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Collaboration for Environmental Mitigation & Nature Inclusive Design (CEMNID)

Mitigation Measures Literature Review

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APPENDIX A



EXECUTIVE SUMMARY

The role of the Collaboration for Environmental Mitigation & Nature Inclusive Design (CEMNID) Project is to address environmental uncertainty for the offshore wind sector in Scotland through two key aims:

1. To Identify the relevant mitigation measures for species receptors that can be applied to offshore wind developments in Scotland when applying mitigation hierarchy; and
2. Identify opportunities to apply Nature Inclusive Design (NID) to Scottish offshore wind projects in order to contribute to biodiversity enhancement and nature positive outcomes from such developments.

This literature review provides a basis to build a suite of good practice environmental mitigation measures by consolidating and compiling existing knowledge regarding the use of deployed and developed, as well as innovative and alternative, mitigation measures for offshore wind farms (inclusive of fixed and floating infrastructure) using knowledge from marine industries in Scotland and elsewhere. To achieve this, publicly available documents were reviewed, including national and international guidelines for offshore wind impacts mitigation, and other good practice guides. Environmental Impact Assessment Reports (EIAR), Scoping Reports, grey and scientific literature were also reviewed. The intention was to assimilate the appropriate information from these reports and determine whether these have relevance for Scottish Offshore Wind projects going forward. In addition, informal discussions were held with key stakeholders for offshore wind in Scotland (regulators, statutory nature conservation bodies, developers) to extract important information about key principles and factors that support or hinder the success of environmental mitigation measures.

The compilation of all this information has been used to provide key emerging findings in this report that can be used to develop a Good Practice Library based on objective criteria that is appropriate for offshore wind farms in Scotland. Further identification of factors which can potentially attest to the success of mitigation measures was also undertaken, through examination of the outputs of available monitoring surveys which have been executed pre-, during or post-construction for offshore wind farms across Scotland, England, and Wales.

Key findings of this review include:

- The highlighted importance of developers' early engagement with regulators and Statutory Nature Conservation Bodies (SCNBs);
- Most, if not all, mitigations used or proposed for use in Scottish/UK windfarms are embedded mitigations (see Section 2.4, Table 2 for definition) that are underpinned in existing national policy or guidance;
- Efficiency of existing embedded mitigation measures are unclear based on available monitoring data from offshore wind farms, especially for demonstrating long term effects, as discussed in Section 3.3;
- Some mitigation measures may also have negative effects on target (or other) receptors, as discussed, where relevant throughout Section 3);
- A suite of potential innovative mitigation measures have been identified which at present time are untested in Scottish wind farms but may have relevance in Scottish waters especially relating to impacts to marine mammals (noise impacts) and seabirds (collision risk);
- Specific mitigation options for noise abatement that may be applicable to Scottish Windfarms are still under review and bespoke protocols such as those developed for piling strategies for the windfarms in the moray region, for



instance would appear to be most suitable for Scotland (MFRAG, 2015). Other noise abatement measures which may not be pursued in Scotland due to technical limitations include measures such as big bubble curtains, Hydro Sound Dampers.

- Innovative mitigations suggested to minimise potential bird collisions include painting blades to increase visibility and automated shut down systems.

Lastly, the outputs of this literature review will underpin the development of a library of Scottish wind farm good practice mitigation measures (the Good Practice Library), drawing on examples from throughout the UK that are appropriate for use in Scotland. Based on the outputs of this literature review, a series of objective criteria have been developed that aim to facilitate the screening in/out of mitigation measures into the Good Practice Library; these objective criteria can be seen in Section 4.1. The Good Practice Library will make recommendations regarding the use of environmental mitigation measures developed, proposed, or deployed on Scottish offshore developments. However, they should not be seen as stifling any new innovating technical development that could also be regarded as mitigation in the future.



1 INTRODUCTION

1.1 Background to the CEMNID Project

The twin crises of climate change and biodiversity loss are arguably the greatest environmental challenges of our era. Energy production from renewable sources (e.g. offshore wind farms) is key for reducing carbon emissions and achieving the Net Zero target by 2045 in Scotland. However, these offshore renewable developments may have adverse environmental impacts on marine species and habitats, hindering biodiversity recovery. The implementation of effective mitigation measures, as well as the development of practices supporting nature recovery present both challenges and opportunities for the sustainable development of the offshore wind sector globally.

The Scottish Offshore Wind Energy Council's (SOWEC) Barriers to Deployment – Enabling Group established the Collaboration for Environmental Mitigation and Nature Inclusive Design (CEMNID) Project to address two key knowledge gaps with regard to environmental uncertainty in relation to impacts from offshore wind developments during construction and operational phases. These gaps are:

- To identify the most appropriate mitigation measures for species receptors that can be applied to offshore wind developments in Scotland when applying mitigation hierarchy; and
- Identify opportunities to apply Nature Inclusive Design (NID) to Scottish offshore wind projects in order to contribute to biodiversity enhancement and nature positive outcomes from such developments.

It is recognised that a key barrier to the consenting and deployment at pace of offshore wind farms is environmental uncertainty, including in relation to impacts from developments during construction and operational phases and the efficacy of environmental mitigation and enhancement measures such as Nature Inclusive Design (NID). These uncertainties directly contribute to risks and delays in the consenting and deployment of Scottish offshore wind developments and therefore threaten the achievement of Scotland's net zero and nature positive targets. Dealing with these uncertainties also exacerbates resourcing pressures across the consenting system for developers, regulators, advisory bodies and NGOs, increases development costs and risks irreversible wildlife losses. To accelerate consenting and facilitate the sustainable and rapid expansion of offshore wind deployment in Scotland, environmental uncertainties associated with offshore wind development therefore urgently need to be addressed.

By addressing above mentioned gaps, the CEMNID Project seeks to develop a holistic framework to identify and apply good practice environmental mitigation, and to provide some understanding on how to deliver environmental benefit through embedding NID in Scottish offshore wind development projects. This will help address key barriers to consenting and deployment and will support Scottish offshore wind projects to tackle the climate and nature crisis in tandem.

The overarching objectives of the CEMNID Project are therefore to:

- Provide a clearer understanding of how to apply the mitigation hierarchy in offshore wind development, including consideration of embedded measures and design decisions;



- Summarise good practice¹ environmental mitigation measures available to deploy through the mitigation hierarchy;
- Identify the principles of NID for offshore wind development, including how these relate to the mitigation hierarchy;
- Identify ecologically promising and practically applicable NID measures that could be applied to Scottish offshore wind projects; and,
- Provide evidence to support the consenting requirement to implement nature-positive development in the marine environment and thereby comply with the adopted National Planning Framework 4 and emerging policies including National Marine Plan 2.

The CEMNID Project is overseen by a steering group comprising technical and consenting experts drawn from offshore wind developers, consultees and regulators. The Project secured funding from Crown Estate Scotland and approval from SOWEC, resulting in Xodus Group Limited (Xodus) being commissioned to deliver the Project scope in line with the objectives. This document has been prepared by Xodus.

1.2 Outputs of the CEMNID Project

The CEMNID Project aims to achieve the objectives outlined above through provision of the following key deliverables:

- **Mitigation Measures Literature Review (current deliverable; A100906-S00-A-REPT-002):**
 - Literature review and associated research regarding the use of environmental mitigation measures for Scottish and other relevant offshore developments which, based on objective criteria, are considered to represent good practice;
- **NID Literature Review (A100906-S00-A-REPT-003):**
 - Literature review and associated research on international evidence of NID approaches which are assessed as ecologically promising, practically applicable, and relevant to offshore wind deployment in Scotland;
- **Mitigation Measures Efficacy Review and Good Practice Library (A100906-S00-A-REPT-004):**
 - Development of a Good Practice Library for environmental mitigation and an associated efficacy review for a subset of key measures;
- **NID Suitability Review and SWOT analysis (A100906-S00-A-REPT-005):**
 - SWOT analysis of identified options for their applicability to offshore wind in Scotland (considering environmental, engineering, supply chain, commercial, consenting, policy and all other relevant factors across construction, operational and decommissioning phases), and associated NID suitability review focusing on ScotWind leasing areas and supporting infrastructure corridors to determine habitat and species suitability;
- **Final Report (A100906-S00-A-REPT-007):**
 - Structured report including discussion of mitigation good practice and guidance on implementing NID at a project level.

¹ Good practice defined in this context as "Good practice is defined as a process or methodology that has been consistently shown to work well and to achieve reliable results" (IEEM, 2021).



1.3 Aim of the deliverable

This deliverable aims to collate information on available/deployed mitigation measures in offshore wind, as well as measures which may be considered innovative or novel. This literature review brings together information from publicly available documents relating to mitigation measures for offshore wind farms, with a focus on abiotic and ecologically relevant receptors. Though the findings of the CEMNID Project aim to inform offshore wind in the Scottish context, this literature review includes jurisdictions beyond Scotland and the UK. Engagement with key stakeholders in Scotland was also sought to inform the understanding of factors which may hinder and promote the success of mitigation measures. Finally, the outputs of monitoring surveys carried out during pre-, during and post-construction phases of offshore wind farms in Scotland, England and Wales were also considered by way of informing efficacy of mitigation measures, as these were considered most relevant to Scotland.

The information collated in this literature review will form the basis of the subsequent Good Practice Library. The Library will synthesise these outputs and aim to define a subset of key mitigation measures considered to be of greatest relevance and importance to offshore wind in Scotland at this time, recognising that this may change over time as post consent monitoring to validate predictions may remove or reduce certain impact pathways.



2 METHODOLOGY

Information on environmental mitigation measures for offshore wind farms has been gathered through the following pathways:

- Informal discussions were held with stakeholders involved with offshore wind in Scotland to understand what contributes to the success of mitigation measures (Section 2.1);
- Publicly available offshore wind farm Scoping Reports and Environmental Impact Assessment Reports (EIARs) were reviewed in order to determine which mitigation measures they implemented. This led to the development of a long list of mitigation measures that are in practice in UK offshore wind farms (Section 2.2);
- A review of monitoring survey reports' findings for offshore wind farms in the UK was undertaken try to understand the efficiency of any mitigation measures deployed (Section 2.3);
- A review of outputs from research groups such as Regional Advisory Groups (RAGs); and
- Consideration was also given to how mitigations apply to other offshore industries.

Each of these steps and actions are briefly described in the following sections.

In reviewing the array of mitigation measures which are utilised in offshore wind, their place in the mitigation hierarchy has also been defined. The application of the mitigation hierarchy is outlined in Section 2.4.

Lastly, the intention is that this literature review provides a comprehensive foundation for subsequent work in defining and compiling a Good Practice Library. In order to set the basis for this Good Practice Library, some objective criteria have been defined (Section 2.5) which can then be considered and applied to mitigation measures in order to objectively determine which measures constitute good practice.

Good practice can be defined as "a process or methodology that has been consistently shown to work well and to achieve reliable results" (IEEM, 2021). Based on this principle, the good practice mitigation measures to be featured in the Good Practice Library would need some level of demonstrable consistency and reliability. Specifically, the Good Practice Library will draw on mitigation measures that have been demonstrated to be either already established regular practice or have direct applicability to offshore windfarms in Scotland. These measures that represent good practice may already be driven by specific guidance that is in place and have a proven track record of being effective. If not clearly demonstrated or routinely practiced, the measure should at least have sound scientific underpinning with supporting evidence. The good practice measures should ideally have been tested at commercial scale and may already be considered as being used in standard practices.

A subset of good practice mitigation measures will be subject to an efficacy review (Mitigation Measures Efficacy Review; A100906-S00-A-REPT-004). The subset of mitigation measures will be screened using specific criteria, initially being assigned to key mitigation categories (see Table 1).

This literature review considers three distinct categories of mitigation namely primary, secondary and tertiary (Table 1). The review also draws on embedded mitigation for inclusion into the Good Practice Library which is considered to represent both primary and tertiary mitigations in that they are truly embedded and will be implemented regardless of the outcomes of the EIAR (i.e. environmental effects that may have arisen without the mitigation in place are not



assessed in the EIAR). As such, inclusion of embedded measures would be included as part of the Good Practice Library.

Table 1 Definition of mitigation categories (adopted from IEMA, 2016)

MITIGATION CATEGORY	DESCRIPTION
Primary (Inherent)	Primary mitigation is an intrinsic part of the project design and should be described in the design evolution narrative and included within the project description. For example, reducing the height of a development to reduce visual impact.
Secondary (foreseeable);	Secondary mitigation requires further activity in order to achieve the anticipated outcome – typically, these will be described within the topic chapters of the ES, but often are secured through planning conditions and/or management plans. For example, description of certain lighting limits that will be subject to submission of a detailed lighting layout as a condition of approval.
Tertiary (inexorable)	Tertiary mitigation will be required regardless of any EIA assessment, as it is imposed, for example, as a result of legislative requirements and/or standard sectoral practices. For example, the adherence to JNCC seismic survey guidelines for minimising the risk of noise to marine mammals.
Embedded Mitigation	Embedded mitigation considers both primary and tertiary mitigation on the basis that both these forms of mitigation definitely will be delivered: thus, any effects that might have arisen without these forms of mitigation do not need to be identified as ‘potential effects’.

2.1 Informal discussions with stakeholders for offshore wind in Scotland

During December 2023 and January 2024, Xodus held a series of informal discussions with key stakeholders involved in the field of offshore wind in Scotland (Marine Directorate Licencing and Operations Team (MD-LOT), NatureScot and offshore wind developers). The main aim of these informal discussions was to identify key parameters that support or hinder the success of environmental mitigation measures for the offshore wind sector in Scotland. The key outcomes of these discussions are presented in Section 3.1.

2.2 Literature review of mitigation measures

The compilation of information for environmental mitigation measures was based on various publicly available sources, which are grouped in three broad categories: Cat 1 – industry practice mitigation guidelines, Cat 2 – project/development specific documentation (e.g. Scoping reports and EIARs), and Cat 3 – innovative/alternative mitigation options.



An important aspect of the CEMNID Project is that the aim is not to rewrite these guidance documents, but rather to build upon those that are relevant to the industry and horizon scan to the direction the offshore wind sector is moving (such as floating technologies). It is necessary to holistically consider the existing guidance and determine the applicability and suitability of these industry standard measures for future offshore wind farm development in Scotland.

This literature review includes the following:

1. Existing Standard practice mitigation guidelines. This includes both national (e.g., National Policy Statement for Marine Renewables, JNCC protocols for mitigation of underwater sound) and international guidelines (e.g., documents from IUCN, Australian Government and the Agreement on the Conservation of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) working group). The outcomes of this review can be seen in Section 3.2.
2. Project/development specific documentation. EIARs/Scoping reports found on the Marine Directorate website² (for offshore wind developments in Scotland) and the National Infrastructure Planning website³ (for offshore wind developments in England). Aiming to extract as much relevant information on mitigation as possible from the available EIARs/Scoping reports, the documents examined covered a wide range including:
 - Recent EIARs as well as EIARs submitted >10 years ago,
 - Reports for both fixed and floating technology wind farms.

It should be noted that variations of similar mitigation measures were seen across several EIARs and Scoping Reports. In light of this, these variations have been amalgamated under a generalised “overarching” mitigation measure. For each of these overarching mitigation measures examples of projects have been named where these variations were found. The outcomes of this review can be seen in Section 3.3.

3. Consideration is given to mitigation adopted for other offshore industries, particularly oil and gas pipelines, floating and piled infrastructure, interconnectors and cables, and coastal developments.
4. Innovative and/or novel mitigation measures are then captured in the literature review. These may have been taken from international guidance (not adopted in UK), novel mitigation approaches identified for international wind farms and any other developing mitigation methods which are being proposed or developed which may have applicability for Scottish Offshore wind farms. In addition, consideration is given to mitigations from other marine industries other than wind.

The focus of the CEMNID Project is on ecological mitigation measures. Therefore, it was decided to explicitly only include measures mitigating impacts to ecological and ecologically relevant abiotic receptors. Measures mitigating potential impacts to human receptors, including commercial fishing activities have been excluded from the review. However, it is recognised that the mitigation measures often overlap both ecological and human issues; for instance, mitigations for avoiding or minimising disturbance to fish and shellfish may also directly or indirectly affect commercial fisheries.

² <https://marine.gov.scot/>

³ <https://infrastructure.planninginspectorate.gov.uk/>



2.3 Review of monitoring survey reports' findings for offshore wind farms in the UK

In order to gain a better understanding of the efficiency of deployed mitigation and the ultimate success (or otherwise) of implemented mitigation measures, a review was also conducted focusing on available monitoring reports in the Marine Directorate and National Infrastructure Planning websites. Through this search, six reports were found which were associated with monitoring of receptors pre-, during and post-construction of offshore wind farms. Specifically, reports for the Beatrice, Moray East, Aberdeen Bay and Robin Rigg (in Scotland), and Thanet and North Hoyle (in England) offshore wind farms were consulted to inform the review. This was supplemented by an additional online search for publicly available monitoring reports. Based on this search, the post-construction monitoring report for the North Hoyle offshore wind farm (in Wales), was also utilised.

2.4 Application of mitigation hierarchy

The mitigation hierarchy is a key guiding principle for any project to address potential adverse impacts. Therefore, as part of this study, consideration is given to where each identified mitigation measure falls within the mitigation hierarchy. The mitigation measures are then listed in order, with avoidance being prioritised as the first step and subsequently minimisation (Table 2). In addition, the mitigation categories outlined in Table 1 will also be considered alongside the mitigation hierarchy such that primary and tertiary measures that target avoidance and minimisation are likely to be considered good practice. In the case of secondary mitigations these are anticipated to fall lower in the hierarchy towards minimisation, restoration and offsetting measures that may be identified following the EIA process. This ordering process will be used in turn to refine the subsequent Good Practice Library that will be delivered as part of the CEMNID Project.

The mitigation hierarchy, as considered in this study, uses the definitions adopted by the Biodiversity Consultancy (2024) (Table 2). While the mitigation hierarchy goes beyond avoidance and minimisation, and further considers habitat restoration and offsets, the CEMNID Project has opted to not to incorporate restoration/enhancement options in this study. However, some possible restoration methods may be considered a form of NID. Where deemed relevant, some discussion has been provided on associated mitigation measures that go beyond minimisation and avoidance in Section 3.4.3. It is important to recognise that the categories of mitigation measures outlined in Table 1 also relate to the mitigation hierarchy. Specifically, primary mitigation measures incorporated into design will typically reflect avoidance and minimisation measures that can be committed at the early stage of a project. Similarly, tertiary mitigations will relate to avoidance and minimisation measures driven by policy and industry guidelines. In the case of secondary mitigations, these can be incorporated to further minimise or may extend to restoration and offsetting measures.



Table 2 Mitigation Hierarchy definitions

MITIGATION TYPE	DEFINITION
<p>Avoidance</p>	<p>The first step of the mitigation hierarchy comprises measures taken to avoid creating impacts from the outset. This may include careful placement of infrastructure or timing construction sensitively to avoid disturbance.</p> <p>Avoidance is often the easiest, cheapest, and most effective way of reducing potential negative impacts, but it requires biodiversity to be considered in the early stages of a project.</p> <p>These will typically be Primary and Tertiary Mitigations</p>
<p>Minimisation</p>	<p>Measures taken to reduce the duration, intensity and/or extent of impacts that cannot be completely avoided are considered as minimisation. Effective minimisation can eliminate some negative impacts such as measures to reduce noise and pollution, designing powerlines to reduce the likelihood of bird electrocutions, reducing the quantity of rock required to protect an underwater cable or building wildlife crossings on roads.</p> <p>Minimisation measures can be either Primary, Secondary and Tertiary Mitigations.</p>
<p>Restoration</p>	<p>The aim of restoration is to improve degraded or removed ecosystems following exposure to impacts that cannot be completely avoided or minimised. Restoration tries to return an area to the original ecosystem that was present before impacts, whereas rehabilitation only aims to restore basic ecological functions and/or ecosystem services such as through planting trees to stabilise bare soil. Rehabilitation and restoration are frequently needed towards the end of a project’s life cycle but may be possible in some areas during operation.</p> <p>Collectively, avoidance, minimisation and rehabilitation/restoration serve to reduce, as far as possible, the residual impacts that a project has on biodiversity. Typically, however, even after their effective application, additional steps will be required to achieve no overall negative impact or a net gain for biodiversity.</p> <p>Restoration measures will likely be categorised as Secondary mitigations.</p>
<p>Offset</p>	<p>Offsetting aims to compensate for any residual, adverse impacts after full implementation of the previous three steps of the mitigation hierarchy. Biodiversity offsets are of two main types: ‘restoration offsets’ which aim to rehabilitate or restore degraded habitat, and ‘averted loss offsets’ which aim to reduce or stop biodiversity loss in areas where this is predicted. Offsets</p>



MITIGATION TYPE	DEFINITION
	<p>are often complex and expensive, so attention to earlier steps in the mitigation hierarchy is usually preferable.</p> <p>It should be noted that the offset measures in this case are separate from derogation provisions under the Habitats Regulations which specifically relate to compensation measures associated with damage of European protected Sites (e.g. Special Area of Conservation).</p> <p>These offset measures will generally be categorised as Secondary mitigations.</p>

2.5 Objective criteria

This literature review will facilitate determination of appropriate mitigation measures which can be incorporated into a Good Practice Library. The Library aims to be appropriate for offshore wind developments in Scotland and cognisant of emerging technologies such as floating wind, and regulatory steer, which will be significant for future Scottish offshore wind developments, inclusive of ScotWind projects.

