) provides an example of monitoring Non-Indigenous Species (NIS) colonisation of gravity base foundations at an offshore wind farm in the southern North Sea. Multiple hypotheses were tested, including that the foundations would promote range-expansion of NIS. The methodology comprised of divers physically obtaining samples from the intertidal and subtidal zones at periodic intervals after construction (De Mesel *et al.* 2015). Early colonisation of infrastructure by NIS already present within the region was observed and the results suggested that newly introduced infrastructure is likely to play an important role in the establishment and the expansion of the population of NIS (De Mesel *et al.* 2015).

Natural England can provide project-specific advice on the monitoring of INNS and NIS on a case-by-case basis.

### 7.2.4.3 Wider community effects

As highlighted above, the long-term effects of infrastructure colonisation upon surrounding biotic and abiotic environment is a key area of uncertainty that can be addressed through post-consent monitoring (MMO, 2014; Lindeboom *et al.* 2015). Localised effects have been shown to extend spatially from infrastructure locations with subsequent effects for benthic communities and higher trophic levels (Degraer *et al.* 2012).

The growth of marine organisms on offshore wind infrastructure can have an effect upon the surrounding faunal communities and sediment nutrient levels (Degraer *et al.* 2020). Filter-feeding bivalves and suspension-feeding arthropods are early colonisers of offshore wind infrastructure. These species filter organic matter from the water column and deposit faecal matter and detritus into the water column which subsequently enriches the local sediments with nutrients (Coates *et al.* 2014; Degraer *et al.* 2020). This can result in changes to the macrobenthic communities present within the adjacent sediments and may affect trophic functioning by attracting predators and scavengers (Coates *et al.* 2014; Degraer *et al.* 2020). Changes to the macrobenthic communities can be highly complex and can result in both positive and negative effects to benthic receptors.

The presence of offshore wind farm infrastructure, and external cable/scour protection, can also affect macrobenthic communities and the composition of subtidal sediments by modifying the local hydrodynamics, such as current flows, and by creating sheltered areas directly around infrastructure (Coates *et al.* 2014). Sheltered areas allows for the accumulation of fine sediments and organic matter which can alter the composition of biological communities present as well as resulting in additional biophysiochemical effects (Coates *et al.* 2014).

Sampling for changes to community composition and other localised effects caused by offshore wind infrastructure can be undertaken through a variety of methods including subtidal cores, grabs, epifaunal trawls, underwater imagery. Where sampling is required on or close to infrastructure, it may be appropriate to use divers or ROVs. The optimal method(s) will depend on the specific hypothesis being tested and the selected indicators.

Monitoring of wider community effects are generally undertaken using the BACI or BAG approaches, as described within Section 7.1.1.4. The number of samples required should be carefully considered to allow for robust statistical analysis. The position of samples should be informed by the aims of monitoring and the specific hypotheses being tested. However, sampling stations should encompass as much variation in habitats and biological communities as possible (NRW, 2019b). Replicates should be collected at sample locations, with a greater number required if substrates show high variability.

One approach for monitoring wider community effects is to use the BAG approach to set transects to focus the spatial distribution of sampling effort at set distances away from infrastructure along relevant pressure or natural environmental gradients (Coates *et al.* 2014; Lindeboom *et al.* 2015; Noble-James *et al.* 2018; NRW, 2019b). Using a BAG approach allows for the detection of gradient effects over spatial and temporal scales (Methratta, 2020).

The alteration of surrounding sediments and benthic communities are thought to extend spatially over time, effecting species differently throughout their life cycles (Coates *et al.* 2014). This is supported by Wolfson *et al.* (1979) who described localised effects to the benthos from an old oil platform extending to at least 100 m. It is possible that the localised effects of offshore wind infrastructure upon benthic communities and abiotic factors will also become more significant over time as well as extending spatially (Lindeboom *et al.* 2015).

It is therefore important that monitoring proposals are of sufficient temporal scale in order to detect and monitor long-term effects of offshore wind infrastructure upon benthic communities and environmental conditions (MMO, 2014; Lindeboom *et al.* 2015). It may be appropriate to monitor less regularly but over a longer duration if understanding long-term effects upon benthic communities is an aim of monitoring. For example, monitoring could be undertaken pre-construction and then at 1-, 3-, 5- and 10-years post-construction. The requirement for adaptive and/or long-term monitoring should be discussed and agreed with the relevant regulator and Natural England. However, it is important that the sampling methodology, locations and time of year are kept consistent between surveys to allow for subsequent statistical analysis (MMO, 2014).

Due to the challenges of monitoring wider community effects and indirect impacts to benthic receptors as a result of offshore wind development, it may be appropriate to consider whether collaborative monitoring projects are possible to collect data over sufficient spatial and temporal scales. Refer to section 4.4 for more information on collaborative monitoring projects.

### 7.2.5 Scour and erosion

The presence of offshore wind infrastructure, such as turbine foundations and external cable/scour protection, can result in areas localised areas of erosion and scour. The extent of scour will be dependent upon the local hydrodynamics, substrate type and underlying geology (Whitehouse *et al.* 2011). Sandy sediments have the greatest mobility and erodes at faster rates than finer sediments (e.g. clay and mud) or more coarse sediment (e.g. cobbles) (Whitehouse *et al.* 2011).

Monitoring is generally undertaken to investigate the extent of scour and secondary scour around infrastructure and whether cable burial depths have been achieved. This information is then used to determine whether remedial action, such as cable reburial or scour pit infilling, or if additional scour protection material is required (Carroll *et al.* 2010; Van den Eynde *et al.* 2013). However, monitoring may also seek to validate predictions regarding the footprint of scour pits and areas of erosion and the resulting impact upon benthic receptors, such as habitat loss or change of community composition. The effects of scour around turbines will also likely vary depending on the foundation type so monitoring may be required to validate predictions for scour with different foundations (Carroll *et al.* 2010).

The presence of scour protection also has the potential to affect benthic receptors through changes to the local hydrodynamics and resulting effects upon the sediment composition and biological community composition of adjacent areas (Coates *et al.* 2011). This is considered further within Section 7.2.4.3.

Geophysical and bathymetric monitoring of scour and erosion is usually undertaken using high-resolution multi-beam echosounder and/or side-scan sonar after construction concludes. Monitoring may focus on the areas deemed at greatest risk of scour or where sensitive receptors are present. The timeframe for monitoring will be defined by the relevant DCO licence condition.

A desk-based scour assessment is generally required to be submitted to the MMO for approval prior to monitoring commencing and a subsequent monitoring report is submitted after monitoring concludes.

Post-consent monitoring may also be required to validate predictions regarding the extent that scour and external cable protection will become covered by natural sediment movement, where this occurs, and for what duration. Monitoring may also seek to validate predictions regarding the colonisation of scour and external cable protection during the operational phase. Refer to Section 7.2.4.1 for more information on the monitoring of colonisation of infrastructure.

## 7.2.6 Recovery of benthic receptors

An important consideration for seabed habitats and species is the timeline at which recovery occurs after an impact occurs and the level of recovery achieved (e.g. if a change of substrate type, biotope or community composition occurs). Recovery of receptors will be highly variable depending on the nature and magnitude of the impact, the sensitivity and recoverability of the receptor and the natural environmental conditions present at the site. Some habitats are especially sensitive and will not physically recover if damaged, such as peat and clay exposures or areas of chalk reef (Roberts *et al.* 2010; Moffatt *et al.* 2019).

Where an impact is expected upon protected sites, designated features and species/habitats of conservation importance, the predicted timeframe for recovery is likely to be a key facet of project ESs and resulting ecological assessments that can be validated by monitoring at the post-consent phase. Monitoring can also inform on the degree of recovery and the requirement for subsequent remedial measures.

### 7.2.6.1 Advice for monitoring the recovery of benthic receptors

The duration and completeness of recovery for benthic receptors affected by offshore wind farm development is a key prediction of ESs at the examination stage. This is especially important if impacts are predicted upon designed features or species/habitats of conservation importance.

Validating the predictions of recovery of benthic habitats may be a key focus of BMPs. However, the timeline for complete recovery may be uncertain. Therefore, post-consent monitoring of receptor recoverability should follow an adaptive approach, as set out within Section 4.3, to address this uncertainty (Bennet *et al.* 2016).

Where an ES, EIA, HRA or MCZ Assessment has predicted full recovery of a benthic receptor or MPA feature within a certain timeframe, an adaptive monitoring approach should be undertaken to monitor until full recovery has occurred and can be agreed between the applicant, SNCB and the MMO. This could occur before or after the predicted timeline for recovery. If a receptor has demonstrated the expected level of recovery within the defined context, the requirement for additional post-construction monitoring may be discharged if agreed by all parties.

It is recommended that monitoring the recovery of benthic receptors should follow the BACI or BAG monitoring approach and occur before the impact occurs (e.g. pre-construction) and then periodically after the impact has taken place until full recovery has been observed. For example, this could constitute as 1-, 3-, 5- and 10-years post-construction, with a commitment to continue monitoring until the expected level of recovery has been achieved. If agreed that the predicted level of recovery will not be achieved, projects should discuss next steps and potential remedial measures to achieve the appropriate level of recovery with the regulator and Natural England.

Natural England can provide site- and receptor-specific advice on the design of BMPs on a project-specific basis.

### 7.2.7 Cumulative and in-combination impacts

Offshore wind farm development in English waters is rapidly expanding which thereby increases the potential for cumulative and in-combination effects to occur over spatial and temporal scales. However, the extent, magnitude and significance of cumulative and in-combination effects upon benthic receptors is currently poorly understood and other impacts may be currently undetected due to lag effects (Miller *et al.* 2013).

Monitoring of cumulative and in-combination impacts as a result of offshore wind development is challenging due to the spatial and temporal scales required to detect regional effects upon benthic receptors and to detect effects in a highly variable and complex environment (Miller *et al.* 2013; Lindeboom *et al.* 2015). In addition, monitoring effects at a regional scale introduces many variables, such as the effects of climate change or other pressures, such as fishing, which can make the identification of causal relationships challenging (Lindeboom *et al.* 2015).

Therefore, it is difficult for individual developments to produce monitoring projects of sufficient scope and scale to detect cumulative and in-combination impacts, collect robust data and draw meaningful and statistically significant conclusions (Lindeboom *et al.* 2015).

Monitoring of cumulative and in-combination effects may therefore be best undertaken collaboratively at a regional or strategic level. Advice on collaborative monitoring and the potential benefits of strategic projects are further discussed within Section 4.4.

Another approach for monitoring cumulative and in-combination effects is improving consistency in the methodology and analysis of benthic monitoring, analysis and reporting across projects (MMO, 2014). However, the feasibility of this and comparability of datasets makes this approach challenging.

Natural England can provide advice on the production monitoring plans or collaborative projects seeking to investigate cumulative and in-combination effects on a case-by-case basis.

### 7.2.8 Floating offshore wind

The design of floating offshore wind farms differs materially from fixed offshore wind farms in various ways, such as the use of chains or tethers to attach turbines to the seabed, instead of monopiles or other fixed foundations, and the use of free-floating ‘dynamic’ cables (Maxwell *et al.* 2022).

Due to the inherent differences between floating and fixed designs, some of the environmental considerations and impact pathways for floating wind will differ from fixed turbines. Areas of uncertainty also remain regarding the effects of floating wind infrastructure upon the wider benthic environment and sediment characteristics, such as scour effects on the seabed from anchors and dynamic cables.

A key evidence priority would be to understand the impact of floating offshore wind construction, operation and maintenance and decommissioning activities upon benthic receptors and the relevant environmental processes that influence them. Understanding the key differences in environmental effects between fixed and floating wind infrastructure would be advantageous. This is particularly important when a potential impact pressure pathway could affect a protected site or species/habitat of conservation interest.

### 7.2.9 Unexploded ordnance

Unexploded ordnance are distributed on the seabed throughout English waters, particularly within the North Sea, and can range in size and weight from 100 g up to over 700 kg (OSC, 2021). Projects are likely to undertake UXO clearance works within the project array and export cable corridor in order to ensure the security of infrastructure and the safety of staff.

Understanding the effects of UXO clearance upon benthic receptors is of particular importance when undertaking works within protected sites designated for benthic features (e.g. SACs, MCZs and SSSIs) or where habitats or species of conservation importance may be affected.

As stated by the joint interim Government position statement, applications should provide a robust environmental monitoring plan to validate the predictions made within the ES and to inform future use. Monitoring should take place whether the clearance procedure is via high order detonation or a low-order alternative (Joint interim Government position statement, 2021).

This section sets out advice for monitoring the effects of UXO clearance works upon benthic receptors.

#### 7.2.9.1 Advice for monitoring UXO craters

There is a current evidence gap for the extent of crater diameter and depth as a result of UXO clearance within the marine environment. The crater size and depth will be dependent upon the size of the UXO, the method used (e.g. low or high order techniques), water depth, the substrate type of the surrounding seabed and the underlying geology. It may also be appropriate to provide information on the level of degradation of each device to be disposed of, if known, which can affect the volume of explosive material.

Monitoring of UXO craters to understand the impact upon the seabed and the subsequent recovery of the seabed is a current evidence gap. Monitoring would be of particular importance when UXO clearance is required within protected sites or when a designated feature or habitat of conservation importance is likely to be affected.

The resulting size and depths of craters produced by UXO clearance programmes may be addressed through BMPs. Monitoring of UXO disposal craters can help to address these uncertainties and improve our understanding of the effects of UXO clearance by providing data on crater sizes and depths in different situations, thereby helping to validate predictions within marine licence applications.

UXO clearance monitoring would also help to provide data on the effects of different methods of disposal (e.g. low order methods) which can be used to determine the level of mitigation measures required for subsequent campaigns within designated sites. Trialling of new technologies, such as low order methods, should only occur outside of designated site boundaries and should be monitored in order to build an evidence base and provide confidence for further use, such as within designated site boundaries.

Projects generally undertake surveys after UXO clearance works conclude to determine whether a UXO is effectively neutralised and to ensure the security of infrastructure and a safe working environment for construction staff. Therefore, it is recommended that the monitoring of UXO disposal craters is undertaken in all instances where disposal occurs until such time as a robust evidence base is in place, especially within MPAs. However, monitoring of crater dimensions should also occur outside of MPAs to build an evidence base to support subsequent works. The results of crater monitoring should be reported to the regulator and relevant SNCB(s) as a matter of best practice.

#### 7.2.9.2 Validating the recovery of benthic receptors

As well as validating the predicted crater size and depths, post-consent monitoring may seek to validate the predicted rate for the natural infilling of craters and the recovery of biological communities.

UXO craters may naturally infill as a result of local sediment movement and hydrodynamics. However, this will be highly variable depending on the local environmental conditions and may not occur within environments with reduced sediment movement, such as relic glacial sandbanks (JNCC, 2018).