Many of the mitigation measures identified in this literature review are driven by existing policy and guidance and identified from the steps outlined in Section 2.2 and 2.3. For these measures, it is considered that many are already incorporated into project plans and designs and can therefore be considered to represent industry standard practices.

However, the CEMNID Project aims to holistically consider other relevant potential novel mitigation options that may be as yet untried in UK waters that may yet be considered good practice. Therefore, the CEMNID Project intends to further identify good practice mitigation measures by screening them against objective criteria. In order to assess the measures identified in the review as being good practice, the following questions are posed for which this review aims to inform:

- Has this measure been suggested in UK or international mitigation guidelines?
- Has this measure been included in any EIARs/Scoping reports for offshore wind farm projects (or other relevant industries) in Scotland? If yes, which are these projects?
- Is the proposed mitigation just a consequence of the engineering design that happens to have a more beneficial environmental outcome or is it truly driven by the need to avoid or reduce pressure on a receptor?
- Is there any publicly available evidence (e.g., scientific publication) that shows the efficiency of the measure? If yes, what is this scientific evidence?
- Has this measure been used in any offshore wind farm projects or other relevant offshore marine industries in Scotland?
- Has this measure been monitored in Scottish waters? If yes, which are the main outcomes from the monitoring of the measure and does this tell us anything about their efficiency?
- Are there any challenges (technical, financial, other) with the use of the measure? If yes, which are these challenges?



- Does this measure have any possible undesired consequences on any physical/biological receptors? If yes, which are these possible consequences?

Further refinement on the objective criteria used for developing the good practice Good Practice Library that are relevant to Scottish offshore wind developments is provided at the end of this report (Section 4.1).



3 RESULTS

3.1 Informal discussions with stakeholders

Informal discussions were centred on factors which contribute to the success of mitigation measures, or factors which hinder their success. Key outcomes are summarised below.

3.1.1 Factors that contribute to the success of environmental mitigation

Stakeholder engagement with offshore wind developers highlighted the importance of early consultation and engagement with stakeholders. These early discussions should incorporate considerations of potential significant effects and what can be done to mitigate it to enable primary mitigations to be recognised and embedded within the Project Design Envelope (PDE). Design parameters such as minimum air gap between the sea surface and blade tip and placement of site boundaries that avoid protected areas are considered truly 'designed-in' or Primary mitigation measures that can be incorporated into early design. Early engagement also enables sensitivities and appropriate mitigations to be realised that are driven by Tertiary mitigations driven by consenting process such as conditions relating to underwater noise from piling. Consultation throughout the impact assessment process also enables identification and refinement of Primary or Secondary mitigations that are specific to the environmental receptors characteristic to the site that may have not been previously apparent. Furthermore, it was recognised that there is a need to consider the understanding of different disciplines, particularly between engineering and environmental interests, early on and to continue this dialogue through the project lifespan. The review revealed that developers were generally aware early on in the process which mitigation measures must be adopted due largely to financial considerations.

Developers were also of the view that when certain mitigation measures were proposed at the EIAR stage, at a point when sufficient technical information was lacking to offer certainty on installation approach, this can later be limiting to a project. As such, it is important to maintain optionality at the consent stage. Furthermore, the consideration of local environmental conditions can support the selection of appropriate mitigation measures and their successful implementation.

Apart from early engagement, the importance of openness and transparency was highlighted, e.g., when there is an issue, developers should approach NatureScot (the Scottish Statutory Nature Conservation Body (SNCBs) for offshore wind) and collectively they can come up with a solution. Willingness to try novel approaches in environmental mitigation was welcomed.

3.1.2 Factors that hinder the success of environmental mitigation

In principle, the opposite parameters/factors of those highlighted above can hinder the success of environmental mitigation e.g., limited openness and late engagement. Specifically, late stakeholder engagement when the project is already mature can significantly reduce the capacity to implement further mitigation into the design.

A key issue identified was that until all geotechnical surveys have been conducted, the availability of information on the seabed for use in the project design process is limited. Due to cost implications, geotechnical surveys do not



always take place early in the project design process. However, it is only when the geotechnical surveys have been carried out that technical specifications and requirements become apparent. This is particularly pertinent to installation methodology of both wind farm turbines and especially cable burial success and any associated cable or scour protection requirements.

Discussions with developers and regulators have shown the importance of getting an advanced understanding about the ecology of offshore ecosystems present in a development, as well as the importance of monitoring the performance of certain mitigation measures. Successful engagement also require clear communication and understanding between disciplines to understand to which extent these are effective.

The lack of monitoring or review of mitigation measures (a conclusion also reached within Section 3.5) impedes understanding of how cost effective or successful the measures are. More often, where monitoring plans are implemented, the approach will typically include the monitoring of a receptor to validate the predictions made in the EIA rather than the specific outcomes of the mitigation measure itself, although it is recognised that monitoring may require both. As such, the monitoring measure, and the method and timing in which it is administered, is an important consideration. This aspect is discussed further in Section 3.5.

The current lack of transparency of monitoring data is considered a significant limitation. Without being able to access or acquire this data, it is more difficult to determine the true success of a measure. In terms of monitoring, it was also suggested in stakeholder discussions that the specific details of the data acquisition, analysis, and results, including who was involved in the analysis, should become publicly available. Some of these gaps may also be addressed somewhat by sharing lessons learned and publishing such findings and learnings to make these accessible. It was mentioned that when considering mitigation, thought should be given to any potential undesired effects that could occur either on the same or differing receptors. An example of this was given for the use of Acoustic Deterrent Devices (ADD) that may also have some undesired consequences on marine mammals through the further introduction of noise in the marine environment. However, in the case of ADD, it should be considered that these devices are used in conjunction with other mitigation measures and/or used where more noisy activities would take place (such as piling). The associated effects are carefully assessed and considered as part of the licencing and consenting process. Therefore, the benefits of deploying ADD would be based on a case by case basis and their use would be dependent on the activity being undertaken and the level of sensitivity. At present, ADD continues to be recommended and used as industry practice, where deemed applicable.

Finally, it was mentioned through stakeholder engagement that contract competition can hinder the success of mitigation. For example, a novel method of Unexploded Ordnance (UXO) clearance, called low order deflagration, exists. There is evidence that this method is effective (including in deeper waters), with NatureScot (among others), being keen that developers move towards utilising low order deflagration. However, there is currently only one supplier for this method which could increase cost to the developers but may also increase the potential for competition. It is important to acknowledge that any mitigation measures identified and incorporated into a Good Practice Library would represent only a guide representative of the best understanding at the time. If a specific technology is identified as good practice it should not deter or prevent new alternative technologies which achieve the same outcome to be accepted. Moreover, a point raised about the development of a Good Practice Library was that it should be kept as a live document to ensure it evolves with emerging technologies and environmental understanding.



3.1.3 Factors for further consideration

Some innovative/alternative mitigation measures were identified during the stakeholder engagement as being under consideration by industry (e.g., painting turbine blades in order to minimise bird collision risk). However, it seems that most of these innovative measures have not yet been tested in Scotland and thus their efficiency and applicability is unknown. Discussion with developers also included the use of alternative installation methodologies available such as suction anchors/foundations which could hold some promise as an alternative to piled structures, especially for floating wind projects and would effectively avoid the noise emissions associated with piling. However, the consideration of such methods will strongly depend on the site conditions and suitability of the substrates to install the equipment which is often not confirmed until much later in the development process (i.e. coarse/stony sediments and are unsuitable for this installation method). Discussions have also shown that some mitigation measures are not universally positive. For example, painting turbine blades to reduce collision risk to birds may have visual landscape implications on sites that are relatively close to shore and within line of site. These points indicate the need for a more a more holistic consideration for mitigation measures across multiple receptors.

It is recognised that monitoring is undertaken where a consenting condition requires a specific mitigation. However, the monitoring data does not necessarily translate into the proven effectiveness (or not) of the mitigation measures deployed. This lack of connection between monitoring data and mitigation effectiveness has implications on the understanding and prediction of environmental impacts associated with the offshore wind industry. For example, where a mitigation measure is found to be inappropriate or unsuccessful, should the measure be adapted or abandoned altogether? Potential learnings from other marine industries could be beneficial to offshore wind in the identification of efficient mitigation measures.

Developing a robust regulatory process that drives environmental recovery and restoration is an area that is still in early development. As part of this, the SNCBs have started considering species spatial distributions through time, including the effects of climate change. The consideration of climate change and associated spatio-temporal distribution of species/habitats could be a key issue for mitigation and monitoring due to shifts in distributions and a changing environment. An example of where this could be significant is the introduction of hard surfaces where increased risk of INNS could be a factor in increasing sea temperatures. Similarly, shifting distributions of foraging seabirds or shifts in fish spawning behaviour or seasonality are significant unknowns in the long term and therefore, where possible, adaptive mitigations should be considered throughout the lifespan of a development.

It was suggested that NID can be seen as part of the mitigation hierarchy. In the future, developers may incorporate NID as an action to mitigate potential environmental impacts from their projects. However, at present there is no legal requirement from the Scottish Government for developers to consider NID in offshore wind farms in Scotland. It is an important aim of the CEMNID project to be able to identify NID options that may be available to developers at the early (pre-consent) stages that may be incorporated into design and considered along with primary mitigation. More detail on the applicability of NID options is the subject of a separate report in the CEMNID Project (NID Suitability Review (A-100906-S00-A-REPT-004)).

3.1.4 Overview of informal discussions with stakeholders

A summary of the results of the stakeholder discussions is presented in Table 3.



Table 3 Summary of key themes resulting from stakeholder discussions

FACTORS CONTRIBUTING TO SUCCESSFUL MITIGATION	FACTORS THAT HINDER SUCCESSFUL MITIGATION	FACTORS FOR FURTHER CONSIDERATION
<ul style="list-style-type: none"> • Early and ongoing engagement • Maintaining design flexibility • Openness and transparentness between developers and regulators/SNCBs • Willingness to innovate 	<ul style="list-style-type: none"> • Lack of certainty in project design • Lack of monitoring on mitigation measures, in particular those where there is no clear correlation with reduction of pollution at source. • Contract competition • Potential extra costs of mitigation • Uncertainty in feasibility 	<ul style="list-style-type: none"> • Testing of efficiency of innovative measures • Holistic consideration of mitigation measure effects • regulatory process that drives environmental recovery and restoration



3.2 Environmental mitigation measures included in existing renewable industry policy and guidelines

This review considered a relevant starting point for identifying of good practice mitigation measures that can be deployed at Scottish wind farms was the broad suite of mitigation measures set out in the UK National Policy Statement for Renewable Energy Infrastructure (also known as the National Policy statement E-3) (UK Government, 2023). This policy statement has only recently been published at the time of writing and provides a robust list of measures based on recent understanding. While its remit is UK-wide, it is still deemed to be directly relevant to Scottish offshore windfarm, although it is noted that there will be certain aspects, such as floating wind, which will have a greater emphasis in Scottish waters than perhaps elsewhere in the UK. As such, the mitigation measures outlined in this UK policy for offshore wind farms is taken as a starting point in defining what good practice mitigation measures look like.

In England, the National Policy Statement E-3 will form the basis for the development of Offshore Wind Environmental Standards (OWES) as part of an Offshore Wind Environmental Improvement Package. At the time of writing, the proposed OWES is not in the public domain, however it is clear that the thinking of how these policy drivers apply to Scottish projects is an important step. It is important to make clear that the focus of the CEMNID project is not to standardise mitigation (which is a goal of OWES), but to provide guidance on good practice mitigation.

Key overarching UK/Scottish policies and guidance included in this review are listed in Table 4. International guidance is listed in Table 5.

Table 4 Key national mitigation policy and guidance documents relating to offshore wind

NATIONAL POLICY/GUIDANCE	RECEPTORS COVERED
UK Government (2023). National Policy Statement for Renewable Energy Infrastructure	Multiple / Overarching
Scottish Natural Heritage (2013). A handbook on environmental impact assessment. Guidance for Competent Authorities, Consultees and others involved in the Environmental Impact Assessment Process in Scotland	Multiple / Overarching
Natural England and JNCC (2022). Nature conservation considerations and environmental best practice for subsea cables for English Inshore and UK offshore waters	Physical environment / Benthic environment
Natural England (2018). Offshore wind cabling: ten years' experience and recommendations	Physical environment / Benthic environment
JNCC (2017). Guidelines for minimising the risk of injury to marine mammals from geophysical surveys	Marine Mammals (underwater noise)
JNCC (2010). Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise	Marine Mammals/ underwater noise
JNCC (2023). JNCC Draft guidelines for minimising the risk of injury to marine mammals from explosive use in the marine environment	Marine Mammals (underwater noise)



NATIONAL POLICY/GUIDANCE	RECEPTORS COVERED
NatureScot (2019). A review of noise abatement systems for offshore wind farm construction noise, and the potential for their application in Scottish waters (Verfuss <i>et al</i> , 2019)	Marine Mammals (underwater noise)
UK Government (2022). Marine Environment: Unexploded Ordnance Clearance Joint Interim Position Statement.	Marine Mammals (underwater noise)
NatureScot (2014). Understanding the potential for marine megafauna entanglement risk from marine renewable energy developments. (Benjamins <i>et al</i> , 2014)	Marine megafauna (Marine Mammals, fish, ornithology)
NatureScot (2020a). Feature Activity Sensitivity Tool (FeAST)	Various receptors
NatureScot (2023). Guidance Note Series. Guidance to support offshore wind application. Marine ornithology	Ornithology (collision and displacement)

Table 5 Key international guidance documents relating to offshore wind

INTERNATIONAL POLICY/GUIDANCE	REGIONAL COVERAGE/ RECEPTORS COVERED
Bennun <i>et al</i> . (2021). International Union for the Conservation of Nature (IUCN) Mitigating biodiversity impacts associated with solar and wind energy development. Guidelines for project developers	Worldwide, Multiple receptors covered
OSPAR (2008). Guidance on environmental considerations for offshore wind farm development	OSPAR region (North East Atlantic). Multiple receptors covered
European Commission (2020). Guidance document on wind energy developments and EU nature legislation	Europe, Multiple receptors covered
DCCEEW (2023). Key environmental factors for offshore wind farm environmental impact assessment under the Environment Protection and Biodiversity Conservation Act 1999	Australia, Multiple receptors covered
ACCOBAMS (2019). Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS) Methodological Guide – Guidance on underwater noise mitigation measures	Mediterranean, Black Sea, contiguous Atlantic. Marine Mammals/Underwater sound
National Oceanic and Atmospheric Administration (2024). Marine Mammal Protection	United States, Marine Mammals/ Underwater sound



The review of existing mitigation guidelines has focused on physical and biological environment receptors with five emerging themes, namely:

1. Physical presence effects on hydrodynamics and sediment transport;
2. benthic impacts from habitat loss/disturbance and sediment turbidity;
3. marine mammals from underwater sound; and entanglement/entrapment;
4. Seabird impacts from collision risk and displacement of seabirds; and
5. Electromagnetic fields (EMF) on marine fauna.

This section outlines the key mitigations identified across the documents outlined in Table 4 and Table 5 respectively which to be considered for all of the primary receptor groups listed above. The focus is therefore on ecological and biodiversity concerns due to the increasing uncertainty that the rapid expansion of major infrastructure of offshore wind may have on the marine environment. For this purpose, associated mitigations relating specifically to human receptors and activities are excluded from the review.

3.2.1 Guidance on physical environment mitigation

Good practice guidance on mitigation measures to avoid or minimise effects on the physical environment and associated processes includes specific considerations in design such as:

- Avoidance of areas sensitive to physical effects;
- Modelling to inform site selection;
- Design of infrastructure and its layout configuration to reduce the effects of the offshore wind farm on natural ocean water currents, waves, and sediment dynamics;
- Consideration of the angles at which cables approach the coast in areas where external cable protection is likely to be needed;
- Avoidance, where possible of placing external cable protection in a dynamic environment perpendicular to the sediment transport (as this can result in formation of large scour pits);
- Consideration of micrositing to avoid vulnerable locations;
- Avoid placement of external cable protection at 90° to near shore sediment transport pathways is to be avoided as it can affect downstream sediment transport;
- Ensure any sediment moved is retained locally; and
- Undertaking Horizontal directional drilling (HDD) at landfall to avoid direct interaction with the intertidal zone and pinning cables to reduce effects of abrasion.

These specific recommendations on mitigating against impacts to physical presence are all broadly considered within the UK policy statement paragraph 2.8.224 (UK Government, 2023), although some of the measures are implied rather than specifically specified with regards to considerations for placement of infrastructure.



3.2.2 Guidance on intertidal and subtidal benthic ecology

The UK policy statement on offshore wind mitigations for intertidal and subtidal benthic ecology are provided from paragraphs 2.8.226 to 2.8.236 within that document (UK Government, 2023). These generally follow the mitigation hierarchy with much consideration for avoidance measures to be identified early in the project initiation phase as primary mitigation and thus embedded in project design, for example appropriate site selection. A summary of key mitigations drawn from the guidance documents listed in Table 4 and Table 5 are provided below as follows:

- Early engagement with statutory nature conservation bodies (landfall, cable approach options);
- Avoidance of sites that have been designated for the conservation of benthic habitats and species (e.g., Marine Protected Areas for Annex I habitats or Priority Marine Features (PMFs));
- Where it is not possible to avoid MPAs, the next step is to avoid designated features of each site;
- Avoidance of sensitive features inside of MPAs (e.g. micro-siting around PMFs and Annex I habitats);
- Minimising the number of cables per project, or co-locating, through project design;
- Early, realistic consideration of cable burial including likely difficulties and the potential for external cable protection;
- Early identification of cable/pipeline crossings, especially those within MPAs;
- The use of anti-fouling paint could be minimised on subtidal surfaces in certain environments, to encourage species' colonisation on the structures, unless this is within a soft sediment MPA and thus would allow colonisation by species that would not normally be present;
- Design and configuration to minimise the seabed area needed for installation and operation (e.g., cable route);
- Consideration of the angles at which cables approach the coast in areas where external cable protection is likely to be needed that could interrupt local sediment transport in sensitive areas. Where possible, external cable protection in a dynamic environment should not be placed perpendicular to the sediment transport;
- Consideration of cable crossings and the removal of out of service cables to reduce the need of external cable protection;
- Consideration of cable crossings, and aligning the route to minimise number of cable crossings within sensitive areas;
- Planning of sufficient survey programmes to characterise the project site early in the process (including geophysical, geotechnical and Digital Aerial Surveys);
- Selection of cable installation methods that minimise turbidity;
- Ensuring sufficient cable burial wherever possible to allow seabed recovery to natural state.
- Selection of Horizontal Directional Drilling (HDD) methods rather than trenching;
- Use of external cable protection should be minimised;
- Selecting cable protection materials to match the environment; and
- Deployment of cable protection that is recoverable on decommissioning and to remove these on decommissioning.

As with the physical environment, the UK policy statement (UK Government, 2023) covers the key areas identified in the bullets above and can be considered to broadly represent good practice. However, it is worth noting that the measure listed above which is to select cable protection materials which match the environment may not necessarily be practical to achieve and is not something that is included in the UK policy currently. This is considered further in the CEMNID literature review of NID options (A-100906-S00-A-REPT-003).



3.2.3 Guidance on fish and other marine fauna mitigation from EMF

Some broad measures for EMF mitigation are shown below which were drawn from the guidance documents in Table 4 and Table 5. Note that cable designs typically contain sheaths that reduce direct electrical fields.

- Engineering controls that reduce EMF emissions considering factors such as cable configuration and design, - Applicable to HVDC cables only (Not HVAC cables).
- Increasing the distance between the cables and sensitive receptors by burying the cables Via trenching and /or external protection (geotechnical./anthropogenic effects).
- For HVDC systems, cable configurations will be optimised to minimise overall EMF strengths e.g. minimising separation between + and – conductors and ensuring these are paired.

These measures will depend on the type and size of cable as well as the level of voltage being transmitted to identify what mitigation would be appropriate. These measures as listed for consideration only. It is worth noting that cable burial has been identified as not being an effective mitigation for the benthic habitat due to the direct transmission of EMF emissions through sediment but that it will have a minimising effect of reducing the maximum level of emissions for surface dwelling benthos and demersal fish (Gill and Desender, 2020). The UK government policy statement on mitigation of EMF notes that the use of external cable protection has been suggested as a mitigation for EMF (by increasing the distance between fish species and individual cables). However, it also highlights that consideration must be given to any undesired consequences from external cable protection on benthic habitats, and a balance between protection of various receptors must be made (UK Government, 2023). It is worth pointing out that this principle applies to all mitigation measures and will be a feature to consider in developing a Good Practice Library as discussed in Section 4.1.

An important consideration for ScotWind projects where floating wind is deployed is that the cables may hang freely in the water and thus potentially require alternative monitoring and mitigation (UK Government, 2023). In these scenarios measures such as sheathing may be considered.

3.2.4 Guidance on marine mammals (and fish) from underwater sound

The main sources of good practice guidelines for measures mitigating the potential impacts of underwater noise are listed in Section 3.2. The primary mitigations adopted for Scotland/UK are largely drawn from JNCC guidance, followed by those in place for other regions or states (e.g., Mediterranean Sea, Australia).