The adjacent benthic communities will also likely show some recovery after the impact has occurred. However, habitats may not recover to their previous state and a lasting change of substrate type and/or community composition may occur. Therefore, the speed and timeframe of crater infilling and the degree of benthic recovery are key uncertainties that can be validated by post-consent monitoring.

Monitoring will be required if UXO clearance works occur within MPAs designated for benthic features, such as SACs or MCZs, but may also be required outside of designated sites to improve the evidence base.

The most appropriate timeframe for monitoring of UXO crater recovery will depend on the predicted time for recovery to occur. However, monitoring may be required periodically until full recovery has been achieved and agreed with the regulator, in consultation with the relevant SNCB(s).

## 7.3 Additional requirements at the post-consent phase

This section provides advice for additional requirements at the post-consent stage other than PCM. For benthic receptors, this is specifically UXO clearance MLAs.

### 7.3.1 Marine licence for UXO clearance

All offshore wind projects will likely require a marine licence from the MMO in order to undertake UXO clearance works prior to construction activities commencing.[59] Pre-construction surveys are required to identify possible UXOs within the wind farm array and export cable corridor for clearance. This section provides advice on the evidence and data requirements for UXO clearance marine licence applications at the post-consent phase.

The main impacts to benthic receptors are ‘abrasion/disturbance of the substrate on the surface of the seabed’ and ‘penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion’. Smothering impacts resulting from sediment plumes should also be assessed.

UXO clearance applications should also consider whether a physical change to another seabed type will occur as a result of UXO disposal, e.g. if underlying substrate will be revealed. Therefore, crater size and depth are key considerations for UXO disposal applications. The sensitivity and recoverability of the marine environment and benthic receptors is another key consideration. For example, craters in areas of sand with high sediment transport are likely to recover more rapidly than in lower energy environments.

The effects of UXO clearance upon benthic receptors is highly dependent upon the size of the UXO, the seabed and substrate type, the method for disposal, and the sensitivity and recoverability of the receptor.

A detailed impact assessment and mitigation plan should be submitted as part of any marine licence application. Predicted impacts should be supported by the best available evidence, including scientific literature and empirical studies if available. Additional evidence requirements are likely to be required where an impact is expected to affect MPAs and designated features in order to inform ecological assessments.

Early engagement with the relevant regulator and Natural England (or other relevant SNCB) is recommended when considering the clearance of UXOs.

#### 7.3.1.1 Monitoring of UXO clearances

Advice on the monitoring of UXO clearance works is provided within Section 7.2.9.

#### 7.3.1.2 Information required to inform a UXO disposal application

UXO disposal MLAs are submitted to the MMO for approval, in consultation with the relevant SNCB(s), and must provide sufficient information to inform ecological assessment and to determine whether a marine licence can be granted.

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[59] https://www.gov.uk/guidance/make-a-marine-licence-application

This section should be read in conjunction with Sections 6.6.4 and 8.5.1 which provide advice on information requirements to inform UXO disposal applications for marine mammals and fish respectively.

As a minimum, UXO disposal applications should include the following:

- Project description and MDS outlining the worst-case scenario for assessment. A 'realistic worst-case scenario' can also be presented for context;
- Number of UXOs for clearance;
- UXO location and size;[60]
- Proposed method(s), including a clearly defined worst-case scenario;
- Timings for clearance. If UXO clearance is proposed to be undertaken in stages, e.g. inshore and offshore, or array and export cable corridor, this should be clearly stated;
- Predicted size and depth of craters produced as a result of UXO clearance activities, supported by strong evidence, justification and/or modelling;
- Total predicted area of impact, both direct and indirect (e.g. sediment plumes);
- Description of the underlying and adjacent seabed habitats, species and biotopes that may be affected by UXOs clearance works. Figures using wire-frame maps should be provided to show the distribution of habitats across the works area (including surface and depth profile where necessary). It may also be appropriate to provide stratigraphic profiles to display the distribution of surface sediments alongside a figure of sediment depth distributions. This can inform whether underlying geological features or sediments may become exposed and if a change of substrate type may occur as a result of UXO clearance works;
- Presence of sensitive species and habitats of conservation importance;
- Overlap with MPAs designated for benthic habitats and species and known feature extents;
- If available, a figure to show all UXOs for clearance, overlayed on to a habitat and biotope map which also displays MPA boundaries and protected feature extents;
- Any mitigation measures required to mitigate for impacts to benthic receptors and designated features;
- Assessment of significance of impact to the seabed habitats, communities and species of conservation interest, supported by robust justification (EIA). Ecological assessments should provide an assessment of significance of residual impact after mitigation measures have been applied;

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[60] UXO investigation works, e.g. using survey method such as magnetometers, may detect a large number of potential UXOs which can make subsequent assessments more precautionary. It may therefore be appropriate to separate the UXO application into investigation and clearance works, so that the former can inform the latter and so assessments are based on a realistic worst-case scenario.

- A RIAA should be submitted to provide information to inform ecological assessments of significance upon SAC designated features (HRA). Sufficient information should be provided to determine whether the project is likely to have an adverse effect on the integrity of an SAC alone or in-combination with other plans and projects;

- Information to inform an MCZ Assessment of impact to an MCZ and designated features (if applicable) to inform the decision of whether the conservation objectives of the site will be compromised; and

- Plans of proposed monitoring and post-detonation surveys, and protocol for reporting results of monitoring to the regulator.

Early engagement with the relevant regulator and SNCB is recommended when considering the clearance of UXOs, especially if novel approaches are proposed.

# 8 Fish

This section provides advice on the production of post-consent monitoring plans for fish species protected by the MPA network (e.g. SACs and MCZs) and other fish of conservation importance, such as those listed under Schedule 5 of the Wildlife & Countryside Act[61] and OSPAR listed species.[62]

Advice is also provided for ecologically important fish species which have clear links to the populations of other protected designated features, such as SPA birds or SAC marine mammals. Ecologically important species include Atlantic herring and sandeel *spp*., but other ‘forage fish’ species may also be relevant.

The Centre for Environment, Fisheries and Aquaculture Science (Cefas) are the advisory body that provides guidance on the monitoring of commercially important fish species and fisheries. Advice for monitoring of these receptors are therefore not considered further within this document. Early engagement with Cefas is recommended for projects undertaking post-consent monitoring of commercially important fish.

This chapter also provides advice on the data and evidence requirements for marine licence applications to undertake UXO clearance works at the post-consent phase in relation to fish receptors (Section 8.5).

## 8.1 Key considerations for post-consent monitoring of fish

This section outlines key considerations for the design and implementation of fish monitoring plans at the post-consent phase. This builds upon Section 4.2 which provides recommendations and advice for PCM of all receptors.

- **Clearly defined aims and hypotheses** – as outlined within Section 4.2, the aims of monitoring should be clearly defined at the start of discussions. Monitoring of fish at the post-consent phase should be targeted and hypothesis-driven in order to fill evidence gaps or validate predictions of the ESs and produce information-rich data (Wilding *et al.* 2017). Monitoring for the sake of undertaking monitoring should be avoided (MMO, 2014). IPMPs should be used as a starting point and framework for discussions at the post-consent phase (see Section 4.1).

- **Designated features of the MPA network and areas of ecological importance** – targeted post-consent monitoring is likely to be required if a project has the potential to result in an adverse effect upon a designated fish feature of the MPA network or other species of conservation importance. In addition, monitoring may be required if works are expected to affect ecologically important areas which support lifecycle events, such as spawning, nesting, nursery or feeding areas, or if barrier effects could occur to prevent fish from moving between these habitats.