The non-exhaustive list of measures taken from the above documents are provide below. It should be borne in mind that these lists do not imply that all of these measures should be applied by every project, but that their requirement should still be considered where deemed appropriate. Specific focus is given to piling, although it is worth mentioning that bubble curtains have been used in UK in shallower water in the North Sea for minimising the effects of noise on marine mammals and salmon respectively (See Section 3.4.4 for more details) and may be applied to specific offshore wind construction activities such as piling. The following measures, taken from guidance, mitigate against impacts of underwater sound, specifically piling:

- Developer to demonstrate that best available technique (BAT) is used;



- Selection of foundation types that do not require pile driving for installation (e.g., suction buckets would be preferred over gravity structures, where possible due to associated seabed disturbance and legacy of latter);
- Selection of vibratory pile driving over impact pile driving techniques;
- If impact piling is selected, underwater noise effect thresholds will need to be determined for use in Scottish waters and then applied to determine effect ranges;
- Select periods with low biological sensitivity;
- Consideration of the local environment in terms of cetaceans' and seal presence;
- Operators should seek to provide dedicated Marine Mammal Observers (MMOs) and Passive Acoustic Monitoring (PAM) operatives;
- The establishment of a mitigation zone is necessary around the piling site before any piling; use sound propagation modelling to define the extension of the exclusion area;
- In the mitigation zone the MMO/PAM operative will monitor for the presence of any marine mammals before the onset of piling;
- Piling should not be commenced if marine mammals are detected within the mitigation zone;
- Application of initiation, soft start and gradual ramp up of pile driver;
- The use of Acoustic Deterrent Devices that have the potential to exclude animals from the piling area should be considered;
- Where impact piling is proposed in biologically important areas and times, application of the best available technology for noise abatement should be applied; it should also be demonstrated how impacts will be managed to acceptable levels, where necessary;
- For Unexploded Ordnance (UXO), the recommendation would be to prioritise low noise alternatives by avoiding where possible or by undertaking low order deflagration. Where this is not possible (and where this can't be avoided), controlled low order detonation. It is recognised that high order detonation may still be needed in certain circumstances (UK Government, 2022).

The mitigation for underwater noise on marine mammals from piling is covered in paragraphs 2.8.237 to 2.8.239 of UK policy statement (UK Government, 2023). These points correspond directly to the JNCC guidance related to underwater noise (JNCC, 2010, 2017 and 2023). In addition, the UK policy takes into account the consideration of Acoustic Deterrent Devices (ADD) as well as noise abatement measures but in the case of the latter, does not specifically outline what these may be. Further information on novel abatement measures beyond standard JNCC protocols and their potential applicability to ScotWind projects is discussed further in Section 3.4.15. This review also includes the piling strategies developed for projects in the Moray Firth which took a different approach from elsewhere in the UK.

3.2.5 Guidance on ornithological receptors including seabird collision risk and displacement

The main sources of good practice guidelines for measures mitigating the potential impacts on ornithological receptors including collision risk and displacement on seabirds, are as follows:

- Guidance note series to support offshore Wind Applications in Scotland : Marine Ornithology (NatureScot, 2023);
- Strategic Assessment of Collision risk of Scottish wind farms to migrating birds (WWT, 2014).



The list of measures shown below mainly refers to the mitigation of impacts (collision risk, displacement) to seabirds.

- Avoidance of sensitive areas (e.g., Special Protection Areas);
- Infrastructure design: Number of turbines and technical specification (use of decoy towers; Burton *et al.*, 2011);
- Management of infrastructure lighting (according to Burton *et al.* (2011) the most effective mitigation measures include: (i) switching from steady, burning red lights (designed to warn aircraft and shipping) to lights which flash; or (ii) the use of blue/green steady warning lights;
- Consideration of the timing of activities (during pre-construction, installation, operation, decommissioning) to avoid disturbing seabirds during sensitive periods (e.g., breeding, migration routes and ranges (flyways);
- Control of construction/operation vessel movements and managing of lighting;
- Physical controls including modification to standard infrastructure (e.g., minimum air gap between turbine blades and sea surface); and

Whilst control of turbine operation (e.g., turbine shutdown on demand to minimise collision risk) has not been proposed on offshore wind farms in the UK, it has been proposed for onshore wind farms and also for offshore wind farms in the Netherlands in relation to bird migration events.

The mitigation for seabirds is covered in the UK policy statement (UK Government, 2023) paragraphs 2.8.240 to 2.8.244 and is largely in agreement with the list above. It is noteworthy that the UK policy statement mentions that shutting down turbines within migration routes during estimated peak migration periods is unlikely to offer suitable mitigation, but that this might be a possibility in the future (UK Government, 2023). However, this does not rule out the use of such technologies for ScotWind projects. In addition, an important source for informing the assessment on migrating birds and developing appropriate mitigations in Scottish Waters is a strategic review of migrating birds in relation to offshore wind (Scottish Government, 2023). Novel approaches such as remote sensor and automated shut down technology are discussed further in Section 3.4.2.

3.3 Environmental mitigation measures and management plans included in scoping reports and EIARs

The literature review of publicly available scoping reports and EIARs enabled the compilation of information on management plans and mitigation measures.

The overarching management plans and that were common across scoping reports and EIARs have been summarised in Table 6 and commonly applied embedded mitigations are provided in Table 7. It is worth noting that Scotland and England have different terminology for plans that do the same or similar things (e.g. Cable Plan in Scotland is the Cable Specification and Layout Plan in England). For the purposes of this report, the focus has been with Scottish plans which are assumed to reflect those in England/Wales. It is important to recognise that in order to consider the use of post-consent plans as a mitigation tool there is a need to ensure that sufficient commitment and detail is available at application to provide reassurance that the impact pathway is mitigatable.

These plans underpin the strategy for management of a wind farm throughout the various stages of the development life cycle and, along with the broad measures outlined in Section 3.2, set the scene of what would be considered to be industry good practice mitigation measures and applicable to ScotWind projects. Similarly, the embedded



mitigations listed in Table 7 are broadly considered here to be generally incorporated for any new development where applicable, and begins to frame the development of a Good Practice Library of environmental mitigation measures for ScotWind projects.

In addition to these, more specific environmental receptor based mitigation measures included in EIARs and for which are accounted for in the subsequent sections, as follows:

- Physical Environment (Section 3.3.1);
- Water and sediment quality (Section 3.3.2);
- Benthic subtidal and intertidal ecology (Section 3.3.3);
- Fish and shellfish (Section 3.3.4);
- Marine mammals and megafauna (Section 3.3.5); and
- Offshore and intertidal ornithology (Section 3.3.6).

Commentary is provided within each of these subsections with discussion on whether they could be considered as representative of good practice, drawing on the criteria explained in Section 2.5 and existing good practice guidance and measures outlined in Section 3.2. The list of the environmental receptors in this report are listed in order to maintain an emphasis on ecologically relevant mitigations which are the focus of this study, any mitigations that are specifically associated with human receptors including offshore industry, socioeconomic and visual impacts have not been discussed in detail in this report. However, it should be made clear that mitigations relating to human receptors are also very pertinent to ScotWind projects, as outlined previously in Section 3.2 and covered in management plans in Table 6.

The list of EIARs and Scoping Reports that were the source of these measures can be seen in Appendix A.



Table 6 Summary table of management plans referenced in EAIRs and Scoping Reports for offshore wind farms in Scotland and England

MANAGEMENT PLAN/DOCUMENT	DESCRIPTION	RECEPTORS
Relevant to Scotland		
Environmental Management Plan (EMP)	<p>The EMP provides a means to ensure the efficient management and communication of commitments made for the management of the potential environmental impacts. The EMP must provide the over-arching framework for on-site environmental management during the phases of development as follows:</p> <ul style="list-style-type: none"> a. All construction as required to be undertaken before the Final Commissioning of the Development; and b. The operational lifespan of the Development from the Final Commissioning of the Development until the cessation of electricity generation (environmental management during decommissioning is addressed by the Decommissioning Programme). <p>It must address, amongst other things, mitigation measures to prevent significant adverse impacts to environmental interests, as identified in the Application and pre-consent and pre-construction monitoring or data collection, and include reference to relevant parts of the CMS;</p>	Various
Project Environmental Monitoring Programme (PEMP)	<p>The PEMP ensures that appropriate and effective monitoring is undertaken to validate of the predicted impacts from the Development. The PEMP must set out measures by which the Company must monitor the environmental impacts of the Development. Monitoring is required throughout the lifespan of the Development where this is deemed necessary by the Scottish Ministers. Lifespan in this context includes pre-construction, construction, operational and decommissioning phases.</p>	Various
Design Statement	<p>The statement details the final design of the offshore development and associated infrastructure. This will include visualisations of how the final design for the offshore development will look from selected viewpoints.</p>	Other sea users
Vessel Management Plan (VMP) and Navigation Safety Plan (NSP)	<p>A VMP main reason is to mitigate the impacts of vessels. confirms the types and numbers of vessels engaged in the development and considers vessel coordination, including indicative transit route planning. This will also detail the ports and transit corridors proposed. The plan contributes to the minimisation of disturbance of seabird species by avoiding bird populations and/or migratory routes and allow the identification of standard routes (guidance should be provided to vessel operators as part of the code of conduct. Vessels should adhere to guidelines laid out in the Scottish Marine Wildlife Watching Code.</p> <p>A Navigation Safety Plan (NSP) details navigational safety measures, construction exclusion zones if required, notices to mariners and radio navigation warnings, anchoring areas, lighting and marking requirements and emergency response procedures during all phases of the project. The NSP sets out the WTG lighting requirements for shipping and navigational safety and adopts good practice in respect of seabird attraction to lighting.</p>	Various



MANAGEMENT PLAN/DOCUMENT	DESCRIPTION	RECEPTORS
Cable Plan (CaP)	Covers details of cable installation in line with consented conditions including Installation methods, routing; technical specifications, attenuation of EMF, cable burial risk assessments, burial and protection plans and methods for surveys of the cables through the operational life.	Benthic subtidal and intertidal; fish and shellfish.
Construction Environmental Management Plan (CEMP) . Set out in a Construction Environmental Management Document (CEMD)	The CEMP sets out procedures to ensure all activities with potential to affect the environment are appropriately managed and includes: description of works and construction processes, roles and responsibilities, description of vessel routes and safety procedures, pollution control, invasive species management, spillage response plans, incident reporting, chemical usage requirements, waste management plans, plant service procedures, communication and reporting structures and timeline of work.	Various
Development Specification and Layout Plan (DSLPL)	Provides the final siting and design of the windfarm component including all wind turbine parameters. The layout of the proposed development ensures, as far as practicable, the reduction of seascape, landscape and visual effects on the closest coastal receptors.	Seascape, landscape, and visual impacts
Marine Pollution Contingency Plan (MPCP)	This plan includes specific requirements of the relevant conditions attached to a Section 36 consent relating to pollution incidents. Specifically This plan will include a risk assessment of the potential sources and likelihood of a pollution incident, including any oil and chemical spill response procedures and actions.	Various
Piling Strategy (PS)	Where required, a Piling strategy will provide full details of the proposed method and anticipated duration of piledriving at all locations; Details of soft-start piling procedures and anticipated maximum piling energy required at each pile location; and Details of mitigation and monitoring to be employed during pile-driving, as agreed by the Scottish Ministers.	Marine Mammals, fish
Marine Mammal Monitoring Plan (MMMP)	The MMMP mitigate potential impacts from underwater noise on marine mammals and fish through good or standard practice actions in order to meet legislative requirements.	Marine Mammals
Construction Method Statement (CMS)	The Statement details how the offshore development activities and plans identified within the CEMP are carried out whilst also highlighting any possible dangers/risks associated with particular offshore development activities. The statement details good working practices for constructing the works, and how the construction related mitigation steps are to be delivered.	Various
Lighting and Marking Plan (LMP)	The LMP confirms appropriate lighting and marking mitigation whilst ensuring compliance with legal requirements with regards to shipping, navigation and aviation marking and lighting. The LMP sets out the Wind Turbine Generators lighting requirements for aviation safety, adopting good practice in respect of seabird attraction to lighting, as recommended by NatureScot (2020).	Various
UXO Management Plan	The purpose of this Unexploded Ordnances UXO Management Plan is to set out the approach to manage and mitigate impacts of potential UXO finds during project construction.	Marine Mammals, Fish



MANAGEMENT PLAN/DOCUMENT	DESCRIPTION	RECEPTORS
Shipboard Oil Pollution Emergency Plan (SOPEP) – Applicable to Scottish projects	Vessels adopt a waste management plan in line with the requirements set out as part of International Convention for the Prevention of Pollution from Ships (MARPOL) and the SOPEP. Applicable to Scottish projects.	Water and sediment quality
Invasive Non-Native Species Management Plan (INNSMP) – Applicable to Scottish projects	An INNSMP is implemented to manage and reduce the risk of potential introduction and spread of INNS as far as reasonably practicable. The plan includes but may not be limited to measures to facilitate vessel compliance with the International Maritime Organisation (IMO) ballast water management guidelines (International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004) and adherence to the IMO guidelines for the control; management of ships' biofouling to minimise the transfer of invasive aquatic species (Biofouling Guidelines). The INNSMP considers the origin of vessels and contain standard housekeeping measures for such vessels as well as measures to be adopted in the event that a high alert species is recorded. Training on MINNS is provided to contractors conducting operation and maintenance tasks so that common INNS can be recognised, and steps to take if such species are observed on moorings to prevent further spread.	Benthic subtidal and intertidal; Marine mammals and megafauna; Shipping and navigation
Construction Project Environmental Management and Monitoring Plan (CPEMMP) (England)	The CPEMMP is specific plan that includes: a Marine Pollution Contingency Plan (MPCP) to address the risks, methods and procedures to deal with any spills and collision incidents of the authorised project in relation to all activities carried out below MHWS; a chemical risk review to include information regarding how and when chemicals are to be used, stored and transported in accordance with recognised good practice guidance; a marine biosecurity plan detailing how the risk of introduction and spread of invasive non-native species will be minimised; waste management and disposal arrangements	Various
Operational Environmental Management Plan (OEMP) England Only – Included in EMP in Scotland)	The OEMP guides operations and maintenance activities during the life cycle of the offshore development. The OEMP also sets out the procedures for managing and delivering the specific environmental commitments including a Marine Pollution Contingency Plan (MPCP) and an Invasive Non-Native Species (INNS) Management Plan. Adopting these protocols reduces the risk in relation to spread of contaminants and radioactive particles across all phases of the offshore developments.	Various
Wet Storage Plan (WSP)	The WSP provides details on requirements (if applicable) for assembled Wind Turbine Generators and cabling.	Various
Marine Mammal Mitigation Protocol (MMMM) Applicable to Scottish waters	This protocol outlines how avoidance/minimisation mitigation will be rolled out during a noisy (or other) activity. In simplest terms, this is a “user guide” for Marine Mammal Observers or others, required to be on the construction site by consent condition, to adhere to reduce risks to marine mammals. In order to meet legislative requirements. This relates to the JNCC guidance on minimising impacts of noise and role of the MMO.	Fish and shellfish; Marine mammals and megafauna;
Aids to Navigation Management Plan (ANMP) (English Waters only)	The ANMP sets out details of the Aids to Navigation (AtoN), including maintenance and repair of AtoN, associated with the offshore Project, in accordance with relevant guidance, during construction and operation and maintenance.	Shipping and navigation
Contractor Safe Systems of Work (SSoW) (Applicable to Scottish projects)	Dependent on the nature of the potential harm, there are appropriate systems in place to manage the risk. Major accidents and disasters are high consequence events which need significantly more robust control measures than low consequence events like slips and trips. It is anticipated that all accident scenarios have safe ways of working, procedures and permits to	Major accidents-disasters



MANAGEMENT PLAN/DOCUMENT	DESCRIPTION	RECEPTORS
	ensure that risk is managed. There are also processes in place (wherever possible) to forewarn and protect against the impacts of disasters such as flood warnings and wind forecasting.	
Emergency Response Co-Operation Plan (ERCOP) (applies to Scottish projects)	The ERCOP refers to the marking and lighting of the WTGs and considers helicopters undertaking Search and Rescue (SAR) operations when rendering assistance to vessels and persons in the vicinity of the proposed development. The ERCOP provides information about the Project, actions and details required in the event of an emergency situation.	Shipping and navigation; Military, aviation, and radar; Other sea users; Major accidents-disasters;
Entanglement Management Plan (applies to Scottish projects)	This management plan aims to reduce the potential entanglement risk to marine life.	Fish and shellfish; Marine mammals and megafauna; Offshore and intertidal ornithology
Pollution Control and Spillage Response Plans	These plans reduce the potential for accidental pollution and in the event of a pollution incident, and ensure a rapid and appropriate response.	Major accidents-disasters; Fish and shellfish; Marine mammals and megafauna; Offshore and intertidal ornithology; Commercial fisheries; Water and sediment quality; Other sea users
Decommissioning Programme – Applicable to Scottish projects	The development of, and adherence to, a Decommissioning Programme, approved by Scottish Ministers prior to construction and updated throughout the Project lifespan.	Physical environment; Water and sediment quality; Benthic subtidal and intertidal; Fish and shellfish; Marine mammals and megafauna; Offshore and intertidal ornithology; Commercial fisheries; Shipping and navigation; Marine archaeology and cultural; Military, aviation, and radar; Seascape, landscape, visual impacts; Socio-economics; Other sea users; Climate change and carbon; Major accidents-disasters



Table 7 Summary table of common embedded mitigations seen in Scoping reports and EIARs for offshore wind farms in Scotland and England

EMBEDDED MITIGATION	DESCRIPTION	RECEPTORS
Site selection	Site selection includes the avoidance wherever possible of a range of sensitive historical, cultural, and ecological conservation areas (including statutory and non-statutory designations).	Physical environment; Water and sediment quality; Benthic subtidal and intertidal; Commercial fisheries; Offshore and intertidal ornithology; Marine Mammals, Military, aviation, and radar; Seascape, landscape, visual impacts; Marine archaeology and cultural; Other sea users
Micrositing of infrastructure including cable routes	<p>Project infrastructure is micro-sited, where reasonably practicable (to an extent not resulting in a hazard for marine traffic and Search & Rescue capability), to avoid interactions with key designations, environmental sensitivities, and notable fishing grounds informed through the undertaking of survey works pre-construction.</p> <p>The appropriate distance for avoidance will depend on the sensitivity that is being avoided so this is not prescribed. For benthic habitats, consideration should be given to the potential expansion of the habitat where the conditions are present (e.g. biogenic reef which would be different from a bedrock reef for instance which is fixed in position).</p> <p>In line with good practice, vehicle movements in the intertidal area should be limited in number and kept within the minimum practicable working area. The amount of rock, grout bags or mattresses used to protect infrastructure should be kept to a minimum.</p>	Physical environment; Water and sediment quality; Benthic subtidal and intertidal; Fish and shellfish; Climate change and carbon;
Guard vessels	Where appropriate, guard vessels are used to ensure adherence with Safety Zones or advisory passing distances to mitigate any impact which poses a risk to surface navigation during construction, maintenance, and decommissioning phases. Such impacts may include partially installed structures or cables, extinguished navigation lights or other unmarked hazards.	Commercial fisheries; Shipping and navigation; Other sea users; Major accidents-disasters
Pre-construction surveys	Pre-construction surveys are implemented in order to identify any potential hazards within the proposed development/offshore export cable corridors. These include geophysical surveys to identify seabed hazards such as discarded fishing gear, wrecks or unidentified objects and magnetometer surveys to identify for the presence of UXO devices and environmental surveys for sensitive habitats. These surveys can sometimes be at plan level, or regional in collaboration with other developers as well as project specific. When undertaken in collaboration the disturbance elements can be reduced and viewed positively in terms of mitigation.	Other sea users; Marine archaeology and cultural, Physical environment, Benthic, Fish and shellfish.
Protocols for managing radioactivity risk	Associated with the risk assessment are a number of recommendations including protocols and procedures for managing and mitigating the risk of coming in contact with and spreading radioactive particles.	Water and sediment quality; Climate change and carbon



EMBEDDED MITIGATION	DESCRIPTON	RECEPTORS
<p>Promulgation of information</p>	<p>The promulgation of information may include: (for commercial fisheries, shipping and navigation, and other sea users receptors)</p> <ul style="list-style-type: none"> • Notification to the UK Hydrographic Office (UKHO)/Kingfisher of the proposed works to facilitate the promulgation of maritime safety information and updating of nautical /admiralty charts and publications; • Timely and efficient distribution of Notice to Mariners (NtMs), Kingfisher notifications and other navigational warning on the location, duration, and nature of works, including, statutory and advisory safety zones. <p>(for the military, aviation, and radar receptors)</p> <ul style="list-style-type: none"> • Notification to the Civil Aviation Authority (CAA) on the locations, heights and lighting status of the WTGs, including estimated and actual dates of construction and the maximum heights of any construction equipment to be used, prior to the start of construction. 	<p>Commercial fisheries; Shipping and navigation; Other sea users; Military, aviation and radar; Socio-economics; Major accidents, disasters.</p>



3.3.1 Physical environment

Mitigation measures that have been identified for the physical environment and associated processes can be seen in Table 8 below. As can be seen, the majority of mitigations that typically apply to physical and coastal processes relate to the construction and installation activities. Of these, one key mitigation follows the first step of the mitigation hierarchy as an avoidance; that of using trenchless designs for landfall which essentially avoid disturbance to potentially sensitive intertidal features and dynamic processes. It would be recommended that such avoidance measures should be embedded in good practice mitigation measures.