- **Selection of appropriate indicators and metrics –** indicators and metrics are used to measure change and reach meaningful conclusions regarding the state of marine environments or the significance of effects. Fish receptors are highly complex and are influenced by a range of environmental factors that vary over spatial and temporal scales. Therefore, the selection of the most appropriate indicators is essential to ensure that the data collected are suitable, statistically robust and will

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[61] https://www.legislation.gov.uk/ukpga/1981/69/schedule/5

[62] [redacted]

answer the specific monitoring hypotheses (Noble-James *et al.* 2018). For MPA designated fish species, monitoring projects should have regard for the relevant site conservation objectives when selecting indicators. Early engagement with Natural England is recommended to ensure the most appropriate indicators are selected.

- **Sampling and survey design** – the design of monitoring plans should be carefully considered so that surveys produce statistically robust data that tests the defined hypotheses.

  Some monitoring objectives may be best addressed following the BACI or BAG monitoring approaches, both of which have advantages and limitations (Methratta, 2020). BACI approaches are commonly used for fish monitoring and are suitable for where effects are predicted to have a limited spatial and temporal extent. However, the BACI approach has a number of limitations and requires the identification of suitable control sites to identify changes attributable to the impact. BAG provides an alternative approach of sampling along a gradient with increasing distance from the source of impact, both within and outside of the wind farm boundary, before and after the impact occurs (Ellis & Schneider, 1997; Methratta, 2020). The BAG approach allows for the detection of gradient effects to fish receptors across a spatial scale, such as effects radiating from an impact area, and is likely to be appropriate for understanding changes to fish communities. Refer to Section 7.1.1.4 for more information on the use of BACI and BAG approaches for PCM.

  There are other possible alternative survey designs for monitoring fish receptors. The optimal approach will be highly dependent upon the questions that monitoring is seeking to answer and the selected indicators. Natural England can provide bespoke project-specific advice on a case-by-case basis.

- **Monitoring methods** – the most appropriate methods for monitoring fish receptors will be varied depending on the receptor and the selected indicators. Otter trawls are suitable for demersal fish whilst beam trawls may be more suitable for flatfish (Cefas, 2004; Franco *et al.* 2020). Mirroring commercial fishing gear can be appropriate for some fish, such as Atlantic herring, whilst other more sensitive receptors such as black seabream nests should be monitored by acoustic methods (e.g. side-scan sonar) or underwater imagery (Cefas, 2004; Collin & Mallinson, 2012; Franco *et al.* 2020). Grab sampling and ichthyoplankton surveys may be used for monitoring of Atlantic herring spawning grounds (Cefas, 2004; Vikebø *et al.* 2011). Natural England supports the exploration of novel and emerging monitoring methods, such as the use of eDNA to monitor sensitive receptors such as seahorses, although early engagement with Natural England is recommended if novel approaches are proposed (Tang *et al.* 2018).

  Advice on suitable monitoring methods for fish are provided by Davies *et al.* (2001) and Judd (2012). It is important that the selected monitoring methods are biologically relevant and consistent across surveys to ensure that data are comparable and statistically robust, whilst also reducing other sources of variation (Davies *et al.* 2001).

  It may be possible to supplement site-specific monitoring data with publicly available datasets, such as from commercial fisheries. Existing datasets can add valuable context to collected monitoring data. However, the validity of including existing datasets in subsequent analysis should be carefully considered and discussed with Natural England and Cefas.

- **Sufficient samples and replicates for robust statistical analysis** – the number of samples required to answer the specific monitoring objectives is another key consideration that should be agreed in consultation with Natural England and Cefas. Fish are complex receptors which exhibit high variation, so it can be challenging to collect sufficient data to identify causal relationships. Therefore, the defined monitoring objectives and the required number of samples should be carefully considered to ensure sufficient power, effect size and statistical significance in subsequent analyses to allow for meaningful conclusions to be drawn. A greater number of samples will be required to reduce sampling-induced variability if high variability in fish sampling data is observed and allow for subsequent robust statistical analysis (Ware & Kenny, 2011; Lindeboom *et al.* 2015; Noble-James *et al.* 2018).

  Depending on the selected monitoring methods and indicators, replicate samples may be required at each sampling station in order to collect data that is statistically robust and to allow for subsequent analysis. Replicates allow for the analysis of small-scale variation and to account for variation within sampling stations, and also helps to reduce the effects of random variation (Noble-James *et al*. 2018). A greater number of replicates is likely to be required where the distribution of focal fish is patchy or if catch/observation rates are highly variable (Noble-James *et al.* 2018).

- **Protocols and standards for monitoring and data analysis** – there are numerous protocols and standards for monitoring methods that are relevant to fish and should be followed as a matter of best practice. MESH Recommended Operating Guidelines for marine monitoring methods, such as underwater imagery or trawl surveys, should be followed where applicable. Geophysical surveys should adhere to the International Hydrographic Organisation (IHO) standards for hydrographic surveys (S45 and S57).[63] Guidelines for the handling of fish trawl and dredge data are provided by MEDIN.[64] Fish species should be recorded using the WoRMS list of accepted scientific names[65] and any biotopes should be recorded using the EUNIS classification system (EEA, 2019). The analysis of sediment samples should follow the NMBAQC protocol provided by Mason (2016) if particle size analysis is undertaken.

- **Spatial and temporal timescales** – it is important to consider the spatial and temporal scales required to detect changes in the selected indicators when undertaking monitoring of fish receptors. Monitoring requires repeat sampling to detect change over time in one or more indicators. The appropriate timescales for monitoring programmes will be highly dependent upon the monitoring aims and hypotheses, the project, expected impacts and the effected receptors. For example, monitoring the effects to fish community composition would require longer timescales over a greater spatial area than monitoring seeking to validate predicted underwater noise levels produced by construction activities that may affect resident fish species. Multiple years of monitoring should be undertaken to take account of high inter-annual variation of fish receptors and sampling variability.

- **Timing and seasonality of surveys** – the timing and seasonality of monitoring surveys is another important factor that must be considered when designing monitoring programmes. Many fish are highly mobile and have complex life histories, which often include seasonal or diurnal movements. Some fish may only be present in an area during certain times of year, such as nesting black seabream, or may be

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[63] [redacted]

[64] [redacted]

[65] [redacted]

best surveyed at specific times of the day due to diurnal movements (Freeman *et al.* 2002; van der Kooij *et al.* 2008). The seasonal timing of surveys is also important for migratory species and care should be taken to survey during months which are most appropriate for focal species. Surveys should be planned in the most appropriate months and should be consistent across surveys and years.

- **Collaborative monitoring** – as highlighted within Section 4.4, Natural England strongly supports collaborative approaches to marine monitoring and can provide advice on a case-by-case basis. Projects should consider whether fish monitoring objectives can be best delivered collaboratively across projects, zones or regions, or through participation in strategic monitoring projects (e.g. led by ORJIP or OSMRF). By working collaboratively, monitoring projects can be of a greater scope and scale to produce statistically robust and information-rich data over sufficient spatial and temporal scales to draw meaningful conclusions and address key evidence gaps (Wilding *et al.* 2017). Collaborative monitoring projects may also be suitable for detecting and quantifying in-combination and cumulative effects to fish receptors as a result of offshore wind development.

Natural England can provide bespoke project-specific advice on the design of post-consent monitoring plans for fish receptors on a case-by-case basis.

## 8.2 Underwater noise

Underwater noise is one of the main predicted impacts to fish as a result of offshore wind development. Fish are sensitive to particle motion and some fish species with swim bladders are also sensitive to sound pressure (Popper *et al.* 2014; Faulkner *et al.* 2018).

Construction and seabed preparation activities, such as impact piling and UXO clearance, generate high levels of sound pressure and acoustic particle motion which have the potential to cause significant disturbance and displacement, as well as injury and direct mortality, to fish species (Hawkins *et al.* 2014; Popper *et al.* 2014). In addition, the operational noise produced by turbines can cause masking effects which can cause stress and interfere with communication (Popper *et al.* 2014; Popper & Hawkins, 2019).

Monitoring projects may therefore seek to validate predictions made in the ES such as the modelled underwater noise produced by piling activities during construction, whilst other projects may address uncertainties, such as how the distribution of focal fish species changes as a result of construction activities.

Refer to Section 8.4.1 for specific advice for monitoring underwater noise produced by the operation of floating offshore wind farms.

### 8.2.1 Validation of predicted underwater noise levels from piling

Similar to marine mammals, underwater noise is a key impact to consider for fish species and underwater noise modelling is often required to support DCO applications where piling will be undertaken in the marine environment. Modelling is used to provide quantitative predictions of underwater noise levels in order to determine predicted impact ranges and effects upon focal fish species. Therefore, the predicted noise levels produced by piling, as set out within the ES, are an important parameter which should be validated by monitoring during construction.

Best practice for offshore wind projects undertaking piling activities is to monitor underwater sound pressure levels at various distances from the noise source, following the NPL Good Practice Guidance Note no. 133 (Robinson *et al.* 2014).[66] This monitoring is typically undertaken for the first four installed piles, to allow for a report to be provided to the MMO to highlight if measured noise levels exceed those predicted within the ES.

Natural England advise that measuring noise levels for piles across the most representative substrates of a project area would also provide useful and meaningful data for how noise levels change across substrate type. For example, whether noise levels generated by piling is greater in coarse or more consolidated sediment types. This could be undertaken in addition to the monitoring of the first four piles.

Currently, these data are submitted to the MMO but may not be shared or made publicly available. Natural England recommends that this information from all projects is hosted in a single central location, such as the MNR[67], and used to improve knowledge of underwater noise impacts generated by piling and to inform future applications. This follows the recommendations as set out within MMO (2014) which states that data should be presented or made available to allow third party, independent evaluation.

Most underwater noise monitoring of the effects upon fish receptors focusses upon sound pressure as methods for monitoring particle motion are currently undeveloped and there is a lack of calibration standards (Robinson *et al.* 2014). Therefore, the effects of particle motion caused by offshore wind development upon fish receptors is poorly understood and represents an evidence gap which could be addressed through PCM. Early engagement with Natural England is recommended if projects are considering monitoring the effects of particle motion upon fish receptors.

## 8.3 Advice for monitoring of specific fish receptors

This section provides species-specific advice for monitoring fish receptors at the post-consent phase. However, early engagement with Natural England is recommended for bespoke project-specific advice.

### 8.3.1 Fish of conservation importance

This section provides advice on the monitoring of fish of conservation importance. This includes features of the MPA network (e.g. SACs and MCZs) as well as those listed under Schedule 5 of the Wildlife & Countryside Act[68] and OSPAR listed species.[69]

Monitoring projects should be proportionate to the expected risk of impact upon fish receptors and monitoring is unlikely to be required if no adverse effects are anticipated. In addition, highly mobile and sparsely distributed species, such as basking shark or angel shark, are unlikely to be present in sufficient numbers to require targeted monitoring plans and it may not be possible to collect sufficient data to answer research questions or address areas of uncertainty. Although they are not considered further within this document, early engagement with Natural England is recommended if highly mobile or sparsely distributed fish are raised as focal species of concern during the examination phase.

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[66] [redacted]
[67] https://mnr.jncc.gov.uk/
[68] https://www.legislation.gov.uk/ukpga/1981/69/schedule/5
[redacted] [redacted]

Therefore, the below advice is focussed upon fish species of conservation importance that are currently expected to be affected by offshore wind development and should be the focus of offshore wind farm post-consent monitoring programmes.

### 8.3.1.1 Migratory fish

Many of the designated fish species protected by the MPA network are migratory at some point of their life cycle whilst also inhabiting coastal waters and estuaries. Atlantic salmon, sea trout, sea lamprey, river lamprey, twaite shad, allis shad, European smelt and black seabream are species protected by the MPA network that are migratory at some stage in their lifecycle, with many being diadromous (migrating between fresh and saltwater) (Clarke *et al.* 2021a).

As highlighted above, monitoring programmes should focus upon species where a project may affect a designated population. Many of the above species are unlikely to be a focal species for offshore wind post-consent monitoring, as the densities of aforementioned fish are likely to be significant in areas outside of offshore wind development, such as estuaries or rivers, and abundance at sea is likely to be low or poorly understood.

However, monitoring could be required if an adverse effect could occur or if offshore wind development could impair the ability of species to migrate and complete life cycle events, such as spawning, through barrier effects.

Clarke *et al.* (2021a) provides useful information on the ecology and life cycles of diadromous migratory fish, such as salmonids and shads, and provides advice for the collection of data through various methods, such as tagging, capture-recapture and eDNA sampling.

In addition, Clarke *et al.* (2021b) provides specific advice on the collection of data from diadromous fish through acoustic tracking methods for marine renewable energy projects. This document should be referred to if considering tagging projects for diadromous fish.

The use of eDNA is an emerging method for monitoring migratory fish species and can also be used for inshore fish populations (Franco *et al.* 2020; Tang, 2020). Further validation of eDNA methods are required but Natural England would welcome further discussions with projects regarding the use of innovative monitoring methods.

### 8.3.1.2 Black seabream

Black seabream are migratory species that reside in deeper shelf waters before migrating to shallower areas of south and west England to nest, with the coastal waters between Dorset and Sussex known to be especially important (Smith, 2020; Doggett & Baldock, 2022). The nesting season can range from March to late-July, with the peak months between May and June (Doggett & Baldock, 2022).

Black seabream are demersal spawners that exhibit highly selective ‘nesting behaviour’ which requires areas of near horizontal bedrock, often covered by a thin veneer of sandy gravel sediment but can also occur in areas of bare bedrock (Pawson, 1995; Collins & Mallinson, 2012; Doggett & Baldock, 2022). The male guards the nest after spawning occurs in April and May but leaves once the eggs hatch, which occurs by July (Ruiz, 2008; Collins & Mallinson, 2012).

Nesting black seabream are especially sensitive to habitat loss and disturbance due to the limited extent of suitable nesting habitat (Collins & Mallinson, 2012). Important black seabream nesting areas are protected by the MPA network, such as the Kingmere MCZ.[70]

Post-consent monitoring of black seabream nests may be required if adverse effects to black seabream nesting sites are expected as a result of the development. Monitoring may focus upon surveying active nests, rather than individuals, due to practicalities of surveying and the sensitivity of seabream at this stage of their lifecycle.

Black seabream nests should be monitored using acoustic survey methods, such as side-scan sonar and multibeam echosounder. Nests are circular craters, typically 1-2 m wide and 5-30 cm in depth, which can be identified by side-scan sonar (Collin & Mallinson, 2012). Acoustic data should be ground-truthed by diver visual observation or by underwater imagery (e.g. drop-down video work). Doggett & Baldock (2022) provides further information on the monitoring of black seabream nests and explores the survey limitations of each method.