All other mitigations identified from EIARs are intended to minimise the environmental effects. The applications of these will depend largely on the site conditions, although some key principles will remain the same. For instance, the primary purpose of cable protection is to ensure offshore cable burial (minimum ~0.5 m) without the need for additional rock protection, which is considered to be good practice where it is technically viable to achieve. Where rock is required to provide appropriate protection, then this should be minimised in extent wherever possible (such as 1:3 ratio berms) to reduce any impacts on coastal processes such as sediment transport. In particularly sensitive areas that cannot be avoided, rock may be potentially substituted by protection such as cast iron shell protection which can significantly reduce the seabed footprint of cable protection. This minimisation is also the same principle for reducing the direct impact to benthic habitats which is discussed further in Section 3.3.3. As these are broadly all encompassed by the existing guidance (see Section 3.2) and commonly used already, it is reasonably considered that the mitigations identified for physical and coastal processes (Table 8) remain suitable and represent good practice for offshore wind projects in Scotland.

ScotWind projects can occur in relatively deep waters all around Scottish offshore area, therefore, there is the need to take account of mixing of fronts and whether there is any effects to the water column structure such as the location and timing of seasonal stratification. This can have a bearing on cumulative impacts and should be considered in site selection and foundation design. However, there are no specific mitigations relating to this that were identified as part of this review.

It is noted that not all measures will be applicable to all projects. In particular, aspects around the consideration of smaller diameter gravity based structures (GBS) are only going to be applicable to installations associated with this technology but the principle of minimising the overall project footprint is relevant. For floating wind, the mooring and anchoring configuration on the seabed will be an important consideration for inclusion in a suite of good practice applicable to Scotland as well as minimisation of associated drag and scouring that may be encountered through installation and operational phases of a floating offshore wind project.



Table 8 Mitigation measures for physical and coastal processes

MITIGATION HEIRARCHY	PROJECT STAGE ⁴	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Avoidance of intertidal direct footprint.	C/I	Trenchless Landfall construction	<ul style="list-style-type: none"> Trenchless techniques, such as Horizontal Directional Drilling (HDD) be used at the Landfall. Landfall construction activities will avoid any works in the intertidal environment and will reduce the potential for sediment disturbance. 	Hornsea Four; Berwick Bank Pentland
Minimisation of effects on hydrodynamics	C/I	Sufficient spacing between wind turbines	<ul style="list-style-type: none"> Sufficient spacing between wind turbines (at least 1,000m). Sufficient spacing between wind turbines to mitigate wake effects and changes to the wave field. 	Morven
Minimisation of seabed impact.	C/I	Use of the smaller diameter GBS foundations (subsequently reverted to suction buckets	<ul style="list-style-type: none"> Predicted direct impacts to the bedform will be primarily mitigated through use of the smaller diameter GBS foundations for the major infrastructure where possible and subject to detailed design criteria on a case-by-case basis. Where possible, jacket substructure/foundations will be preferred to reduce the need for seabed preparation (and limit potential sediment release and consequent contaminant remobilisation). Note that Final installed design actually used suction buckets which has added value in that it allows more straight forward removal at the end of operational life. 	Seagreen Alpha and Bravo Moray West
Minimisation of long term impacts to seabed	C/I	Cable burial	<ul style="list-style-type: none"> Where practicable, cable burial will be the preferred means of cable protection. Cable burial will be informed by the Cable Burial Risk Assessment (CBRA) and detailed within the CaP. 	Hornsea Four; Caledonia Moray West Hornsea 3
Minimisation of rock/scour and effects to sediment transport.	C/I; O/M	Scour protection	<ul style="list-style-type: none"> Scour protection will only be implemented where required and will be minimised as far as is practicable. This will be informed by a scour studies/assessment. While this is generally a standard practice and acknowledged that this is largely driven by cost reduction, it is nonetheless important to note that the optimisation of rock does ensure that the minimum amount of material is deployed that is technically sufficient, i.e. contingency quantities will not be deposited unless there is a technical reason to do so. Therefore it is considered that this is still merited as a mitigation measure to minimise rock. 	Pentland, Morven; Muir Mhòr; Marram Wind Moray West Near Na Gaoithe Hywind Hornsea 3 West of Orkney

⁴ C/I: Construction/Installation; O/M: Operation/Maintenance



MITIGATION HEIRARCHY	PROJECT STAGE ⁴	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Minimisation of rock armour on cables	C/I; O/M	Cable protection	<ul style="list-style-type: none"> Additional external cable protection (e.g., rock placement) will only be used where the minimum target burial depth cannot be achieved, for example in areas of hard ground or at third-party crossings, or where cables become exposed during the project lifetime. Cable protection will be minimised as far as practicable. Rock utilised in berms will be clean with low fines. Use of graded rock and 1:3 profile berms at areas of rock protection will reduce potential fishing gear snagging risk. Rock protection placement will be informed by outputs from the CBRA. 	Berwick Bank; West of Orkney
Minimisation	C/I; O/M	Cable protection monitoring and management	<ul style="list-style-type: none"> To ensure that the Cable Plan has been successfully implemented, monitoring will be undertaken as part of wider Array Project. Pre- and post-construction geophysical surveys are likely to involve a combination of MBES or high-resolution SSS. This minimises the risks of underwater allision with cable protection, anchor or fishing gear interaction with subsea cables and interference with magnetic position fixing equipment. Any damage, destruction or decay of cables notified to MCA, NLB, Kingfisher and United Kingdom Hydrography Office (UKHO) no later than 24 hours after discovered. Secured through the Navigation Safety and Vessel Management Plan. 	Morven
Minimisation of potential for release of contaminants		Optimisation of Dredging and drilling	<ul style="list-style-type: none"> 	Moray West
Minimisation of seabed footprint	C/I;	Optimise cable laying by Nearshore Survey to inform cable laying	<ul style="list-style-type: none"> Nearshore surveys were conducted to determine the optimal design of the intertidal and nearshore cable laying activities. 	Near Na Gaoithe West of Orkney
Minimisation of long term impacts to sea bed	C/I;	Backfilling of trenches	<ul style="list-style-type: none"> Upon completion of the cable trenching activities the seabed sedimentation which was disrupted was backfilled. This allowed for the environment to be restored to similar state prior to any construction works being undertaken 	Hornsea 3 Moray East Near Na Gaoithe
Minimisation of long term impacts to sea bed	C/I;	Micrositing of WTGs and associated infrastructure	<ul style="list-style-type: none"> Micrositing of the WTGs and associated infrastructure is undertaken to avoid areas of higher sensitivity to construction/installation activities reducing the potential impacts which the activities may have on the surrounding receptors. 	Pentland Hornsea 3



3.3.2 Water and sediment quality

Mitigation measures that have been reviewed for water and sediment quality in Scoping Reports and EIARs can be seen in Table 9 below. There are a number of avoidance measures that came out in the review, which would seem fundamental to early project planning. A key observation is that early identification of site conditions can assist with siting a project at the very early stages of the development and can ensure that sensitive features or contaminated sites can be avoided and also that protective material can be reduced. The use of PLONOR chemicals for directional drilling was identified in the review and this measure also discussed in conversations with developers (Section 3.1) where it was generally agreed that this was a typical embedded measure for any directional drilling operations and thus considered good practice. The deposition of materials such as manufactured concretes for example should also be environmentally inert and such avoidance of toxic contaminants is considered here to be representative of good practice. Any siting of a project to avoid protected areas, where possible is considered to be best practice. Specific aspects that are included for the Pentland offshore wind project to ensure containment of leaks from the nacelle tower would appear to be integrated in design to avoid leaks to sea could be something that should be considered for future projects.

A potential impact on water quality that may have implications on blade construction was the possibility of microplastics in the environment from the degradation of the blade material over time. While there was no specific mitigation identified although it was recommended that consideration of hard wearing and durable materials that are resistant to abrasion and associated release of microplastics to the environment should be taken. It is noted that this would not strictly be an environmental mitigation but a more fundamental design consideration for efficient wind turbine function and reduced maintenance activities.

It was considered that the remainder of the minimisation measures included in this list are generally good practice where the situation arises. In addition, the Seagreen offshore wind farm proposed some measures to reuse dredged sediment for the inclusion of additional substructure ballast material. It was unclear if this was utilised in practice.



Table 9 Mitigation measures for water and sediment quality

MITIGATION HEIRARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Avoidance of sensitive sites.	C/I	Locations of the anchors and OSP foundations	<ul style="list-style-type: none"> The locations of the anchors and OSP foundations will be determined in advance using survey information, therefore the location of each anchor will be chosen to avoid the need for seabed preparation (i.e., avoiding pock marks or straddling through micro-siting). 	Green Volt
Avoidance of dispersing contaminants.	C/I; O/M	Deposition of material on seabed	<ul style="list-style-type: none"> Ensure that any material to be deposited in the sea (metal components, rock for armour, concrete mattresses) does not contain toxic materials that could leach into the sea water and result in toxic effects. 	MarramWind
Avoidance of contaminated sediments.	C/I	Avoidance of localised dredge disposal sites	<ul style="list-style-type: none"> Localised dredge disposal sites have been avoided in all export cable routing options. 	Green Volt
Avoidance of protected areas.	C/I	Transition pits sited to avoid Marine Protected Areas (MPAs)	<ul style="list-style-type: none"> Transition pits sited to avoid Marine Protected Areas (MPAs). 	Green Volt
Minimisation of releases to sea.	C/I	Nacelle, tower, and rotor design	<ul style="list-style-type: none"> The nacelle, tower, and rotor are designed and constructed in order to contain leaks thereby reducing the risk of spillage into the marine environment. It is noted that this measure is not considered a true mitigation as the standard practice of such as design is a given rather than something incorporated specifically as an environmental mitigation measure. 	Pentland
Minimisation of releases to sea.	C/I	Wind Turbine Generator (WTG) and Offshore Substation Platform (OSP) design	<ul style="list-style-type: none"> The WTG and OSP topsides are designed and constructed to contain leaks, thereby reducing the risk of spillage into the marine environment. It is noted that this measure is not considered a true mitigation as the standard practice of such as design is a given rather than something incorporated specifically as an environmental mitigation measure. 	West of Orkney
Minimisation of seabed footprint.	C/I	BPEO for Seabed preparation and installed infrastructure	<ul style="list-style-type: none"> This will necessarily consider details of the areas and materials to be dredged and a BPEO Assessment for deposit of the materials, including consideration of re-use of material as substructure/foundation ballast, beneficial use and disposal at sea. 	Seagreen Alpha and Bravo
Minimisation of effects from sediment resuspension	C/I	Landfall HDD	<ul style="list-style-type: none"> Good practice guidance will be followed to ensure that potential damage to coastal environmental features by disruption of sediment transport is minimised throughout the proposed construction works. 	MarramWind; Green Volt



MITIGATION HEIRARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
			<ul style="list-style-type: none"> The use of HDD activities for the installation of export cables at the landfall will assist in minimising impact. HDD use results in no potential resuspension of sediments within the intertidal and near shore area. Prior to the last one to two metres of HDD drill out before punch out, the borehole will be flushed with water to minimise the risk of bentonite slurry entering the marine system. No rock dumping or surface protection of cables in shallow inshore water is necessary as cables will be buried. The HDD Contractor, through their construction method statement(s) shall commit to contain, handle, and dispose of drilling fluids in accordance with the standard requirements and good practice, and to ensure that a Competent Person (for purposes of the relevant licensing requirements, regulations and standards) is present on site whenever HDD activities are undertaken. 	
Minimisation of toxic effects from drilling	C/I	Use of "Pose Little or No Risk (PLONOR) substances" at Landfall	<ul style="list-style-type: none"> Small quantities of drilling fluids may be discharged to the marine environment, however good practice mitigation will be implemented to reduce the amount of drill mud/cuttings released in the event of a release. To limit environmental damage, only biologically inert PLONOR listed drilling fluid will be used. 	Berwick Bank
Minimisation	C/I	Minimisation of drill mud discharge	<ul style="list-style-type: none"> Drill mud discharge will be kept to a minimum and will be water-based, rather than oil-based, with minimum drilling lubricants used during the final exit phase onto the seabed. 	Green Volt
Minimisation of barrier effects to fish migration.	C/I	Minimisation of barrier effect to fish migration due to mobilised sediments by appropriate timing of operations	<ul style="list-style-type: none"> Minimise potential for creation of a temporary barrier to fish migration in any river adjacent to cable landfall(s) due to a plume of mobilised sediment obstructing the river entrance by appropriate timing of operations close to the shore regarding tidal flows and fish migration seasons. 	MarramWind
Minimisation of scour around infrastructure	C/I; O/M	Scour protection	<ul style="list-style-type: none"> Scour protection or other appropriate mitigation to be employed around seabed infrastructure where there is the potential risk for significant scour to develop. 	Muir Mhòr
Minimisation of turbine particles to sea.	C/I; O/M	Robust Turbine component materials to reduce abrasion and breakdown into sea.	<ul style="list-style-type: none"> Ensure Turbine blades are constructed of robust materials with lo degradation rates to minimise pollution resulting from eroded blade particles entering the sea. 	No project example. Raised in discussions Potential future concern.
Optimisation of cable laying	C/I;	Nearshore Survey to inform cable laying	<ul style="list-style-type: none"> Nearshore surveys were conducted to determine the optimal design of the intertidal and nearshore cable laying activities. 	Near Na Gaoithe West of Orkney



MITIGATION HEIRARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Minimisation of long term impacts to sea bed	C/I;	Backfilling of trenches	<ul style="list-style-type: none"> Upon completion of the cable trenching activities the seabed sedimentation which was disrupted was backfilled. This allowed for the environment to be restored to similar state prior to any construction works being undertaken 	Hornsea 3 Moray East Near Na Gaoithe
Minimisation of long term impacts to sea bed	C/I;	Micrositing of WTGs and associated infrastructure	<ul style="list-style-type: none"> Micrositing of the WTGs and associated infrastructure is undertaken to avoid areas of higher sensitivity to construction/installation activities reducing the potential impacts which the activities may have on the surrounding receptors. 	Pentland Hornsea 3



3.3.3 Benthic subtidal and intertidal ecology

Mitigation measures that have been proposed for benthic subtidal and intertidal ecology can be seen in Table 10 below. The primary avoidance mitigation identified is to completely avoid intertidal impact through trenchless techniques. This mitigation was also highlighted for the physical environment (Section 3.3.1) and applies here as representing good practice. Similarly, micrositing was proposed as an avoidance measure to avoid of sensitive benthic habitats. While it may seem obvious, avoidance measures would be expected to be considered into the siting of specific offshore wind infrastructure as good practice. It is noteworthy that such site selection and any such considerations were not documented in the EIARs reviewed and it could be that these were included in earlier stages of project design. However, it is acknowledged that from a broad perspective, the site selection planning for ScotWind was refined through the Scottish Governments Sectoral Marine Plan (SMP) that covers the regional locational guidance and defines geographic scope and identification of the 15 plan option areas (Scottish Government, 2020).

Cable burial success and measures taken to reduce rock protection were widely adopted and can be considered to be an embedded good practice, where it is applicable. It is noted that in some instances, the substrate may not be suitable for cable burial and that alternative mitigations may need to be considered to achieve cable protection while minimising the seabed impact. It is worth noting that some of the minimisation measures identified are specific to GBS' and foundations associated with conventional wind turbines and this may not be necessarily applicable to floating wind technologies that will likely be a common feature in ScotWind projects.

A mitigation that came up in the review is that cable protection would match up as much as possible with the existing hard substrate, in terms of size, shape and type of rock/ materials used in order to reduce habitat alteration. At the time of writing, there is limited evidence of this having been deployed and or what its effectiveness would be. Such mitigation measures where surrogate habitat such as modified rock protection has been identified as an NID measure is subject to further consideration in the CEMNID Project literature review of NID options (A-100906-S00-REPT-A-003) and NID Suitability Review (A-100906-S00-REPT-A-005).



Table 10 Mitigation measures for benthic subtidal and intertidal

MITIGATION HEIRARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Avoidance of sensitive seabed features	C/I	Locations of the anchors and OSP foundations	<ul style="list-style-type: none"> The locations of the anchors and OSP foundations will be determined in advance using survey information, therefore the location of each anchor will be chosen to avoid the need for seabed preparation (i.e., avoiding pock marks or straddling through micro-siting). 	Green Volt
Avoidance to intertidal sensitivities	C/I	Landfall construction/installation methodology	<ul style="list-style-type: none"> Trenchless techniques, such as Horizontal Directional Drilling (HDD) will be used at the Landfall for the construction of the Marine Scheme. Landfall installation methodology (HDD) will avoid direct impacts to the intertidal area. Works associated with Landfall construction activities will avoid any works in the intertidal environment and will reduce the potential for sediment disturbance. Depending on the site characteristics and the final landfall(s) selection/design taken forward, a cofferdam construction may also be considered. 	Berwick Bank; West of Orkney
Minimisation of Seabed footprint from rock placement.	C/I	Cable burial	<ul style="list-style-type: none"> Cables will be buried, where possible, for both the inter-array and export cables aiming to reduce the need for additional cable protection, and therefore as the amount of hard substrate required. This will provide some separation distance between the cables and the majority of benthic ecological receptors, therefore minimising potential effects of EMF. Application of target cable burial depth will reduce the potential for cable exposure from interactions between metocean regimes (e.g. wave, sand and currents) and will reduce interaction with fishing gear. Cable burial also reduces risk of interference with magnetic position fixing equipment. Cable burial will be informed by the CBRA and detailed within the CaP. The cable burial target depth will be informed by a CBRA and implemented through the Cable Plan (CaP) produced post-consent. Sections of cable may also be fitted with additional cast iron or synthetic external cladding to provide localised protection in certain areas. 	Berwick Bank; Caledonia; Hornsea Four; Pentland Moray West Near Na Gaoithe
Minimisation of effects from EMF	C/I	Cable grouping	<ul style="list-style-type: none"> Grouping cables of opposite polarity will result in deleterious interference between the EMFs from adjacent cables, which will further reduce the field EMF strengths resulting from the Marine Scheme. The design of the Marine Scheme will be further refined, informed by onward detailed engagement with the supply chain and various technical, practical, and commercial 	Berwick Bank



MITIGATION HEIRARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
			<p>considerations. As part of this refinement, the cable configuration will be optimised and options to reduce EMF assessed.</p> <ul style="list-style-type: none"> Beyond the configuration commitment detailed above, practical solutions for reducing EMF arising from the Offshore Export Cables may include reducing cable separation or adopting a bundled solution. 	
Minimisation of rock placement on seabed	C/I, O/M	Cable protection	<ul style="list-style-type: none"> Cable protection may be necessary in some locations where a sufficient target cable burial depth cannot be achieved or where cables become exposed during the lifetime of the Array Project. Cable protection needs will be informed by outputs from the Cable Burial Risk Assessment completed by the installation contractor(s) prior to the commencement of installation. Burial or protection of cables increases the distances between cables and benthic subtidal and intertidal ecology receptors, reducing EMF effects. The use of cable protection will be minimised as far as practicable, and only used where required. Rock utilised in berms will be clean with low fines. Use of graded rock and 1:3 profile berms at areas of rock protection will reduce potential fishing gear snagging risk. To ensure that the Cable Plan has been successfully implemented, monitoring will be undertaken as part of wider Array Project pre- and post-construction geophysical surveys and are likely to involve a combination of multibeam echosounder or high-resolution side-scan sonar. This minimises the risks of underwater allision with cable protection, anchor or fishing gear interaction with subsea cables and interference with magnetic position fixing equipment. Cable protection will be monitored as per cable suppliers' recommendations, and in agreement with power purchase customers. Should any sections of the marine cable require additional protection following combined lay/burial operation, then this will be provided by post lay jet burial (if possible), engineered, localised rock placement or concrete mattresses. 	Caledonia; Green Volt; West of Orkney
Minimisation/Restoration of stony/rocky seabed (may be form of NID)	C/I, O/M	Material for cable protection	<ul style="list-style-type: none"> Where possible, cable protection will match up as much as possible with the existing hard substrate, in terms of size, shape and type of rock/ materials used in order to reduce habitat alteration. 	Berwick Bank Moray East
Minimisation	O/M	Monitoring of cable protection	<ul style="list-style-type: none"> Suitable implementation and monitoring of cable protection (via burial, or external protection where adequate burial depth as identified via risk assessment is not feasible). 	Caledonia; west of Orkney



MITIGATION HEIRARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Minimisation of scour protection requirements	C/I, O/M	Application of scour protection	<ul style="list-style-type: none"> Scour protection will be installed around the anchor installations, where required, based on the detailed design of the final anchor option selected and supporting assessments. This will therefore negate the introduction of scour during the operation and maintenance phase. 	Pentland, Morven; Muir Mhòr; Marram Wind Moray West Neart Na Gaoithe Hywind Hornsea 3 West of Orkney
Minimisation of toxic effects from drill mud and cuttings.	C/I	Pose Little or No Risk (PLONOR) substances	<ul style="list-style-type: none"> Use of good practice mitigation will be implemented to reduce the amount of drill mud/cuttings released in the event of a release. To limit environmental damage, only biologically inert PLONOR listed drilling fluid will be used. 	Berwick Bank
Minimisation of impacts to sea bed	C/I;	Optimisation cable laying - Nearshore Survey to inform cable laying	<ul style="list-style-type: none"> Nearshore surveys were conducted to determine the optimal design of the intertidal and nearshore cable laying activities. Noted that this would be undertaken from an engineering perspective in any case and this measure is not necessarily Environmentally driven. 	Neart Na Gaoithe West of Orkney
Minimisation of long term impacts to sea bed	C/I;	Backfilling of trenches	<ul style="list-style-type: none"> Upon completion of the cable trenching activities the seabed sedimentation which was disrupted was backfilled. This allowed for the environment to be restored to similar state prior to any construction works being undertaken 	Hornsea 3 Moray East Neart Na Gaoithe
Minimisation of long term impacts to sea bed	C/I;	Micrositing of WTGs and associated infrastructure	<ul style="list-style-type: none"> Micrositing of the WTGs and associated infrastructure is undertaken to avoid areas of higher sensitivity to construction/installation activities reducing the potential impacts which the activities may have on the surrounding receptors. 	Pentland Hornsea 3



3.3.4 Fish and shellfish

Mitigation measures that have been identified for fish and shellfish can be seen in Table 11 below. The avoidance measures of ensuring that deposits to the sea and any associated discharges do not have the potential to incur toxic effects (e.g. use of inert materials and using PLONOR chemicals) are an important consideration for fish and shellfish receptors and would be considered good practice. In addition, underwater noise mitigation such as piling protocols and those associated with cable burial to minimum depth as protection against EMF, minimising additional rock protection, are all commonly embedded into development mitigation practices already and largely required by existing policy and or guidance. As such, it should be considered by developers whether or not these practices are applicable to a particular project or activity. The overall aim is to provide a list of good practice measures that can be considered on a project basis.