Monitoring of black seabream nests should occur during the peak nesting season between May and June and should occur over appropriate spatial scales. Monitoring should also be undertaken over multiple years to take account of inter-annual variation (Cefas, 2004).

The specific aims of monitoring should be carefully considered when designing a monitoring programme for black seabream and setting hypotheses to test. Monitoring should be designed to produce robust data for subsequent statistical analysis in order for meaningful conclusions to be drawn.

#### 8.3.1.3 Seahorse *spp.*

The long-snouted and short-snouted seahorses are protected species that are highly sensitive to habitat loss and disturbance.

Seahorses can be monitored using divers and may also be observed using other fishing methods (e.g. beam trawls). However, seahorses are highly protected and sensitive to sampling methods, and reside in highly sensitive habitats such as seagrass beds, so traditional sampling methods for fish are not suitable and should be avoided.

In addition, the monitoring of seahorses is challenging as seahorses are highly cryptic and have low density and abundance, which means any monitoring project will have low sample sizes, which impairs the ability for robust statistical analysis (Pinnegar *et al.* 2008; Garrick-Maidment *et al.* 2010).

It may be possible to monitor seahorses through novel methods, such as eDNA monitoring (Tang *et al.* 2018). The non-intrusive collection of water samples can be used to detect seahorse eDNA through metabarcoding techniques. This is an emerging method which could reduce sampling effort without damaging seahorse habitats (Tang *et al.* 2018). Further testing is required in order to validate this method for seahorse monitoring, but Natural England would welcome further discussions with projects regarding its use.

Early engagement with Natural England is recommended if seahorse populations may be a species of concern for offshore wind projects.

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[70] [redacted]

## 8.3.2 Ecologically important fish species

As well as fish species of conservation interest, such as MPA designated populations, monitoring programmes may also seek to monitor populations of ecologically important 'forage fish' which have direct links to populations of other designated species, such as SPA protected seabirds and SAC protected marine mammals. Advice is provided below for Atlantic herring and sandeel *spp*.

Additional ecologically important forage fish species may also be relevant for post-consent monitoring due to their importance as prey for marine mammals and/or seabirds. As well as Atlantic herring and sandeel *spp.*, forage fish can include other small aggregating pelagic species, such as European sprat and Norway pout. The relevance of other forage fish for PCM will be informed by the results of baseline characterisation surveys, the outcomes of the examination stage and IPMPs. Early engagement with Natural England is advised if other forage fish are focal species for PCM.

Natural England can provide bespoke project-specific advice on the design of monitoring programmes on a case-by-case basis.

### 8.3.2.1 Atlantic herring

Atlantic herring are pelagic fish that are an important food source for seabirds, such as tern species and red-throated diver, and marine mammals (Dierschke *et al.* 2017; SCOS, 2020). Herring populations have complex meta-population structure and can have geographically limited distributions and their spawning is very habitat dependent.

Herring are hearing specialists and are especially sensitive to pressures from construction activities, such as underwater noise generated by piling (Perrow *et al.,* 2011; Hawkins & Popper, 2017). Herring also lay eggs on the seafloor in spawning grounds, usually in areas of coarse sediment, which makes them sensitive to smothering and changes to the sedimentary environment caused by construction and cabling activities (Cefas, 2004).

Changes in the abundance of herring populations have been shown to affect the foraging success of seabird species, such as little tern, which can result in population level effects (Perrow *et al.* 2011). Monitoring programmes may therefore seek to survey Atlantic herring if projects are expected to affect herring populations and important spawning grounds or reduce food availability for higher trophic predators protected by the MPA network.

Herring can be surveyed by pelagic trawling methods, using gear that mirrors that used by local commercial fisheries (Cefas, 2004). Suitable gear may include modified Riley push-nets or otter trawls (Cefas, 2004; Perrow *et al.* 2011). Herring spawning grounds can be surveyed by using grab sampling, underwater imagery, such as drop-down video, and ichthyoplankton surveys (Dickey-Collas *et al.* 2001; Cefas, 2004; Vikebø *et al.* 2011). Katara *et al.* (2021) provides advice on hotspots for fish habitats, including herring, and should be referred to when considering monitoring important areas for herring lifecycle events. It may be appropriate to supplement monitoring data with publicly available datasets, such as catch data, however caution should be used if using existing datasets for statistical analysis.

Heat maps of potential herring spawning habitat have been produced by Marine Space for four regions within English waters using existing datasets, such as the International Herring Larval Survey (IHLS) and fishing fleet Vessel Monitoring System (VMS) data. The heat maps cover four regions: the South Coast, Thames, Anglian and Humber. It is recommended that the reports produced by Marine Space are considered to inform post-consent monitoring of Atlantic herring populations (Marine Space, 2018a; 2018b; 2018c; 2018d).

Sampling designs can follow the BACI or BAG approaches to investigate the effect of offshore wind development upon herring populations, depending on the aims of monitoring and hypotheses being tested.

#### 8.3.2.2 Sandeel *spp.*

There are five species of sandeel in English waters, with the three most common species comprising of the lesser sandeel, greater sandeel and Raitt's sandeel. Sandeels play a key role in the food web within English waters and are an important food source for many top predators (Greenstreet *et al.* 2010). The abundance of sandeel *spp.* are directly linked to the populations of seabirds, such as kittiwake and puffin, marine mammals and commercially important fish species (Furness & Tasker, 2000; Rindorf *et al.* 2020; Holland *et al.* 2005; Greenstreet *et al.* 2010; SCOS, 2020).

Sandeel are highly vulnerable to habitat loss due to their life history and population structures. Sandeels have a strong preference for sandy habitats or mixed sand and gravel habitats, burying themselves in the sediment as a predator avoidance mechanism (van Deurs *et al.* 2012). Sandeels also have a highly seasonal lifecycle. In the spring and summer months they have diurnal movements, feeding on plankton in the water column by day and burying themselves at night (Freeman *et al.* 2002; van der Kooij *et al.* 2008). Sandeels hibernate during autumn and winter, emerging only occasionally for activities such as spawning. Sandeel populations show evidence of sub-structures, suggesting that localised populations may be vulnerable to local impacts (Greenstreet *et al.* 2010).

Post-consent monitoring may seek to survey sandeels populations if an adverse effect is expected upon sandeel populations or areas which are important areas for lifecycle events, such as known spawning grounds. Similarly, sandeel populations may be monitored if a project is expected to reduce the availability of sandeels which could result in population-level effects for higher trophic predators (e.g. SPA designated seabirds).

In addition, monitoring of sandeel populations could be required to validate the success of compensation if measures are enacted to increase prey availability for SPA seabirds, e.g. closure of sandeel fisheries (Greenstreet *et al.* 2010; MacArthur Green, currently unpublished).

Multiple methods can be used to survey sandeels and the most appropriate method will depend on the specific aims of monitoring and the chosen hypotheses. Grab sampling can be used to provide data on sandeel density and habitat preferences, as well as sediment composition of supporting habitats (Holland *et al.* 2005; Greenstreet *et al.* 2010). Models may be required to estimate wider population abundance and to take account of high variability in catch data (Greenstreet *et al.* 2010). Sandeel age data can be obtained by measuring the length of individuals (Leonhard *et al.* 2011).

Sandeels can also be surveyed by dredge and trawl methods, such as a sandeel dredge, which comprises of a modified scallop dredge (Leonhard *et al.* 2011; van Deurs *et al.* 2012). Dredge and trawl sampling can cover greater area than possible using grab samples but also require a large mesh size to prevent the gear becoming clogged by sediment, which can affect catch rates (Holland *et al.* 2005).

Sampling is best undertaken when sandeels are present within sediment as opposed to feeding within the water column. Sampling should be undertaken during autumn or spring months or during the night in early summer (Holland *et al.* 2005; van Deurs *et al.* 2012).

Hydroacoustic monitoring, such as multibeam echosounder, can be used to determine sandeel habitat preferences and to obtain data on sediment characteristics, such as substrate type and seabed roughness and hardness (Greenstreet *et al.* 2010).

Sampling design should be carefully considered, and sufficient samples should be collected to reduce sampling variability and to enable greater power in subsequent statistical analysis. Ware & Kenny (2011) provides further advice as to the design of marine surveys. Sampling designs can follow the BACI or BAG approaches to investigate the effect of offshore wind development upon sandeel populations, depending on the aims of monitoring.

Sandeel monitoring proposals should have regard for the sandeel habitat maps produced by Marine Space (Marine Space, 2018a; 2018b; 2018c; 2018d). The reports map the location and extent of potential and marginal seabed habitat used by sandeels within four regions: South Coast, Thames, Anglian and Humber.

## 8.4 Impact pathways associated with floating offshore wind

The construction of floating offshore wind farms is predicted to result in different effects upon fish receptors to fixed wind farms, however the extent and magnitude of effects are currently poorly understood and can represent an evidence gap which can be addressed through PCM (Maxwell *et al.* 2022).

There are currently two constructed floating offshore wind farms in the UK, namely the Kincardine and Hywind Scotland projects which are located within Scottish waters. The data and findings of PCM for these projects will help to inform the design of post-consent monitoring plans for floating offshore wind projects in English waters.

Natural England can provide site-specific, bespoke advice on the design of post-consent monitoring plans to address key evidence gaps for floating offshore wind farms on a case-by-case basis.

### 8.4.1 Impact pathways relating to underwater noise

It is widely considered that underwater noise levels generated by floating turbines during the construction phase is likely to be significantly less than for fixed turbines with piled foundations (Maxwell *et al.* 2022). However, the underwater noise levels generated by floating offshore wind farms during the operational phase is less well understood and has the potential to affect fish receptors and their behaviour (Mooney *et al.* 2020; Gill *et al.* 2020).

Operational noise can be continuous in nature and so contribute to elevated noise levels in and around the wind farm throughout the development’s lifecycle. Although thought to be low-level, the production of continuous noise levels could cause masking effects which can cause stress and interfere with communication (Popper *et al.* 2014; Popper & Hawkins, 2019; Gill *et al.* 2020). This is an impact pathway which is currently poorly understood, and which post-construction monitoring could help to address.

Another potential source of underwater noise from floating offshore wind turbines is the impulsive ‘snapping’ noise detected by monitoring at the Hywind DEMO site during the operational phase (Martin *et al.* 2011). This operational noise source is thought to be generated by cables and turbine tethers ‘snapping’ in underwater currents. However, there are limited data on this operational underwater noise from other projects and the subsequent impacts to fish receptors are yet to be quantified or fully understood (Martin *et al.* 2011;

Burns *et al.* 2022). Floating offshore wind farms may therefore seek to quantify this effect through PCM programmes.

There is a current OWEAP-funded evidence project, led by Cefas, which seeks to assess underwater noise risk impacts of floating offshore wind turbines upon marine receptors, including fish. The outputs of this project will be incorporated into this document when available.

### 8.4.2 Novel impact pathways relating to dynamic cables

A key difference in the design of floating offshore wind farms, rather than fixed, is the use of ‘dynamic’ cables which are suspended in the water column, rather than buried within sediment. These can include the inter-array and export cables as well as the tethers which anchor the turbines to the seabed.

The use of dynamic cables introduces a new pathway for electromagnetic fields (EMF) to affect fish species (Maxwell *et al.* 2022). Fish are sensitive to electromagnetic fields and some species use geomagnetic and bioelectric fields for navigation and to detect prey (Gill *et al.* 2020; Hutchison *et al.* 2020). Therefore, the use of ‘dynamic’ cables is predicted to increase the exposure of fish to EMF which could have behavioural modification effects, although the extent and magnitude of this is currently unknown, especially at the population level (Hutchison *et al.* 2020; Maxwell *et al.* 2022). Monitoring at the post-consent phase may seek to address this evidence gap and provide further evidence as to the effects of EMF upon focal fish species and populations, until a sufficient evidence base has been collected.

Dynamic free-floating cables, along with anchor chains or tethers, pose another new potential impact pathway to fish species through primary or secondary entanglement (Maxwell *et al.* 2022). Primary entanglement is where animals are entangled on the dynamic cables or the anchor chains or tethers that secure the turbines, and is more likely for larger fish species, whilst secondary entanglement is where other materials, such as fishing gear or marine litter, becomes entangled on floating offshore wind infrastructure which then entangles fish (Maxwell *et al.* 2022). Entanglement is likely to be a more significant issue if floating offshore wind arrays overlaps with MPA boundaries or known migration pathways for MPA designated migratory species (see Section 8.3.1.1).

The extent and magnitude of entanglement impacts from offshore wind development are thought to be low but are currently unknown. It may be possible to collect data on entanglement risk (or lack of) through routine offshore wind farm monitoring during the operational phase, which could then be used to address this evidence gap and validate predictions of the ES, until a sufficient evidence base has been collected.

## 8.5 Other considerations at the post-consent phase

As well as monitoring, projects will also have to consider fish receptors when applying for a marine licence to undertake UXO clearance works at the post-consent phase. Advice for this is provided below.

### 8.5.1 Marine licence for UXO clearance

Unexploded ordnance are distributed on the seabed throughout English waters, particularly within the North Sea, and can range in size and weight from 100 g up to over 700 kg (OSC, 2021). The disposal of UXOs can produce significant underwater noise, which has the potential to disturb, injure or kill fish within a certain impact radius, depending on the UXO (Robinson *et al.* 2020). The scale of potential impacts of clearing UXOs will depend upon the disposal method, the size of the UXO and its location.

Pre-construction surveys are required to identify possible UXOs within the wind farm array and export cable corridor for clearance. However, it is likely that all projects will need to undertake UXO clearance campaigns prior to construction commencing due to health and safety concerns and to protect infrastructure. UXO disposal requires a marine licence from the MMO at the post-consent phase.[71]

A detailed impact assessment and mitigation plan should be submitted as part of any licence application. Early engagement with the relevant regulator and Natural England (or other relevant SNCB) is recommended when considering the clearance of UXOs.

As well as underwater noise impacts, the clearance of UXOs has the potential to impact seabed habitats and species through abrasion and penetration of the seafloor. This has the potential to affect fish receptors if located within areas which are important for lifecycle events, such as spawning grounds.

Applicants should have regard for the joint interim Government position statement that provides an update to this guidance and a shared position for projects undertaking UXO clearance campaigns (Joint interim Government position statement, 2021).[72]

#### 8.5.1.1 Monitoring of UXO clearances

Monitoring of UXO clearance campaigns is important and can provide useful data to validate predictions of the marine licence application ES, address evidence gaps and key areas of uncertainty.

As stated by the joint interim Government position statement, applications should provide a robust environmental monitoring plan to validate the predictions made within the ES and to inform future use. Monitoring should take place whether the clearance procedure is via high order detonation or a low noise alternative (Joint interim Government position statement, 2021).