Floating wind EIAs have highlighted specific mitigation that is specific to floating wind operations. The Pentland project included the removal of debris from offshore floating lines. Debris could cause secondary entanglement of fish (and other pelagic species), and could have technical integrity implications if left unmanaged during the operational life of a project. However, available data on the risks associated with entanglement are unclear at the time of writing (SEER, 2024). Such maintenance may be considered as good practice for future Scottish offshore wind projects that may not have been captured in standard policies. Additional maintenance activities such as removal of marine growth from foundations or mooring lines may potentially have implications for fish / shellfish/ water quality and also possibly INNS, the effects from which could be monitored through periodic surveys. Indeed, removal of marine growth has been cited as embedded mitigation (for instance the Pentland EIAR), although this is strictly to manage weight/drag and induced fatigue of the infrastructure rather than have an environmental driver. Furthermore if marine growth is periodically actively removed, there may be a level of organic enrichment of the seabed which could have implications on the sediment and water quality and potentially fish and shellfish species. Specific mitigation against these effects were not encountered in the review but may potentially be worth considering.



Table 11 Mitigation measures for fish and shellfish

MITIGATION HIERARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Avoidance/ minimisation of toxic effects to benthic fauna.	C/I, O/M	Material deposited in the sea	Ensure that any material to be deposited in the sea (metal components, rock for armour, concrete mattresses) does not contain toxic material that could leach into the sea water and result in toxic effects.	MarramWind
Avoidance/ minimisation	C/I	Presence of Environmental Clerk of Works (ECoW) during Horizontal Directional Drilling (HDD) works at the landfall	Ensure appropriately qualified Environmental Clerk of Works (EcoW) presence during HDD works at the landfall.	West of Orkney Pentland
Avoidance/ minimisation of impacts to fish spawning.	C/I	Period of piling	Seasonal restriction of piling activities (out with fish spawning period). No impact piling will be undertaken between 1st September and 16th October unless otherwise agreed with the relevant stakeholders.	Hornsea Four Near Na Gaoithe
Avoidance/ minimisation	O/M	Removal of debris from floating lines and cables	Mooring lines and floating inter-array cables will be inspected with a risk-based frequency during the operational life-cycle of the Offshore Development, starting at a higher frequency and likely declining after a number of years, based on evidence gathered during inspections. Any inspected or detected debris on the floating lines and cables will be recovered based on a risk assessment which considers impact on environment, risk to asset integrity and cost of intervention.	Pentland Kinkardine Windfarm Offshore
Minimisation of impacts from noise to fish	C/I	Piling Strategy	A Piling Strategy will be written for the Offshore Development if impact piling is selected as the optimal installation mechanism for the turbine foundations. <ul style="list-style-type: none"> Development and adherence to a piling strategy for fixed accommodation platform(s) and other offshore substation(s) or platform(s). It will detail the method of pile installation, duration of activities and associated underwater noise (UWN) levels. It will describe any mitigation measures to be implemented (e.g., soft stat and ramp up measures, use of acoustic deterrent devices) prior to and during pile installation to manage the effect of UWN. 	Hornsea Four; MarramWind, Moray West Hornsea 3 Pentland West of Orkney Moray East
Minimisation of contaminant leaks	C/I	Nacelle, Tower and Rotor Design	<ul style="list-style-type: none"> The nacelle, tower and rotor are designed and constructed in order to contain leaks thereby reducing the risk of spillage into the marine environment. 	Pentland



MITIGATION HIERARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Avoidance of noise associated with Piling	C/I	Utilisation of suction bucket foundation	<ul style="list-style-type: none"> Installation of suction bucket foundations removed the requirement for piling. Where technically viable, suction buckets generally have a lower long term footprint and are easier to decommission than Gravity based structures. would be preferred to gravity based structures 	Aberdeen Bay Windfarm; Seagreen
Avoidance of noise associated with Piling	C/I	Utilisation of GBS foundations (WTG type)	<ul style="list-style-type: none"> Specification of maximum number of GBS foundations (WTG type) to be utilised. The location of GBS foundations, if used for WTG, will be confirmed through a construction method statement which will include details of foundation installation methodology 	Hornsea Four
Minimisation of EMF exposure	C/I	Cable burial	<ul style="list-style-type: none"> Cables will be buried, where possible, for both the inter-array and export cables aiming to reduce the need for additional cable protection, and therefore as the amount of hard substrate required. Application of target cable burial depth will reduce the potential for cable exposure from interactions between metocean regimes (e.g. wave, sand and currents) and will reduce interaction with fishing gear. Cable burial also reduces risk of interference with magnetic position fixing equipment. Cable burial will be informed by the CBRA and detailed within the CaP. Static cables will be trenched and buried. Where burial target depth for static cables cannot be achieved, remedial cable protection will be applied. This will provide some separation between the cables and benthic ecology receptors, therefore reducing the effect of EMF. The cable burial target depth will be informed by a CBRA and implemented through the CaP produced post-consent. Should any sections of the marine cable require additional protection following combined lay/burial operation, then this will be provided by post lay jet burial (if possible), engineered, localised rock placement or concrete mattresses. Sections of cable may also be fitted with additional cast iron or synthetic external cladding to provide localised protection in certain areas. An appropriate trenching depth will be used to ensure a limit to the rise in sediment temperature 	Hornsea Four; Muir Mhòr; Pentland Moray West Near Na Gaoithe Hywind Hornsea 3
Minimisation of EMF exposure	C/I, O/M	Cable protection	<ul style="list-style-type: none"> Cable protection may be necessary in some locations where a sufficient target cable burial depth cannot be achieved or where cables become exposed during the lifetime of the Array Project. Cable protection needs will be informed by outputs from the Cable Burial Risk Assessment completed by the installation contractor(s) prior to the commencement of installation. Burial or protection of cables increases the distances between cables and benthic subtidal and intertidal ecology receptors, reducing EMF effects. The use of cable protection will be minimised as far as practicable, and only used where required. Rock utilised in berms will be clean with low fines. Use of graded rock and 1:3 profile berms at areas of rock protection will reduce potential fishing gear snagging risk. To ensure that the Cable Plan has been successfully implemented, monitoring will be undertaken as part of wider Array Project pre- and post-construction geophysical surveys and are likely to involve a 	Muir Mhòr; Caledonia; Hornsea Four



MITIGATION HIERARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
			<p>combination of multibeam echosounder or high-resolution side-scan sonar. This minimises the risks of underwater allision with cable protection, anchor or fishing gear interaction with subsea cables and interference with magnetic position fixing equipment.</p> <ul style="list-style-type: none"> Cable protection will be monitored as per cable suppliers' recommendations, and in agreement with power purchase customers. 	
Minimisation of exposure to noise	C/I	Foundation installation	<ul style="list-style-type: none"> No more than a maximum of two foundations are to be installed simultaneously. 	Hornsea Four
Minimisation of exposure to noise	C/I	Clearance of UXO using low order techniques	<ul style="list-style-type: none"> Low order techniques for UXO detonation will be utilised wherever practicable to reduce underwater noise effects. It should be noted that low order deflagration causes UXOs to burn out without detonating and is the preferred mitigation for UXO mitigation (over controlled detonations per above). Deflagration further reduces underwater noise effects compared with detonation. 	West of Orkney
Minimisation of disturbance	C/I	Landfall installation methodology	<ul style="list-style-type: none"> The offshore export cable will be installed at the landfall(s) using most likely either open-cut/cut-and-fill construction or trenchless construction (e.g. HDD). Depending on the site characteristics and the final landfall(s) selection/design taken forward, a cofferdam construction may also be considered. Landfall installation methodology (HDD) will avoid directly impacting the tidal reaches (i.e., between MHWS and MLWS) to protect salmonid river entry. 	MarramWind West of Orkney
Minimisation of disturbance	C/I	Cable landfall	<ul style="list-style-type: none"> Minimisation of adverse effects on water and sediment quality from loss of drilling muds when using HDD across the littoral zone by employment of a site-specific good practice protocol and use of the least toxic additives. 	MarramWind
Minimisation of long term impacts to sea bed	C/I;	Backfilling of trenches	<ul style="list-style-type: none"> Upon completion of the cable trenching activities the seabed sedimentation which was disrupted was backfilled. This allowed for the environment to be restored to similar state prior to any construction works being undertaken 	Hornsea 3 Moray East Near Na Gaoithe
Minimisation of long term impacts to sea bed	C/I;	Micrositing of WTGs and associated infrastructure	<ul style="list-style-type: none"> Micrositing of the WTGs and associated infrastructure is undertaken to avoid areas of higher sensitivity to construction/installation activities reducing the potential impacts which the activities may have on the surrounding receptors. 	Pentland Hornsea 3



MITIGATION HIERARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Minimisation of marine growth	O/M	Removal of marine growth	<ul style="list-style-type: none">The removal of marine growth prevents fish prey species from colonising the marine infrastructure and avoids the creation of an artificial reef effect which would influence the local species.	Pentland



3.3.5 Marine mammals and megafauna

Mitigation measures that have been identified for marine mammals and megafauna can be seen in Table 12 below. The primary direct effects on marine mammals from offshore renewable developments are related to underwater noise. It is considered that the mitigations identified for noise associated with geophysical data acquisition and in particular piling are representative of good practices. However, review of EIARs revealed a relatively few avoidance mitigation measures for marine mammals, with regard to piling although one commitment was a seasonal restriction with regard to avoidance of piling during summer months as a result of increased abundance of minke whale at Moray West.. First considerations would be the necessity for piling at all and alternatives such as suction bucket or gravity based foundations (GBF) should be considered, especially if sensitivity is high, although it is noted that suction buckets are limited by the suitability of seabed conditions. Two good examples were identified where suction bucket design was employed instead of hammered piles at the Aberdeen Bay Windfarm and Seagreen. These windfarm projects are also examples of a project design which fundamentally changed through the pre and post consenting process to such an extent that one of the key potential impacts (noise from piling) was avoided altogether. This therefore resulted in reducing the applied mitigations associated with underwater noise that were proposed to be deployed during the construction activity. In this way, the avoidance approach falls within the mitigation hierarchy and benefits the environment in numerous ways. Suction piles may also reduce the decommissioning cost and associated impacts given that they can essentially theoretically be reverse installed (pumped out the seabed) without extensive dredging and cutting of piles. As such this avoidance measure would be considered good practice, where applicable.

However, a commitment to an alternative to piling is driven by seabed conditions which may not be known until later in the post-consent process and detailed design. Mooring deployment for floating wind and associated ballast/anchoring requirements may also present alternative options to piling. This lack of avoidance identified may be due to the early design parameters of the projects that were already mature enough to predict that such alternatives were going to be unsuitable for technical valid reasons. It is worth bearing in mind that the avoidance of piling at the expense of installing a gravity based foundation, for example, will increase the project footprint on the seabed and introduce potential further challenges at decommissioning. Therefore trade-offs on the merits of each option need to be taken into consideration.

It was noted that broad minimisation approaches such as the development of Marine Mammal Mitigation Protocols (MMMP) and adoption of JNCC guidance relating to underwater noise such as pile driving, geophysical surveys and UXO clearance (if needed) are generally implemented as standard practice with project specific plans developed in consultation with regulators and SNCBs. Under certain circumstances there may be the requirement to consider further mitigation, especially where there are particularly sensitive areas (e.g. site integrity plans for the southern North Sea SAC, and Moray Firth (MFRAG, 2015)). More discussion of additional options are included in Section 3.4.1.

There is good evidence to suggest that ADD are effective as a seal deterrent and potentially also small cetaceans. based on tests undertaken by Harris *et al.* (2014). The use of ADD are used as industry standard practice and included within existing guidance to be potentially used in conjunction with measures such addition to soft start piling protocols and use of MMO and PAM operators. ADD is included within existing guidelines. However, it is worth noting here that a degree of caution should be taken about the parameters that the ADD operate, particularly for deterring small cetacean species such as harbour porpoise which are more sensitive to high frequency noise emissions. It cannot be



ruled out that the ADD emitted sound could have a cumulative effect. Despite this there was no evidence of this from the monitoring report.

Of particular note was the development of the protocol for mitigating risk from piling to marine mammals for the Beatrice and Moray wind farms (MFRAG, 2015). This work recognised limitations in carrying out pre-piling MMO visual searches and deploying PAM equipment, and highlighted that detection of many species such as seals can be very low or virtually zero. As such, the work by MFRAG identified a need for more effective mitigation measures. A key data gap highlighted was that there was no assessment on the efficacy of the JNCC guidelines, nor the confidence of the effectiveness of additional measures such as ADDs. The protocol that was devised was the initial deployment of ADDs ahead of soft start ramp up of piling (MFRAG, 2015).

In the Moray West Offshore Windfarm, where there were specific sensitivities for bottlenose dolphins and minke whales, the piling mitigation protocol also included vibro-piling the upper part of the piles (where possible) prior to impact piling. Vibropiling (or drilling), still generates underwater noise but does not generate “impulsive” sound which is considered the most harmful to marine species and thus reduces the exposure of marine mammals to piling noise. As was described above, the MFRAG protocol (MFRAG, 2015) was carried out by which ADDs were proposed to displace marine mammals prior to piling soft start procedure for impact piling was proposed for this windfarm.

The mitigations derived for a project should consider the associated sensitivities of the receptors in all cases and ties back to the EIA and supporting studies. For marine mammals, the sensitivity this will vary across the ScotWind offshore wind areas, with species and possibly seasonal distribution to the north and west of Scotland being different than in the North Sea. Thus, mitigations must be appropriate to the site conditions and type of activity and an acceptance that one size will not fit all.

There were a few additional environmental issues that were emerging from the CEMNID review process for m discussions that did not get much coverage (if any) in the literature. One of these issues related to potential with seal entrapment in J-tubes, checking now occurs leading to full prevention.

There was mooring cable noise has been identified associated with two floating mooring cables at Hywind and Kincardine (Risch *et al*, 2023). However, there are no associated mitigations relating to this noise source but it may be an operational noise that might be considered with regard to mitigations in the future, perhaps solutions such as a s alternative mooring tensioning systems developed through engagement with turbine, mooring and platform engineers and designers (Risch *et al*, 2023).

In addition to piling, it is also very important to take account of other noise sources , particularly those associated with the windfarm construction phases when vessel activity is at its highest. Vessel noise can add additional pressure to sensitive species, and may take place over extended periods (numbers of years). Therefore mitigations should consider the timing and density of vessel activity in line with the conditions of the site. Some further measures on reducing vessel noise through their design are outlined in Section 3.4.1. While vessel design is not going to be a specific aspect of an offshore wind development , the selection of vessels which have a lower underwater noise footprint can have an effect on reducing the overall in combination effects of underwater noise during construction and should be considered.



Table 12 Mitigation measures for marine mammals and megafauna

MITIGATION HIERARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Avoidance of piling noise	C/I	Suction Bucket installation (instead of hammered piles)	Avoidance of piling noise (and requirement for associated mitigation can be achieved through suction bucket installation design, effectively removing the noise impacts of hydraulic hammering.	Aberdeen Bay Windfarm Seagreen Hywind Windfarm Kincardine Wind Farm NNG
Avoidance of piling during sensitive periods	C/I	Seasonal restrictions of piling activities	Avoid undertaking piling during particularly sensitive periods. E.g. peak Minke Whale abundance during summer months.	Moray West Wind Farm
Avoidance/ Minimisation of exposure to seismic survey noise emissions	C/I	Mitigation for geophysical surveys	If required, mitigation for geophysical surveys (particularly if using Sub-bottom profilers (SBP), Sparkers and Ultra-Short Baseline (USBL) system) will follow the JNCC (2017) 'Guidelines for Minimising the Risk of Injury to Marine Mammals from Geophysical Surveys'.	Green Volt;
Minimisation of exposure to noise from UXO	C/I	Marine Mammal Mitigation Protocol (MMMP) for UXO Clearance	<p>A detailed MMMP will be prepared for UXO clearance during the pre-construction phase.</p> <ul style="list-style-type: none"> Unexploded ordnance (UXO) risk will be mitigated by reviewing magnetometer, MBES and SSS survey data to ensure the Site is clear of UXO before any contact with the seabed for sampling purposes. No detonation of UXO is proposed even in event of discovery. Good practice guidelines will be followed when conducting all surveys. The MMMP for UXO clearance will ensure there are adequate mitigation measures to minimise the risk of any physical or permanent auditory injury to marine mammals as a result of UXO clearance. The MMMP for UXO clearance will be developed in the pre-construction period, when there is more detailed information on the UXO clearance which could be required and the most suitable mitigation measures, based upon best available information and methodologies at that time. The MMMP for UXO clearance will be prepared in consultation with regulators and statutory nature conservation bodies. <p>The MMMP for UXO clearance will include details of all the required mitigation measures to minimise the potential risk of PTS as a result of underwater noise during UXO clearance. This would consider the options, suitability, and effectiveness of mitigation measures such as, but not limited to:</p>	Green Volt Moray West NNG Hornsea 3



MITIGATION HIERARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Minimisation of exposure to noise from UXO	C/I	Low order Deflagration	<ul style="list-style-type: none"> • Low-order clearance techniques, such as deflagration. • The use of bubble curtains if any high-order detonation is required (taking into consideration the environmental limitations). • Monitoring requirements for MMOs. • Requirements for ADD. • Other UXO clearance techniques, such as avoidance of UXO; or relocation of UXO. • If more than one high-order detonation is required, other measures such as the use of scare charges; or multiple detonations, if UXO are located in close proximity, will also be considered. 	Moray West
Minimisation of noise from impact piling	C/I	Piling Strategy (PS)	<p>A Piling Strategy will be drafted if impact piling is selected as the optimal installation mechanism for the WTG foundations. The strategy will provide full details of the piling activities and parameters, including expected noise levels, duration of activities, and any required mitigations for this installation technique.</p> <p>This will include details of the embedded mitigation, for the soft-start and ramp-up, as well as details of any additional mitigation measures required in order to minimise potential impacts of any physical injury or PTS, for example, the activation of ADD prior to the soft-start.</p> <p>In Moray West there was also an additional mitigation to use vibrohammer/vibropiling in advance of impact piling where possible to reduce the associated noise associated with the latter.</p> <p>As per overarching guidance indicated in Table 7, The Piling Strategy will incorporate mitigation measures to be implemented during any piling activities (e.g., soft-start and ramp-up procedures) to reduce the risk of injury to negligible levels. The mitigation measures will be informed by relevant guidance such as:</p> <ul style="list-style-type: none"> • JNCC (2010): JNCC guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys. • JNCC (2010): JNCC guidelines for minimising the risk of injury to marine mammals from using explosives. • JNCC (2017): JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys. 	Hornsea Four, Moray West Moray East Pentland Hornsea 3



MITIGATION HIERARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Minimisation of collision risk	C/I	Minimum Spacing between WTGs	<ul style="list-style-type: none"> The minimum spacing between each WTG (from the centre of each WTG structure) will be 800 m. This will reduce the likelihood of collision and entanglement to marine mammals. 	Pentland
Avoidance of piling noise	C/I	Utilisation of GBS foundations (WTG type)	<ul style="list-style-type: none"> GBS foundations (WTG type) will be utilised at a maximum of 110 of the 180 WTG foundation locations. The location of GBS foundations, if used for WTG, will be confirmed through a construction method statement which will include details of foundation installation methodology. 	Hornsea Four
Minimisation of multiple noise sources	C/I	Maximum number of foundations installed simultaneously	<ul style="list-style-type: none"> No more than a maximum of two foundations are to be installed simultaneously. 	Hornsea Four
Minimisation of EMF exposure	C/I	Cable burial	<ul style="list-style-type: none"> Static cables will be trenched and buried. Where targeted depth of burial cannot be achieved, remedial cable protection will be applied. This will provide some separation between the cables and basking sharks, therefore reducing the effect of EMF. The cable burial target depth will be informed by a CBRA and implemented through the CaP produced post-consent. 	Pentland; Green Volt
Minimisation	C/I	Development of and adherence to a Piling Strategy (PS)	<ul style="list-style-type: none"> Development of and adherence to a PS (applicable where piling is undertaken). The PS will detail the method of pile installation and associated noise levels. It will describe any mitigation measures to be put in place (e.g., soft starts and ramp ups, use of Acoustic Deterrent Devices) during piling to manage the effects of underwater noise on sensitive receptors. 	Muir Mhòr, Moray East Windfarm, Beatrice Windfarm
Minimisation of EMF exposure	C/I, O/M	Cable protection	<ul style="list-style-type: none"> Suitable implementation and monitoring of cable protection (via burial or external protection). External cable protection will be used where adequate burial cannot be achieved and this will be minimised as far as is practicable. This will be informed by a CBRA, following results of the geotechnical survey. Burial or protection of cables increases the distances between cables and marine mammal and megafauna, reducing EMF and barrier effects. Cables, wherever possible, will be buried to a minimum target depth of ~ 0.6 in accordance with relevant guidance such as (Carbon Trust, 2015), which will reduce the potential for impacts relating to EMF. Cables will be specified to reduce EMF emissions as per industry standards and good practice such as the relevant IEC (International Electrotechnical Commission) specifications. 	West of Orkney, Pentland; Green Volt



MITIGATION HIERARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Minimisation of entanglement risk	O/M	Removal of debris from floating lines and cables	<ul style="list-style-type: none"> The accumulation of marine debris on floating lines and cables has the potential to generate adverse interactions between mobile marine species and project infrastructure. Derelict fishing gears are of particular concern due to the secondary entanglement risk they introduce to marine megafauna, including marine mammals and basking sharks. Mooring lines and floating inter-array cables will be inspected during the operation and maintenance phase using a risk-based adaptive management approach. Mooring line and cable inspections are expected to occur at a higher frequency initially and then reduce in frequency over a number of years, with changes to inspection periods based on evidence of risk garnered from the inspections. A small number of floating substructures will likely be equipped with sensors monitoring tension and inclination on mooring lines. This will detect any larger debris and anomalies. Any inspected or detected debris on the floating lines and cables will be recovered, based on a risk assessment which considers the impact on the environment, risk to asset integrity, and cost of intervention. 	Pentland
Minimisation of Marine mammal entrapment in J-Tubes	C/I	Capping of J-Tubes	<ul style="list-style-type: none"> Capping of J-Tubes prior to cable installation will ensure that the risk of entrapment to seals or other marine mammals. 	No example.



3.3.6 Offshore and intertidal ornithology

Mitigation measures that have been identified for offshore and intertidal ornithology can be seen in Table 13 below.

One of the most important impacts for ornithology receptors relates to the collision risk from rotating turbines. In most, if not all, cases the setting of a minimum blade tip clearance and lower air draught seems to be successful for mitigating impacts on seabirds.

The minimum distance driven by safety and navigation policy is 22 m above Mean High Water Spring (MHWS); however, a greater distance lowers the collision risk for many seabird species that fly close to the sea so that increasing the air gap between the lowest sweep of the turbine blades and the sea surface, therefore a larger gap generally provides more mitigation to seabirds. It must be taken into consideration though that by increasing the air gap also has a knock on effect of increasing the blade height which may have implications on other receptors such as aviation, for instance. This will be specifically driven by the technical requirements and site conditions of the array as well as by the extent of seabird collision risk and the associated species that are likely to be present. As such, the minimum blade gap is variable between the example projects that were reviewed in the study.

The design parameters proposed for the wind farms in the review ranged from of 27.05 m to 40 m above Mean Sea Level (MSL) for fixed installation, and from 22 above MSL (Kincardine Wind), 24 m above MHWS (Marram Wind) to 35 m above MSL (Pentland Windfarm) for floating installations, although it was noted that an air gap of 35 m was actually untried for a floating facility. Furthermore, water depth (and potentially other factors) will influence what clearance is possible and therefore, fixed turbines in deeper waters with 24 m likely to be more standard. There was no evidence that a minimum air gap of 22 m is sufficient for Scottish wind farms, however in the absence of any other data it is expected that that all new wind farms in Scotland would include this key mitigation within their development plan, with the onus to increase the gap as much if there is particular sensitivities predicted through the EIA process and its technically feasible to do so.

For nearshore activities such as cable landfall where impacts to intertidal ornithology may be sensitive to disturbance (e.g. waders will be sensitive to flushing from their nests as a result of visual disturbances), temporary screens or boards (baffle boards) may be put up to obscure visual disturbance and reduce sound propagation from a construction site. However it is worth noting that an HDD drilling rig may be far larger than any kind of temporary board structure could obscure, so might be of limited effect.

In addition to the above commonly embedded mitigation, management of excessive lighting can be implemented in early design and applied throughout the lifespan of a development.

Vessel routing and timing is also a factor for managing collision risk to at the sea surface to seabirds that are moulting and flightless, particularly given the large seabird populations around Scottish coasts. Therefore, where applicable, appropriate mitigations should also be in place to minimise the potential for collisions on the sea surface from vessels. The mitigations relating to the collision risks to marine birds can be considered within the suit of good practice measures for minimising collisions.



Table 13 Mitigation measures for offshore and intertidal ornithology

MITIGATION HIERARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Avoidance/Minimisation of exposure to excess lighting	C/I, O/M	Lighting	<ul style="list-style-type: none"> Excess lighting, above levels set by regulatory requirements for navigation, aviation, escape/emergency procedures and general activity, will be avoided wherever possible. External general lighting will use timers and/or Passive Infrared (PIR) devices to reduce excessive lighting of the WTGs and OSPs. 	West of Orkney, Aberdeen Bay Windfarm, Kinkardine, Moray East
Avoidance/Minimisation of disturbance	C/I	Environmental Clerk of Works (ECoW)	<ul style="list-style-type: none"> An independent ECoW will be appointed to audit site activities and will advise on implementation of mitigation. The ECoW will help to mitigate the construction impacts on marine ornithological receptors by ensuring that good working practice is implemented on the ground. 	Pentland, Kinkardine
Minimisation of collision risk	C/I	Minimum blade tip clearance (Fixed turbine)	<ul style="list-style-type: none"> Minimum blade clearance variable of 27.05 to 40 m above Mean Sea Level (MSL) (or 42.43 mb above LAT) 	West of Orkney Hornsea Four, Moray West, NNG, Hornsea 3
Minimisation of collision risk	C/I	Minimum blade tip clearance (Floating)	<ul style="list-style-type: none"> There will be a minimum blade tip clearance of at least 24m above mean sea level. To up to 35 m MSL. 	Muir Mhòr, Morven, MarramWind, Caledonia, Pentland
Minimisation of collision risk	C/I	Rotor swept area reduction	<ul style="list-style-type: none"> By reducing the rotor swept area the number of collisions will automatically be reduced. 	NNG
Minimisation of disturbance	C/I	Piling strategy	<ul style="list-style-type: none"> The use of soft-start during construction will be undertaken as routine mitigation measure. By doing so, this might reduce the impacts on prey species upon which seabirds rely on. This relates to overarching JNCC guidance mentioned earlier. 	NNG, West of Orkney, Pentland
Minimisation of disturbance	C/I	Timing the construction activities in intertidal zone so that they occur out-with Seasonal sensitivities	<ul style="list-style-type: none"> Avoidance of sensitive seabird breeding seasons or overwintering periods for waterbirds for undertaking onshore/nearshore construction works such as landfall cable trenching. 	No example given but considered good practice



MITIGATION HIERARCHY	PROJECT STAGE	MITIGATION MEASURE	DESCRIPTION (BASED ON SPECIFIC PROJECT EXAMPLES)	PROJECT EXAMPLES
Minimisation of direct intertidal disturbance	CI	Horizontal Directional Drilling (export cable installation)	<ul style="list-style-type: none"> The installation of the offshore export cables at landfall will be undertaken by Horizontal Directional Drilling or other trenchless methods. HDD works at landfall option (if chosen) will be undertaken outside the bird breeding season to avoid disturbance of cliff nesting birds in SPA. 	Hornsea Four, Berwick Bank
Minimisation intertidal disturbance	CI	Installation of screens/boarding (Baffle boards) to reduce visual and noise disturbance for onshore works.	<ul style="list-style-type: none"> Installation of screens/boarding (Baffle boards) to reduce visual and noise disturbance for onshore/intertidal works. 	No specific example given but nonetheless considered good practice
Minimisation of collision or displacement	CI	Turbine layout	<ul style="list-style-type: none"> Consideration of turbine layout. By avoiding placing turbines in areas of relatively higher concentrations of birds the risk of an impact occurring is reduced accordingly 	NNG



3.4 Innovative/alternative environmental mitigation measures

While previous sections of this report have outlined mitigation measures which are largely considered to constitute good practice and/or have been embedded in mitigation plans within EIARs/Scoping reports, the following sections aim to describe possible mitigation measures which have not appeared outright in any of the previously investigated literature, may have been mentioned from international guidance but not undertaken in the UK to date (such as ACCOBAMS, 2019) or implied by UK policy but not fully embedded in industry practices (UK Government 2023). Therefore, these measures are considered to be innovative/alternative at the time of writing.

The review of mitigation approaches that may not be represented in current industry practices in the UK is an important part of this study and falls within the UK Government (2023) policy statement on mitigation for offshore wind farms that states that “Applicants should undertake a review of up-to-date research and all potential avoidance, reduction and mitigation options presented for all receptors.”

The measures outlined below originate from scientific or grey literature and are presented here with specifics per the available information. Analysis of the efficacy of these measures are presented where data is available, but no commentary has been provided on the accuracy of their claims.

Generally, these innovative/alternative measures relate to:

- Underwater sound impacts on marine mammals and megafauna, and fish, as generated during construction/installation and operational and maintenance phases of a project/development (Section 3.4.1); and
- Collision risk, displacement, barrier effects of turbines on birds (and bats) during the operational and maintenance phase (Section 3.4.2).

Brief commentary is also provided on restoration methods that were identified within the review (Section 3.4.3).



3.4.1 Underwater sound

A range of underwater sound mitigations have been identified in Table 14 which may be considered in addition to the more standard approaches that have been outlined in Sections 3.2 and 3.3. Many of these may have the potential to supplement the existing, more generally embedded minimisation mitigations on underwater sound, especially where an increase in receptor sensitivity, or overall magnitude of the source may occur. Promising approaches include, those associated with bubble curtains, sound mitigation screens and hydro-sound Damper (HSD) systems (Bennun *et al.*, 2021; Dähne *et al.*, 2017; Verfuss *et al.*, 2019). Of particular importance to this review of novel underwater sound mitigations is a report commissioned by NatureScot that reviewed noise abatement methods for offshore wind farm construction (Verfuss *et al.*, 2019). The review by Verfuss *et al.* (2019) is not replicated here but key methods identified for consideration and outcomes on the theoretical applicability of identified noise abatement systems to Scottish offshore wind farms are taken into account along with the others in Table 14. Where available, the reported efficiency data of these measures in terms of reducing Sound pressure level (SPL) and Sound Exposure Level (SEL) has been provided in Table 14 where available. The reported efficiencies indicate that many of the noise abatement options presented have potential to reduce the underwater noise levels to below key thresholds for Temporary and Permanent Threshold Shift (TTS/PTS) for sensitive species and potentially reduce the area of influence. As such, this suite of noise abatement options certain options would appear to be promising and could be considered to be incorporated as good practice under certain circumstances.

Verfuss *et al.* (2019) noted that big bubble curtains (BBC) had been successfully commercially deployed for a wind farm in German North Sea and it would therefore seem that this approach would have particular applicability in Scottish waters in addition to the 'soft starts' and marine mammal searches. Indeed, Verfuss *et al.* (2019) concluded that the most promising available noise abatement systems for Scottish wind farms (in 2019) sites are the BBC and the HSD. However, Verfuss *et al.* (2019) did not rule out the applicability to Scottish offshore wind farms of other measures that were assessed in their report such as alternative hammer technologies (rather than hydraulic piling) and the use of screens, casings or novel resonator systems. However, they outlined that for those methods, there was insufficient data or to support their recommendations based on lack of trials or commercial deployments. It is also worth noting that some abatement technologies may be limited to the water depth at which they are effective (e.g. the HydroNAS prototype was tested to 12 meters). More information on bubble curtains used in other industry applications is provided in Section 3.4.4. The Borselle wind farm for instance recorded successful noise abatement using big bubble curtains in combination with the AdBm resonator (ADBM, 2024). However, this was at 28 m water depth so cannot be said to be proven in deeper waters on a commercial scale. Such limitations may significantly affect their applicability in some Scottish wind sites which may be deeper than the test/applied sites such as those in the southern North Sea. If such technologies must be fabricated specifically for the project, the associated cost-effectiveness of such a measure must be taken into account and may be prohibitive. Nonetheless, the reported noise abatement efficiencies are promising and it is therefore proposed that those that have been demonstrated to be effective at a commercial scale and at water depths that are in the range of Scottish offshore wind farm areas such as Big bubble curtains and Hydro Sound Dampers (HSD) should be featured as potential options for use in Scottish projects, where it is applicable to a projects parameters, albeit with a potential limit on their applicability to deeper waters (Verfuss *et al.*, 2019).

Avoidance of significant underwater sound represents the first step in mitigation and there are potentially suitable options for both fixed and floating offshore wind installation that may be considered good practice. In the case of the Aberdeen Bay project the EIA originally proposed piled turbines but ultimately opted for a suction bucket design,



though it must be noted that this option will only be applicable where the sediments are suitable for such a measure. Gravity-based designs will avoid the hammered piling noise but introduce additional new seabed substrate which introduces a trade-off with increased seabed impacts that needs to feature as a balanced consideration. Better still are suction bucket foundations which not only avoid piling noise but also have the potential to reduce the associated long term seabed footprint compared with gravity based designs and are also inherently designed to be recovered (reverse installed). However, in the case of suction bucket designs, there is limitations on their applicability with the requirement for soft sediments essential for their deployment. In the case of harder substrates and the requirement to introduce fixed foundations, there is a potential place for NID measures to be included in the discussion around such considerations.

Another key noise emission is associated with vessel noise which can be known to displace seabirds from an area but nonetheless noteworthy are novel methods which aim at reducing vessel noise, many of which are associated with either structural design or propeller modifications which may be available but will depend on availability and cost (ACCOBAMS, 2019). The deployment of which would perhaps be unlikely to significantly reduce noise impacts but may have value cumulatively in sensitive areas during construction.

This review showed that there are promising noise abatement technologies and mitigation approaches that could potentially be applicable for Scottish wind farms. This is particularly so with applications which have been tested in both trials and especially at commercial level. This assessment of how the suitability of these mitigation measures to Scottish wind farms and their potential to be incorporated into a Good Practice Library for Scottish offshore wind farms is discussed further in Section 4.1 regarding the next steps and the development of the Library.



Table 14 List of alternative mitigation measures for underwater sound

MITIGATION HIERARCHY	PROJECT STAGE	MEASURE ^{5,6}	DESCRIPTION	EFFICIENCY/ NOISE REDUCTION	CITATION
Avoidance/ minimisation	C/I	Concrete Gravity Foundations	Reinforced, self-buoyant concrete structures. They are towed to a site and directly placed to the seabed. Applications: foundation installation (instead of piling)	No noise emissions	ACCOBAMS (2019 and references therein)
Avoidance/ Minimisation	C/I	Suction Bucket foundation	Large steel caisson which is installed in the seafloor by suction pumps. The water is pumped out of the cavity underneath the caisson. The vacuum in combination with the hydrostatic pressure makes the caisson penetrate into the seabed up to its final depth. Applications: foundation installation (instead of piling)	Very low noise expected	ACCOBAMS (2019 and references therein) Bennun <i>et al.</i> (2021 and references therein); Thomsen and Verfuss (2019)
Minimisation	C/I	Big Air Bubble Curtain	In this technique bubbles of air are created through a nozzle hose on the seabed to rise up and surround the relevant operations aiming to reduce sound levels beyond the curtain. The method has been found to be effective at the DanTysk offshore wind farm, Germany. Applications: Pile driving, Drilling, Detonations. Proven to be effective in depths up to 77m (non-offshore wind farm)	Single bubble curtain: <ul style="list-style-type: none"> • 12 dB (SEL), 14 dB (peak) • 11 dB (SEL), 15 dB (peak) • 10 – 15 dB (SEL) Double bubble curtain: <ul style="list-style-type: none"> • 17 dB (SEL), 21 dB (peak) • 15 – 18 dB (SEL) 	Dähne <i>et al.</i> (2017); ACCOBAMS (2019 and references therein); Bennun <i>et al.</i> (2021 and references therein)
Minimisation	C/I	Small Air Bubble Curtain	A small bubble curtain can be customized and placed closer to the sound source, compared to the big bubble curtain. Applications: Pile driving, Drilling, Close proximity to the pile makes the small bubble curtain vulnerable to currents decreasing its effectiveness.	Several tests: <ul style="list-style-type: none"> • 12 dB (SEL), • 14 dB (peak) • 11-13 dB (SEL) • 4-5 dB (SEL) • 14 dB (SEL), 20 dB (peak) 	ACCOBAMS (2019 and references therein) Verfuss <i>et al.</i> (2019)
Minimisation	C/I	Shell-in-Shell/Noise mitigation Screen	Use of sound mitigation screens. Associated with a double-wall steel tube into which the pile is inserted. The space between the walls is filled with air to reflect sound.		Bennun <i>et al.</i> (2021 and references therein) Verfuss <i>et al.</i> (2019)

⁵ According to Bennun *et al.* (2021), combinations of these measures (e.g., bubble curtains, hydro sound damper, cofferdams) may be used in construction, but almost always in conjunction with real-time field observations (marine mammal observers and passive acoustic monitoring).

⁶ Many other alternative technologies are being developed or are already available in the market (vibro piling, floating wind turbine, etc.) - See more information on Merck & Werner 2014 (OSPAR).