Monitoring the impact of UXO clearance works upon fish receptors should primarily focus on the underwater sound pressure levels generated by UXO disposal, in line with the National Physical Laboratory noise monitoring protocol (NPL, 2020)[73]. However, monitoring of other factors, e.g. UXO craters, may be required if seabed impacts are a concern for fish receptors, such as if works are occurring within known spawning areas (see Section 7.3.1).

As noted within Section 8.2.1, the effects of acoustic particle movement are poorly understood and represent an evidence gap which could be investigated through post-consent monitoring (Robinson *et al.* 2014). Natural England can provide bespoke advice on a project-specific basis on this point.

The results of monitoring of UXO clearance campaigns should be uploaded to the MNR as a matter of best practice.[74]

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[71] https://www.gov.uk/guidance/make-a-marine-licence-application

[72] https://hub.jncc.gov.uk/assets/24cc180d-4030-49dd-8977-a04ebe0d7aca

[73] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/955204/NPL_2020_-_Protocol_for_In-Situ_Underwater_Measurement_of_Explosive_Ordnance_Disposal_for_UXO.pdf

[74] https://mnr.jncc.gov.uk/

### 8.5.1.2 Information required to inform a UXO disposal application

UXO disposal MLAs are submitted to the regulator (MMO) for approval, in consultation with the relevant SNCB, and must provide sufficient information to inform ecological assessment and to determine whether a marine licence can be granted.

This section should be read in conjunction with Sections 6.6.4 and 7.3.1 which provide advice on information requirements to inform UXO disposal applications for marine mammals and benthic receptors respectively.

As a minimum, UXO disposal applications should include the following:

- Project description and MDS outlining the worst-case scenario for assessment. A ‘realistic worst-case scenario’ can also be presented for context;
- Number of UXOs for clearance;
- UXO location and size;
- Proposed method(s), including a clearly defined worst-case scenario;
- Timings for clearance. If UXO clearance is proposed to be undertaken in stages, e.g. inshore and offshore, or array and export cable corridor, this should be clearly stated;
- Estimation of underwater noise levels generated by UXO clearance, supported by robust justification, evidence and/or modelling;
- Presence of sensitive species and supporting habitats for important lifecycle events, such as known spawning or nursery grounds, taking account of seasonal variations which can vary significantly over spatial and temporal scales;
- Overlap with MPAs designated for fish or known migration routes for migratory species protected by the MPA network, taking account of local seasonal variations;
- If available, a figure to show all UXOs for clearance, overlayed on to a habitat and biotope map which also displays MPA boundaries and important areas for lifecycle events (e.g. spawning or nursery grounds);
- Mitigation measures required to mitigate for impacts to fish receptors and designated features (if applicable);
- Assessment of significance of impact to each focal fish receptor, supported by robust justification (EIA). Ecological assessments should provide an assessment of significance of residual impact after mitigation measures have been applied;
- A RIAA should be submitted to provide information to inform ecological assessments of significance upon designated SAC fish populations (HRA). Sufficient information should be provided to determine whether the project is likely to have an adverse effect on the integrity of an SAC alone or in-combination with other plans and projects; and
- Information to inform an MCZ Assessment of impact upon MCZ designated fish features (if applicable) to inform the decision of whether the conservation objectives

of the site will be compromised; and

- Plans of proposed monitoring and post-detonation surveys, and protocol for reporting results of monitoring to the regulator.

Early engagement with the relevant regulator and SNCB is recommended when considering the clearance of UXOs, especially if novel approaches are proposed.

# 9 Decommissioning plans

Projects are required to submitted draft decommissioning plans to the MMO for approval, in consultation with the relevant SNCB(s). The final approach to decommissioning will then be agreed prior to decommissioning works commencing.

Decommissioning plans should outline the proposed approach for decommissioning the offshore components of offshore wind infrastructure, including the turbines, cables, offshore converter platforms and external cable/scour protection. Decommissioning plans should also outline an indicative timetable for works.

Decommissioning plans should consider the environmental effects of removing infrastructure from the marine environment when considering the most appropriate approach. The potential effects of removing infrastructure should be compared to leaving *in situ* (Smyth *et al.* 2015). The presence of MPAs should be carefully considered as it is likely that infrastructure will require decommissioning if located within MPAs designated for benthic features.

When drafting decommissioning plans, projects should have regard for the guidance produced by the Department of Business, Energy and Industrial Strategy (BEIS) for renewable energy installations.[75]

Due to the long timeframe between projects submitting a draft decommissioning plan and decommissioning activities commencing, it is important that plans incorporate flexibility to take account of changes to the regulatory environment, evolving best practice for decommissioning and the emergence of new technologies and methods.

Decommissioning of offshore wind infrastructure is an emerging area that will come into clearer focus as currently operational projects come to the end of their cycle and explore detailed decommissioning plans. Natural England can provide bespoke advice on decommissioning plans on a case-by-case basis.

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[75] https://www.gov.uk/government/publications/decommissioning-offshore-renewable-energy-installations

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# 11 Annex I – Scientific names

A number of common names are used throughout this document. Annex I documents all of the scientific names for species described within this document.

| Common name | Scientific name |
|---|---|
| Allis shad | *Alosa alosa* |
| Angel shark | *Squatina squatina* |
| Atlantic herring | *Clupea harengus* |
| Atlantic salmon | *Salmo salar* |
| Atlantic sturgeon | *Acipenser sturio* |
| Basking shark | *Cetorhinus maximus* |
| Black seabream | *Spondyliosoma cantharus* |
| Blue mussel | *Mytilus edulis* |
| European smelt | *Osmerus eperlanus* |
| European sprat | *Sprattus sprattus* |
| Gannet | *Morus bassanus* |
| Greater sandeel | *Hyperoplus lanceolatus* |
| Greater sandeel | *Hyperoplus lanceolatus* |
| Green turtle | *Chelonia mydas* |
| Grey seal | *Halichoerus grypus* |
| Guillemot | *Uria aalge* |
| Harbour porpoise | *Phocoena phocoena* |
| Honeycomb worm | *Sabellaria alveolata* |
| Kemp’s Ridley turtle | *Lepidochelys kempii* |
| Kittiwake | *Rissa tridactyla* |
| Leatherback turtle | *Dermochelys coriacea* |
| Lesser black-backed gull | *Larus fuscus* |
| Lesser sandeel | *Ammodytes tobianus* |
| Lesser sandeel | *Ammodytes tobianus* |
| Little tern | *Sterna albifrons* |
| Loggerhead turtle | *Caretta caretta* |
| Long-snouted seahorse | *Hippocampus guttulatus* |
| Maerl | *Lithothamnion corallioides* |
| Maerl | *Phymatolithon calcareum* |
| Native oyster | *Ostrea edulis* |
| Northern horse mussel | *Modiolus modiolus* |
| Norway pout | *Trisopterus esmarkii* |
| Puffin | *Fratercula arctica* |
| Raitt’s sandeel | *Ammodytes marinus* |

| | |
|---|---|
| Raitt’s sandeel | *Ammodytes marinus* |
| Razorbill | *Alca torda* |
| Red-throated diver | *Gavia stellata* |
| River lamprey | *Lampetra fluviatilis* |
| Ross worm | *Sabellaria spinulosa* |
| Sandwich tern | *Thalasseus sandvicensis* |
| Sea lamprey | *Petromyzon marinus* |
| Sea trout | *Salmo trutta* |
| Short-snouted seahorse | *Hippocampus hippocampus* |
| Twaite shad | *Alosa fallax* |

**Table 11.1.** List of scientific names for species described within this document.