MITIGATION HIERARCHY	PROJECT STAGE	MEASURE ^{5,6}	DESCRIPTION	EFFICIENCY/ NOISE REDUCTION	CITATION
			Proven in offshore wind farm projects in water depths up to 45 m.		
Minimisation	C/I	HydroNAS	Similar in principle to noise mitigation screen. Noise abatement system developed by W3G Marine Ltd. Surrounds a foundation during piling activity with sound absorbing or reflective material.	<ul style="list-style-type: none"> • 25dB SEL and 35dB peak (across a single barrier) 	Verfuss <i>et al.</i> (2019) W3G Marine (2024)
Minimisation	C/I	Tuneable resonator system	Sound abatement system. It uses a simple collapsible framework containing arrays of acoustic resonators with two fluids (air and water). Applications: Pile driving, Drilling, Seismic sources	<ul style="list-style-type: none"> • >20 dB in the 20 Hz to 20 kHz band 	ACCOBAMS (2019 and references therein)
Minimisation	C/I	Resonator - Hydro Sound Damper (HSD)	Use of fishing nets with small balloon filled with gas and foam – tuned to resonant frequencies- fixed to it. Applications: Pile driving, Drilling, Detonations deployed in offshore wind farm projects in water depths up to 45 m	<ul style="list-style-type: none"> • 4 - 14 dB (SEL) • 8 – 13 dB (SEL) 	Bennun <i>et al.</i> (2021 and references therein) Verfuss <i>et al.</i> (2019)
Minimisation	C/I	Resonator - AdBm-NAS	Resonator-type (Helmholtz) (Noise Abatement System developed by AdBm Technologies LLC. Consists of standard size panels with submersible air-filled resonators that encircle the pile during construction Applications: Pile driving, Drilling,	<ul style="list-style-type: none"> • Approximately 8 dB using system alone – • Up to 20 dB in combination with single bubble curtain. 	Verfuss <i>et al.</i> (2019) AdBm, 2024
Minimisation	C/I	Cofferdams	Single-walled steel tubes from which water is evacuated and into which the pile is inserted, such that the sound is reflected. Applications: Pile driving, Drilling	<ul style="list-style-type: none"> • up to 22 dB (SEL) and 18 dB (Peak) • 10 – 20 dB (SEL) 	Bennun <i>et al.</i> (2021 and references therein)
Minimisation	C/I	IHC Noise Mitigation System (IHC-NMS)	This is a double layered screen, filled with air. Between the pile and screen there is a multi-level and multi size bubble injection system. Applications: Pile driving, Drilling	<ul style="list-style-type: none"> • 5 – 20 dB (SEL) • 10 – 14 dB (SEL) 	ACCOBAMS (2019 and references therein)
Minimisation	C/I	BEKA_shells	Double steel wall with polymer filling - Inner and outer bubble curtain - Acoustic decoupling (vibration absorber) Applications: Pile driving, Drilling	<ul style="list-style-type: none"> • 6-8 dB (SEL) 	ACCOBAMS (2019 and references therein)
Minimisation	C/I	BLUE Piling® technology	Hammer technology that is alternative to conventional piling. solution. It uses the deceleration of a large water column to deliver a long-duration blow to the pile. It reduces sound at the source during installation. Applications: Pile driving, Drilling	<ul style="list-style-type: none"> • 20 dB (SEL) compared to conventional hammers (Limited data on technical applications) 	https://iqjp.com/expertise/noise-mitigation/ Verfuss <i>et al.</i> (2019)



MITIGATION HIERARCHY	PROJECT STAGE	MEASURE ^{5,6}	DESCRIPTION	EFFICIENCY/ NOISE REDUCTION	CITATION
Avoidance/ Minimisation	C/I	VibroHammer (VH)	Hammer technology that is alternative to conventional piling Note: perceived risk from VH due to limited experience of use in offshore wind farm-projects commercially deployed in offshore wind farm projects in water depths up to 45 m.		Verfuss <i>et al.</i> (2019)
Avoidance/ Minimisation	C/I	Drilled foundation	Drilling can be done within a concrete pile. The drill head can be placed outside the pile if there is resistance. The pile will sink within the drilled hole.	<ul style="list-style-type: none"> No information available 	ACCOBAMS (2019 and references therein)
Avoidance/ minimisation	C/I	Vibro-drilling	It combines a vibrator tandem PVE and a drill head in one unit. The pile is driven into the sea floor by vibrating. Drilling is applied when there is resistance with vibrating.	<ul style="list-style-type: none"> Less than 130 dB @ 750 m expected 	ACCOBAMS (2019 and references therein)
Minimisation	C/I	Marine Vibroseis (MV)	Hydraulic and electromechanical MVs can be towed in the same configuration as airgun arrays or operated in a stationary mode much like land vibrators. They will have lower source signal rise times, lower peak pressures, and less energy above 100 Hz than seismic airgun arrays	<ul style="list-style-type: none"> Source Level: 203 dB re 1µPa; 6-100 Hz 	ACCOBAMS (2019 and references therein); Teyssandier and Sallas (2019).
Minimisation	C/I	Low level Acoustic Combustion Source (LACS)	This system is a combustion engine producing long sequences of acoustic pulses at a rate of 11 shots/s with low intensity at non-seismic (> 100 Hz) frequencies. Suitable for shallow-penetration, towed streamer seismic surveys or vertical seismic profiling.	<ul style="list-style-type: none"> Source Level: 218 dB re 1µPa Peak-to-Peak 	ACCOBAMS (2019 and references therein)
Minimisation	C/I	Infra-red cameras	They gradually become a mature technology enhancing mitigation effectiveness of visual monitoring. They can detect by temperature contrast whale blows as well as the surfacing portion of the body of several marine mammals (including pinnipeds).	<ul style="list-style-type: none"> Infra-red cameras make it possible to carry out visual monitoring at night, and can support MMOs., 	ACCOBAMS (2019 and references therein)
Minimisation	C/I, O/M	Shipping - structural dumping	It aims to the reduction of sound produced by the vibration of the structure of the ship, through a decrease in the amplitude of the resonances. Measure implementation: At the shipbuilding stage.	<ul style="list-style-type: none"> 5-10 dB 	ACCOBAMS (2019 and references therein)
Minimisation	C/I, O/M	Shipping - Increasing hull thickness	Reduce sound transmission by increasing the spacing between stiffeners. Measure implementation: At the shipbuilding stage.	<ul style="list-style-type: none"> Up to 10 dB in the 100 Hz-5 kHz range 	ACCOBAMS (2019 and references therein)
Minimisation	C/I, O/M	Shipping - Use of lightweight	<ul style="list-style-type: none"> Lighter ship, requiring less power and - creating less noise Higher internal damping than steel 	<ul style="list-style-type: none"> Up to 50% weight reduction of the 	ACCOBAMS (2019 and references therein)



MITIGATION HIERARCHY	PROJECT STAGE	MEASURE ^{5,6}	DESCRIPTION	EFFICIENCY/ NOISE REDUCTION	CITATION
		materials like FRP (Fiber Reinforced Plastic)	<ul style="list-style-type: none"> • Non-magnetic properties • Can however exhibit larger vibration levels Measure implementation: At the shipbuilding stage. Not used in vessels larger than 50m because of the lack of tools and methods.	ship	
Minimisation	C/I, O/M	Shipping - Propeller repair or maintenance	Little imperfections can reduce ship efficiency and increase the noise impact. Measure implementation: Easy to implement, during routine dry dockings in order to reduce costs	<ul style="list-style-type: none"> • Increase the efficiency of a propeller by 2% 	ACCOBAMS (2019 and references therein)
Minimisation	C/I, O/M	Shipping - Propeller modification or change	Designing an optimal propeller for the ship. Measure implementation: Propeller replacement in one-week dry docking.	<ul style="list-style-type: none"> • Noise will be reduced by reducing the ship power necessary to reach a certain speed. 	ACCOBAMS (2019 and references therein)
Minimisation	C/I, O/M	Shipping - High skew propellers	Reduction of propeller induced vibration Measure implementation: Easy to implement, during routine dry dockings aiming to reduce costs.	<ul style="list-style-type: none"> • Used in warships and in high powered merchant ships. 	ACCOBAMS (2019 and references therein)
Minimisation	C/I, O/M	Shipping - Schneekluth duct	Installed on the hull of the ship, It aims to improve the flow on the upper part of the propeller and decrease cavitation. Measure implementation: Easy to implement, during routine dry dockings aiming to reduce costs.	<ul style="list-style-type: none"> • Reduction of vibrations up to 50%. Propulsion efficiency up to 4%. 	ACCOBAMS (2019 and references therein)
Minimisation	C/I, O/M	Shipping - Becker Mewis Duct	Positioned in front of the propeller along with an integrated fin system. Measure implementation: Easy to implement, during routine dry dockings aiming to reduce costs.	<ul style="list-style-type: none"> • Energy saving up to 8%. 	ACCOBAMS (2019 and references therein)
Minimisation	C/I, O/M	Propeller boss cap fins	Improves the propeller performance via minimising hub vortex and resultant rudder cavitation. Measure implementation: Easy to implement, during routine dry dockings aiming to reduce costs, maintenance free after installation.	<ul style="list-style-type: none"> • 3-5% fuel consumption reduction. 	ACCOBAMS (2019 and references therein)
Minimisation	C/I, O/M	Shipping - ErgoProFin (Wartsila)	An energy saving propeller cap with fins that rotate together with the propeller. Measure implementation: Easy to implement, during routine dry dockings aiming to reduce costs.	<ul style="list-style-type: none"> • Average fuel savings of 2%. 	ACCOBAMS (2019 and references therein)



MITIGATION HIERARCHY	PROJECT STAGE	MEASURE ^{5,6}	DESCRIPTION	EFFICIENCY/ NOISE REDUCTION	CITATION
Minimisation	C/I, O/M	Shipping - ECO-Cap (Nakashima)	Newly designed propeller cap for propeller hub reduction. Measure implementation: Easy to implement, during routine dry dockings aiming to reduce costs.	<ul style="list-style-type: none"> Energy saving effect of 3%. 	ACCOBAMS (2019 and references therein)



3.4.2 Collision risk, displacement, barrier effects

A key measure that is widely recognised and employed in minimising seabird collision is by increasing the air gap between blade tip and the sea surface. Being able to completely avoid collision risk is very difficult and the risk is heavily dependent on numerous factors such as the location of the windfarm and abundance and distribution and type of sensitive species in the vicinity. There is some evidence that minimising this risk through considered design works, such as that from Aberdeen Bay Wind Farm which have demonstrated no actual collisions or any species displacement during a 2 year study (further discussed in Section 3.5.4). However, there are a number of other innovative measures that have been devised to minimise this risk beyond keeping a minimum blade distance (Table 15). These can include Increasing visibility of rotor blades, deploying acoustic deterrent devices and careful management and design of turbine lighting systems that can offer may all contribute to better manage collision risk, primarily to birds.

The review identified Automated shutdown technologies (shutdown on Demand (SDOD) which are another way in which collisions with fauna (mainly birds) can be minimised or potentially avoided altogether (Bennun *et al.*, 2021). This technology works through detection which can then emit a warning sound and can be accompanied by a temporary shutdown or slowdown of the turbine mechanism. The mode of detection can be using camera technology or radar and examples are described below for each. These systems may have some practical application in areas where bird collision risk is high. Detection equipment has been considered and this may have associated shut down or slow down measures that are incorporated into the turbine design that may have, along with other measures an even greater reduction in collision risk in areas where seabirds are particularly at risk, it is recommended that such technology is considered in the design. Given that the speed of the blades will also be a factor in the collision risk, constraints on the maximum rotor speed may result in reduced collision risk.

In addition, recommendations on lighting have been identified that a reduction in attracting birds at night can be achieved through either using blinking lights or continuous red light which was reported as attracting significantly fewer birds on starless nights than continuous green, blue or white lights (Rebke *et al.* 2019; Bennun *et al.* 2021).

Painting blades may have some potential to increase visibility and reduce the overall risk of collision to seabirds (Martin and Banks, 2023). The principle is that it is a simple and practical solution to enhance detectability by bird species and reduce collision. Martin and Banks (2023) also pointed out that such measures do not interfere with statutory requirements already required for the marking of turbines for the benefit of shipping and aircraft. Therefore, if demonstrated to be effective, could represent simple and relatively low cost solution. However, at the time of writing, there is limited evidence to indicate how effective these measures are and will depend on the types of species that are at risk, the behaviour of species and the specific location. Some evidence has been presented by May *et al.* (2020) for a before and after control impact approach in Norway on raptor collision (not seabirds). Which showed a 70% reduction in collisions.

It should generally be taken into account that mitigations deployed in combination with other collision risk measures could be presented as having more of a beneficial effect than is greater than the sum of all the mitigations put together. As such, any list of good practice measures needs to account not just each mitigation measure on their own merit but the contribution to a desired effect in combination with other measures.



As with noise abatement technology discussed in the previous section, this review showed that there are promising collision risk mitigation technologies that could potentially be applicable for Scottish wind farms, where necessary. An assessment of how the suitability of these mitigation measures to Scottish wind farms and their potential to be incorporated into a Good Practice Library for Scottish offshore wind farms is discussed further in Section 4.1 regarding the next steps.



Table 15 List of innovative/alternative mitigation measures for collision risk, displacement, and barrier effects

MITIGATION HIERARCHY	PROJECT STAGE	MEASURE	RECEPTOR	DESCRIPTION	EFFICIENCY	CITATION
Minimisation	O/M	Increasing visibility of rotor blades	Birds	Painting blades in a high contrast colour to reduce 'motion smear' or in ultraviolet paint. According to the IUCN (2021) the measuring of painting blades/avoiding pure white/light grey colours may have regulatory, engineering, and societal constraints.	Measure has not been tested yet in offshore wind farms. It has been tested in onshore wind farms in Norway: Painting black two-thirds of a single blade reduced white-tailed eagle (<i>Haliaeetus albicilla</i>) fatalities by 100% over unpainted controls.	Bennun <i>et al.</i> (2021)
Minimisation	O/M	Acoustic Deterrent Devices on the turbines	Bats	Emissions of high frequency sounds making bats to avoid wind turbines (masking echo perception, creation of airspace that bats may avoid).	Measure not tested yet for offshore wind farms. Tested in onshore wind farms in North America: ADDs resulted in a 50% reduction in overall bat fatalities with varying species-specific responses.	Bennun <i>et al.</i> (2021)
Minimisation	O/M	Operational phase lighting	Birds	Restricting light to a minimum using blinking light as opposed to continuous light, and if continuous light is required using red light.	Spotlight experimental work in Sylt island (North Sea) showed that no light variant was constantly avoided by nocturnally migrating passerines crossing the sea. Birds were drawn more towards continuous than towards blinking illumination, when stars were not visible. Red continuous light was the only exception that did not differ from the blinking counterpart. Continuous green, blue and white light attracted significantly more birds than continuous red light in overcast situations.	Rebke <i>et al.</i> 2019; Bennun <i>et al.</i> (2021) and references therein)
Avoidance/ Minimisation	O/M	Automated Shutdown - Camera technology DTBird® (Includes daylight and /or thermal imaging cameras placed on individual turbines or other similar infrastructure)	Birds	<ul style="list-style-type: none"> Once birds are identified, the system produces a warning sound or automatically shut turbines down using specific criteria. Detection distance is associated with size of birds. 	<ul style="list-style-type: none"> System was installed in 2015 for three years at offshore Platform FINO1 (North Sea) close to farms Alpha Ventus, Borkum Riffgrun 1 and Trianel Windpark Borkum. (The IUCN (2021) have no information on the outcomes of the use of DTBird in the North Sea). System has been tested in onshore wind farms: a) Detectability was shown to be >80% at an onshore test site in California, b) Warning 	Bennun <i>et al.</i> (2021) JNCC, (2022)



MITIGATION HIERARCHY	PROJECT STAGE	MEASURE	RECEPTOR	DESCRIPTION	EFFICIENCY	CITATION
					<ul style="list-style-type: none"> • sounds reduced flights in the collision risk zone in trials in Sweden and Switzerland by 38-60%. • It is noteworthy that DT bird has been successfully deployed in Scottish Waters at the Kincardine offshore Wind Farm for monitoring collision risk rather than functioning a shut-down system. 	
Avoidance/ Minimisation	O/M	Automated Shutdown – Camera technology Identiflight (includes daylight and / or thermal imaging cameras placed on infrastructure)	Birds	<ul style="list-style-type: none"> • Use of algorithms to classify items – potentially species-specific. • Supports automated shut down of turbines. • Operational range: 1000 m. 	<ul style="list-style-type: none"> • System has been tested in onshore trials in Wyoming (USA) where it showed a 96% detection rate. 	Bennun <i>et al.</i> (2021 and references there in).
Avoidance	O/M	Automated Shutdown – Radar technology Robin Radar Max© (real-time detection, 3D tracking)	Birds	<ul style="list-style-type: none"> • A 15km maximum detection range; • Capacity for Automatic shutdown based on pre-set criteria; • Potentially species-specific; • High financial cost; • Use may be constrained due to military/aviation legislation. 	<ul style="list-style-type: none"> • The system has been tested in offshore wind farms in Finland aiming to prevent collisions with white-tailed sea eagles and black-backed gull. • The system has been operated in wind farms in Bulgaria shutting down turbines for the protection of migratory species. 	Bennun <i>et al.</i> (2021 and references there in)
Minimisation	O/M	Automated Shutdown – Radar technology STRIX Birdrack© (automatic detection and tracking of individual birds or bats)	Birds and bats	<ul style="list-style-type: none"> • No identification of species; identification of size classes; • Detection range: 12 km; This depends on the size of bats/birds; • Automatic shutdown; • May be restricted by military/aviation legislation; • Used in combination with observers. 	<ul style="list-style-type: none"> • Used in Barão de São João wind farm – zero fatalities over five years. Use of radar was done in combination with observers. • Use in Egypt contributed to fatality. Levels kept at 5–7 fatalities per year – it needs to be considered that approx. 370,000 birds pass through the wind farm each season. • It is noteworthy that STRIXX technology has been deployed in Scottish waters for monitoring seabird collision risk and displacement at the Neart Na Gaoithe Windfarm (NNG). 	Bennun <i>et al.</i> (2021 and references there in)



3.4.3 Restoration and offsetting measures for offshore wind farms

All of the mitigation measures outlined in this report thus far have fallen within the first two steps of the mitigation hierarchy outlined in Section 2.4; those being avoidance and minimisation with the presumption that this is sufficient to ensure environmental impacts are appropriately managed within the project. It has been previously explained that restoration and offsetting are not specifically a focus of the CEMNID Project and are therefore not explored in any detail in this report.

However, one mitigation measure was identified during the review which may be best categorised as a restoration or offsetting method. Recently, three artificial nesting structures were installed close to the east Suffolk Coast to compensate for the predicted residual impacts of the Hornsea 3 offshore wind farm on black-legged kittiwake (Ørsted, 2023b). This was undertaken in line with project consent requirements. Each artificial nesting structure comprises an octagonal top with capacity for around 500 breeding pairs of kittiwake supported above the water on a single monopile. The roof pitch and overhang were specifically designed to mitigate avian predators. As these have only recently been deployed, there has been no data as yet on the effectiveness of these structures at the time of writing. The purpose of these structures can be considered as a type of offsetting measure given that the driver for their creation was as a compensation measure to alleviate the residual impacts on seabird populations. However, a similar type design may be considered as a category of NID, in a case that such a structure was installed on another structure with a purpose. As a mitigation measure, the deployment of artificial nesting structures is not something that is likely to feature as a good practice measure for Scottish offshore windfarms as habitat availability is not a limiting factor in Scotland, compared to England. .

Another mitigation measure which would seem similar in some ways to NID options and restoration that was identified in the review worth noting was an example associated with the relocation of rocky habitats in the Anholt offshore wind farm in Denmark. This example is of particular relevance to ScotWind projects as often one of the key early activities is site preparation which may include boulder clearance. In this example, the boulder clearance and subsequent relocation is undertaken in a way that creates new stony reef habitat. For the construction of the Anholt offshore wind farm wind farm, around 5,000 boulders of up to 30 tonnes had to be moved. With the agreement of the Danish Nature Agency, DONG Energy (now Ørsted), did not just reallocate the boulders on the reef existing in the wind farm area. The developer used the boulders to create approximately 28 artificial reefs with crevices/openings of various sizes within the wind farm (EU, 2020). This action aimed to support biodiversity. According to publicly available information, ten years after their reallocation the boulders support rich biodiversity and large biomass of algae, sea anemones, sea stars; fish (goldsinny wrasse and cod) have also been observed. The boulders provide breeding and nursery grounds for fish and benthic fauna as well as feeding and hiding places (Ørsted, 2023a). It should be mentioned that the Anholt wind farm was not in a Natura 2000 site, and no Annex I reef habitats were affected by it. However, this approach highlights a potential pathway to restore or even create Annex I reef habitats using boulders that were already naturally occurring in the site (EU, 2020).



3.4.4 Mitigations from other marine industries

In addition to the measures mentioned above which relate to considerations specifically for offshore wind, it is important to also consider how these relate to other industries and whether similar or different practices have been adopted and whether there are lessons for the offshore wind industry with this regard. In particular, parallels can be drawn with more established offshore oil and gas industry which is now well established and is entering a different development phase with much of the infrastructure being removed through decommissioning. In the oil and gas industry many of the standard good practice protocols that were identified for wind apply. For instance the JNCC guidance for minimising the effect of underwater noise from seismic survey, piling and UXO are all well established and incorporated into impact assessment for surveys, piling activities and explosive use (JNCC, 2023, 2017, 2010).

There are parallels also to be drawn with the approach to pipeline protection and cable protection with the emphasis to micro-siting where possible to avoid sensitive areas by conducting appropriate seabed surveys, as well as measures to minimise introduction of rock protection where possible. In the case of pipeline protection there is another important consideration is mitigation against pipeline spanning in areas where there are mobile sediments and undulating topography, such as sandbanks. In these areas frond mattresses have been deployed to encourage accumulation of sediments around the infrastructure and decrease the level of scour and winnowing of sediment. Furthermore, these can reduce the need to apply further rock protection which may increase the environmental footprint of the activity. While the introduction of plastic materials in the marine environment is generally discouraged as this is a source of microplastic pollution, these frond mattresses can potentially have applications in Scottish offshore wind farms and development. For instance field trials on protective mats that are plastic-free have been undertaken (NetZero Technology centre, 2024) that have promising results and innovations such as this may also extend to application of fronds mattresses too.

From a technical perspective the burial via trenching and backfill of such lines is generally the default position, although it will be dependent on the site conditions and may require rock protection. It should be noted that a key difference between pipelines and cables is the EMF associated with cables, thus the burial (i.e. through trenching or rock protection) aids to reduce the exposure to EMF by increasing the distance to the receptor. This is also seen in Interconnector projects.

Another parallel where lessons can be learned is around floating structures. In particular, the use of mobile offshore drilling units and the long term installation and decommissioning of Floating, Production, Storage and Offloading vessels which deploy very similar mooring technology to floating wind platforms. The suction piled anchors for instance can be deployed in soft soils and are designed to be reverse installed, essentially being pumped back out of the seabed, and can therefore leave the seabed in a similar condition as when it was installed, although it is acknowledged that in very soft sediments, excavation may be required to remove these from the seabed and some further intervention can be required to backfill any trenches and/or craters which can be left behind.

Lessons can be taken from other coastal developments and the use of environmental mitigations. Examples can be drawn on infrastructure projects such as the Aberdeen Harbour expansion Project at Nigg Bay where double bubble curtains were deployed along with other mitigations such as ADD and MMOs to protected marine mammals during excavation and blasting activities (Dragados, 2019). It is important to note that in this case, there were limitations in the effectiveness of the bubble curtains in the deeper water of the bay. This provides an indication that the use of bubble curtains in the offshore environment where wind turbines would be installed are likely to be unsuitable for



use. Nonetheless where such activities are happening in shallower water they may have applicability in sensitive areas as a part of a mitigation plan for marine mammals or fish. An example of successful use of bubble curtains being deployed was within the Tyne river at South Shields during piling activities to reduce the impact of the noise on migrating salmon (New Civil Engineer, 2023). In this cases the deployment of the mitigation were deemed to be successful, however it should be noted that this was in much shallower water that would be encountered in the offshore ScotWind Lease areas. Other mitigations that have been cited for noise impacts include minimisation of vessel noise through the adherence to the Scottish Marine Wildlife Watching Code (SMWWC) (SNH, 2017b) that was proposed for installing Wave Energy Convertors (Mocean Energy, 2023).

Marine developments have the potential to significantly impact birds, both offshore and onshore. Mitigations in place from offshore oil and gas with regards to seabirds are largely focussed on effective management and contingency plans for oil spills and thus the avoidance of such an incident, as the first line of mitigation. However, in the context of offshore wind and other developments which may be in the vicinity of important areas for offshore seabirds or overwintering waterfowl, the risks of displacement or collision are potentially significant. Therefore in the management of vessel movement is important to limit disturbance, particularly at vulnerable times and consideration for the size of vessels in certain areas may be important to minimise presence. In the case of Aberdeen Harbour Expansion Project, the breakwaters themselves that were constructed as part of the project were actually identified as being a mitigation which aided the potential loss of habitat and disturbance to sensitive sea ducks and divers (Aberdeen Harbour Board, 2015).

The spatial and temporal avoidance mitigations can be seen across a number of marine industries. For instance, in the case of oil and gas activities, seasonal concerns and restrictions are placed on specific Oil and gas licence blocks for undertaking seismic surveys in fish spawning grounds (OPRED, 2022). These are then incorporated into mitigation decisions for undertaking such activities. Similar periods of concern have been identified for undertaking oil and gas drilling during periods of high seabird vulnerability (OPRED, 2022). Onshore cable landfall is a particular area that receives important consideration with regard to breeding seabirds or overwintering waterfowl which may be affected should construction activity interfere with key coastal habitats. In particular, in the case of open trenching for a cable for instance, boarding can be used to obscure the visual impact and help reduce sound impacts to sensitive overwintering or breeding bird species such as waders.

Spatial avoidance of sensitive protected features is often cited as embedded or primary mitigation across the marine industry from oil and gas, offshore wind, through to tidal array developments (Orbital, 2023) and coastal development (Shetland Isles Council, 2023). While siting of offshore wind lease areas is already determined in part though marine panning, decisions on where specific infrastructure must go falls largely with the developer. For instance, routing of cables and deciding which option to take can be strongly influenced by the sensitivity of features that may be affected.

In addition to the above, it was noted that additional plans to protect bird species within Special Protection Areas (SPAs) include Construction Bird Mitigation Plan and Biosecurity Management plans (Shetland Isles Council, 2023). These related to coastal developments that were not seen in windfarm mitigations, perhaps as these were identified as additional mitigations and not embedded or tertiary measures.



3.5 Review of the monitoring reports

This section presents the main outputs of the literature review of monitoring surveys for offshore wind farms in Scotland, England and Wales carried out across various development phases (pre-, during and post-construction) for various receptors. Where available, mitigation measures as presented within the respective project documentation, have also been considered along with the monitoring findings to help provide any context on the effectiveness of the mitigation measures deployed, supporting the understanding of the extent certain mitigation were successful (or effective).

A detailed overview of available Environmental Monitoring surveys for six offshore wind farms: Beatrice (Scotland), Aberdeen Bay wind farm (Scotland), Robin Rigg (Scotland), Thanet (England) and North Hoyle (Wales) (as outlined in Section 2.3). In addition, a fisheries monitoring report was identified for the Neart na Gaoithe (Scotland) offshore wind farm. For the purposes of this review which focusses on the ecological rather than the human environment, the details of this fisheries monitoring report have not been included.

3.5.1 Data Gaps and uncertainties

As part of the Scottish Marine Energy Research (ScotMER) programme, evidence maps have been created for key receptor groups (including ornithology, marine mammals, fish, benthic, physical processes) that have been designed to guide research projects (Scottish Government, 2024). As part of this, it is recognised that there are key data gaps in our understanding for these key receptors. For instance, considerable data sets must be acquired in order to understand the effects of offshore windfarms in order to more accurately predict and quantify the responses to the effects and also better understand ecosystem dynamics such as predator-prey relationships. This data can be acquired through acoustic surveys, remote tracking and importantly through post construction monitoring. As acquisition of more data through post-construction monitoring is acquired and analysed, a better picture of overall effects both on a project level and larger cumulative scale can be derived. Therefore, it should be recognised that any indications on the apparent effectiveness (or not) of mitigation measures can only tentatively be derived from project monitoring in this report should be considered tentative.

3.5.2 Beatrice Offshore Wind Farm

The construction of the offshore elements of the Beatrice Offshore Wind Farm Ltd (BOWL) began in April 2017. The first turbine was installed and operational by July 2018 and the final turbine was installed on the 14th May 2019. The post-construction monitoring surveys for Beatrice refer to ornithology, fish, and benthic receptors. It is acknowledged that there is a Marine Mammal Monitoring Programme that covers the Beatrice, Moray East and Moray West windfarms and includes a 10 year monitoring programme for marine mammals. However, associated reports or data could not be sourced for this review. Data from the Moray Est Piling Strategy was used to supplement this data gap (See section 3.5.3).

Ornithology

With regard to ornithological mitigation, the EIAR acknowledged that “The only mitigation measures appropriate with regards to effects on birds are those already performed as best practice within industry standards”. In addition, “No specific mitigation has been identified for ornithological effects in relation to the construction, operational or



decommissioning phases of the proposed wind farm". This position appears to have remained unchanged throughout the determination process.

Table 16 below summarises the outcomes of the post-construction monitoring surveys that have taken place for Beatrice ornithological receptors. First year post construction monitoring identified that overall, for all species examined (i.e., guillemot, razorbill, puffin, kittiwake and herring gull), the pooled analysis found no indication of systematic turbine avoidance. That is to say that there would appear to be no clear indication of disturbance. However, this report did not appear to actually report whether there was any impacts to populations.

The EIAR was submitted considerably earlier than the post consent reports this and there was less transparent detail on the associated mitigation measures. As such this lack of information in the EIAR and related documentation limits how much interpretation can be made on the proposed deployed mitigations which limits the comments that can be made associated with any effectiveness.

Fish

Through the EIAR and determination process, Atlantic cod and sandeels were identified as being of particular risk through habitat loss, EMF and thermal effects of the cables as well as noise. With regard to mitigation associated with effects to cod and sandeels specifically, the following measures were applied:

- Use of soft start piling to avoid exposure to the highest noise levels;
- If concurrent piling operations are undertaken, vessels will operate at no more than 5 km from each other. The purpose of this will be to minimise the potential area of ensonification from that presented in the worst case, and the use of two vessels should also decrease the installation programme; and
- Cables will be buried/protected where feasible.

The piling strategy consent plan provides more detailed information on the proposed piling strategy and mitigations for underwater noise (Beatrice Offshore Windfarm, 2015) This consent plan specified that deployment of the soft start would be reported in an audit trail would be in place to ensure that Hammer energies would remain within agreed limits within soft start periods and that the addition of Acoustic Deterrent Devices (ADD) would also be deployed.

Cod and sandeels were directly monitored through otter trawl and dredge trawl studies respectively, post installation to determine if there was any discernible longer term impacts. The outcomes of the environmental monitoring results concluded that cod spawning occurred in the survey area pre-construction and that this continues to be the case post-construction (Beatrice Offshore Windfarm, 2021a). In the case of sandeels, the monitoring report concluded that there was no evidence to suggest that the construction of Beatrice Offshore Wind Farm has resulted in negative impacts on the local sandeel population (Beatrice Offshore Windfarm, 2021b). However, these monitoring results do not indicate how successful a single mitigation measure was but simply that in combination, the residual project impacts, would appear to have had no discernible impact on these species. For instance, these fish species may have been potentially impacted by the physical installation activities and associated seabed disturbance (especially sandeels), so the actual measurement of the receptor doesn't tell the full picture on the relative success of a single mitigation. It is noteworthy that the Beatrice EIAR addendum mentions that the objective of these surveys was to assess potential effects of the development and to validate assessments made in the EIAR. Therefore, the key driver for the survey was to specifically monitor and evaluate the impact to the receptor, and not necessarily the



effectiveness of mitigation measures. Here, we have looked at the monitoring data to see if this can tell us anything about the effectiveness of the mitigation measures deployed.

Outputs from the monitoring are detailed in Table 16.

Benthic ecology

While no specific mitigations were deployed for the benthic impacts, infaunal benthic monitoring was undertaken. Table 16 below summarises the findings of post-construction monitoring surveys for benthic receptors. EIA commitments included monitoring of infauna using a series of replicated grab samples within and outside of the wind farm site, to detect any changes that can be attributed to the development of the wind farm itself. This included monitoring of non-native species as well as habitat recovery. The results seemed to show no conclusive evidence of change from baseline. This should be taken with caution through as it is only a single measurement without real overview of sampling frequency measuring change over time and also the specific sampling plan itself.



Table 16 Post-construction monitoring survey findings for BOWL

RECEPTOR	SUMMARY OF FINDINGS	CITATION
Ornithology	<ul style="list-style-type: none"> Based on the design-based population estimates, the post-construction surveys found broadly similar overall abundance (within the total study area) for all species. Within the wind farm, five species were (on average) more abundant in 2019 than in 2015: guillemot, razorbill, kittiwake, great black-backed gull and herring gull, and two were less abundant: gannet and puffin. A more robust assessment of an overall wind farm effect can be produced from the spatial models fitted to the “before” (2015) and “after” (2019) construction data: the affects varied across species with increases in abundance observed in auks and significant redistribution effects of Kittiwake and gannet. Year 2 monitoring found increased abundance across the period for guillemot kittiwake and Puffin although puffin was originally down after year one, compared with pre-development which highlighting variation in the year on year. Razorbill and large gull abundance generally peaked in the second year Gannet numbers were consistently down after year two data was analysed and this species demonstrated the most consistent clear pattern of response, although there was no difference between year one and year two, indicating that gannet abundance may have reached an equilibrium. Overall, for all species examined (i.e., those with sufficient data; guillemot, razorbill, puffin, kittiwake and herring gull), the analysis found no indication of systematic turbine avoidance. Year two data suggest that within wind farm boundaries there were no clear trends in abundance with the exception of gannet for which there did appear to have been a consistent decline. 	<p>MacArthur Green (2021). Year 1 Post-construction Ornithological Monitoring Report 2019</p> <p>McArthur Green (2023) Year 2 Post-construction Ornithological Monitoring Report</p>
Fish and shellfish	<p>The results suggest that cod spawning occurred in the survey area pre-construction and that this continues to be the case post-construction.</p> <hr/> <p>There is no evidence to suggest that the construction of BOWL has resulted in negative impacts on the local sandeel population.</p>	<p>Beatrice Offshore Windfarm Cod Spawning Survey Results – Technical Report (2021a)</p> <hr/> <p>Beatrice Offshore Wind Farm Post-construction Sandeel Survey–Technical Report (2021b)</p>



RECEPTOR	SUMMARY OF FINDINGS	CITATION
Benthic ecology	<ul style="list-style-type: none">• Monitoring of biofouling on monopiles was carried out in 2020 and 2021. Overall, the colonisation and zonation patterns on the BOWL jacket legs observed in 2020 (APEM 2021) were apparent in 2021; further monitoring will shed light on how stable the communities recorded on the jacket legs are over time.• Extensive biofouling on all turbine jacket legs with signs of zonation and successional development. Findings are consistent with findings at other wind farms.• The mussel <i>Mytilus edulis</i> was found at two of the turbine foundations in low numbers during this second BOWL monitoring survey (<i>M. edulis</i> mussels were not recorded in 2020).• High abundance of small newly settled fish at all depths along the jacket legs. Adults were abundant around the base of the jacket legs and surrounding seabed.• No conspicuous non-native species were recorded.• Monitoring indicated that there has been a shift in the dominant biotope from 'Moerella spp. With venerid bivalves in Atlantic infralittoral gravelly sand' (referred to as MoeVen) during the 2020 survey to "Echinocyamus pusillus, Ophelia borealis and Abra prismatica in circalittoral fine sand" biotope (referred to as EpusOborApri). This shift was apparent in the offshore wind farm site and at reference stations.• Available data suggest that biotopes at the site are mainly transitional between the MoeVen and EpusOborApri biotopes with a natural fluctuation between these biotopes.• There is no evidence that the Beatrice OWF development has had an impact on the MoeVen biotope beyond changes due to natural variation.• Juveniles of conservation significance bivalve <i>Arctica islandica</i> (ocean quahog) (PMF, OSPAR T&D List) were found; this was in agreement with the 2010, 2015 and 2020 survey outputs.	APEM (2021, 2022)



3.5.3 Moray East Windfarm

Moray East is located in the outer Moray Firth, approximately 22.5 km southeast of the Caithness coastline consisting of 100 turbines and became fully operational in 2022. The Moray East conducted a pre-construction environmental monitoring survey and a post-construction survey. The pre-construction survey consisted of seven survey campaigns within the Moray East site and eight survey campaigns across the cable corridor.

Benthic

The Moray East monitoring programme highlighted that in instances where scour surveys showed significant changes in the seabed, monitoring would be undertaken. Post installation monitoring data indicated that scour protection around the 3 OSP locations and 2 WTG locations met the design specification of 1 m thick above seabed around the piles. No significant change in the seabed was reported. (MOWL, 2020)

Fish

The Moray East Offshore Windfarm underwent the Moray Firth Tracking Project to monitor the diadromous fish species across the following rivers in line with the PEMP: Conon, Deveron, Findhorn, Shin, Ness, Oykel, and Spey. This monitoring programme was a large scale operation with a total of 358 receivers placed across these rivers and in three lines across the inner and outer moray Firth. The monitoring programme tagged 850 smolts with acoustic transmitters for monitoring. The monitoring study was completed in 2019 and no further studies were undertaken. Data and analysis of results were unavailable so further comment cannot be made.

Marine Mammals

During the Moray East construction period a variety of marine mammal mitigations were used this included: Acoustic deterrent devices, soft start, hammer energies, breaks in piling, and phased piling. An MMO and PAM operator was always used for monitoring purposes during the piling activities. During the course of the activities there were no recordings which occurred during the piling or ADD activities. Outwith these periods there were a total of four sighting, three minke whales and one unidentified seal sighting. (MOWL, 2021).

The information that was acquired on marine mammals was not a comprehensive dataset and as therefore it is tricky to make broad assumptions on the success of mitigations deployed at this windfarm. Nonetheless, the fact that no marine mammals were sited during the pre-piling ADD deployment and during piling activities provides a gauge that the intended avoidance behaviour was observed by marine mammals and that there was relative success in the measure.

3.5.4 Aberdeen Bay Windfarm

Aberdeen Bay Windfarm project is made up of 11 x 8.8 megawatt Vestas wind turbines and is located just off the coast of Aberdeen. With regards to specific mitigations deployed, these were limited to industry standards (although notably hammer piling for installation was avoided altogether). A notable commitment in the EIAR was that detailed monitoring measures would be further developed to avoid, remove, or reduce any potentially significant impact. As such, this project incorporated numerous offshore wind monitoring studies during the operation of the wind farm to corroborate the predictions made in the EIAR. The follow up monitoring includes bottlenose dolphin monitoring, diadromous fish (trout/salmon) tracking and bird tagging and avoidance studies.



The seabird monitoring study at the Aberdeen Bay Windfarm involved radar-camera monitoring unit deployed on the wind turbine structures that collected radar tracks and video footage over a two year period. The sensors enabled species identification and analysis of meso- and micro-avoidance behaviours in an operational offshore wind farms. In summary, the results recorded significantly high levels of micro-avoidance in all target species and concluded that seabirds will be exposed to very low risks of collision during daylight hours. This was confirmed through observations that no collisions or even narrow escapes were recorded in over 10,000 bird videos during the two years of monitoring. (Skold Tjørnløv *et al.*, 2023).

These results helped corroborate the EIAR which proposed no significant effects with limited embedded mitigation deployed. However, it is worth noting that the observations were based on the design parameter of blade tip clearance of approximately 26 m above the sea level which evidently, in this case would seem adequate to reduce bird collision to a negligible level and enabling micro-avoidance. Another important aspect of this is the space between the rotor blades. The monitoring survey recorded that seabirds displayed attraction to the areas in between the turbine rows (Skold Tjørnløv *et al.*, 2023). Therefore, it can be said that spacing and number of turbines is important also for enabling avoidance behaviour. In the case of the Aberdeen Bay Windfarm the rotors were evenly spaced, large (164 m diameter) and have a rotation speed of up to 13.98 rpm (Vattenfall, undated). This was a site specific survey and therefore cannot be assumed to be applicable of wind farms generally. Even in the case of the Aberdeen Bay windfarm, it may be tentatively considered that the development parameters result in a lessened risk of seabird collision but it should also be factored in that this windfarm is located close to the shore and therefore could still present some risk to birds. It should be noted that In more sensitive areas, closer to breeding or foraging areas, further mitigations would perhaps need to be considered.

3.5.5 Thanet Offshore Wind Farm

Thanet Offshore Wind Farm (TOWF) is located approximately 11.3 km off the Kent coast and was installed in 2010. The wind farm consists of 100 wind turbine generators (WTGs) installed on monopile foundations in shallow water (~25 m) (Vattenfall Wind Power Ltd, 2019). The original Thanet EIA documentation does not appear to be in the public domain; however, seabed monitoring data was identified in the literature review (Marine Ecological Surveys Ltd, 2013).

A post-construction benthic survey of the area using both grab sampling and acquisition of seabed imagery (Marine Ecological Surveys 2013). Table 17 below summarises the outputs of post-construction monitoring survey for the TOWF, largely focussed on benthic receptors. Not much can be derived from this in the absence of the actual mitigation information that was deployed but it can be inferred that the *Sabellaria spinulosa* aggregations that were a key conservation objective of the project were not significantly affected by the project and that aggregations appear to have increased following the construction, with any negative impacts restricted to localised areas around scour pits. While this indicates some resilience of this habitat forming species, it is limited in the information it provides with regard to associated mitigation. This species requires mobile sands to form their tube structures, therefore available sand habitat is essential for their ability to persist. It is anticipated that good practice minimisation mitigation measures (as presented in Section 3.2 and 3.3) were deployed to reduce the amount of sandy seabed lost for this species, however this cannot be confirmed based on review of the monitoring report and therefore conclusions on the efficiency of any mitigation cannot be provided.



Table 17 Post-construction monitoring survey findings for TOWF

FEATURES	SUMMARY OF FINDINGS	CITATION
Physical environment / Benthic ecology	<ul style="list-style-type: none"> The comparison of results between pre- (2005 and 2007) and post-construction (2012) showed that sediment composition has remained broadly similar following the construction and operation of TOWF. Temporal comparisons of faunal data between pre- and post-construction, revealed an increase in mean infaunal abundance, diversity and biomass across the TOWF site. Benthic assemblages at TOWF showed significant differences between pre- and post-construction accounted for by an increase in the number of taxa. differences can be attributed to natural variation. A direct comparison of the <i>S. spinulosa</i> distribution between 2007 and 2012 showed that in 2012 there was a wider distribution of 'moderate <i>Sabellaria</i> growth' and 'dense <i>Sabellaria</i> growth'. Sediment within the scour pits which had formed included a mixture of coarse sediments which, on average, were coarser than those sampled throughout the TOWF site. Infauna samples analysis from scour pit locations showed that that the most abundant and commonly occurring taxa were similar to those found across the TOWF site and surrounding region. No <i>Sabellaria spinulosa</i> reef aggregations were found in seabed images collected from the scour pits. Any impacts on <i>Sabellaria spinulosa</i> aggregations/benthic features are likely to be constrained to the base of the monopile plus an approximate 5 metre circumference. 	Marine Ecological Surveys Ltd (2013). Thanet Offshore Wind Farm: A Post-Construction Monitoring Survey of Benthic Resources



3.5.6 North Hoyle Offshore Wind Farm

North Hoyle Offshore Wind Farm is located in Liverpool Bay and commenced operation in 2003. At the time of writing, the relevant chapters of the EIAR for the North Hoyle Offshore Wind Farm are not publicly available. As one of the very first offshore wind farms in the UK, it is unclear what mitigations were deployed based on available evidence.

Table 18 below summarises the outputs of post-construction monitoring survey for the North Hoyle offshore wind farm receptors (physical environment, benthic ecology, marine mammals, ornithology).

The physical environment and benthic ecology (infaunal and epifaunal) results did not show any significant changes, although some scour around rock armour was noted but this was considered within the design parameters and not of concern.

With regards to cetaceans in the North Hoyle wind farm it was mentioned that there were no long-term distributional changes of any cetacean species between before and after wind farm construction; however, systematic effort-related observations were not available. In North Hoyle due to limited data availability, it was not possible to identify any impact of the construction or operation of the wind farm on seal numbers.

The ornithology surveys indicated that there was some evidence to suggest that avoidance behaviour had occurred in some species including sandwich tern and auks (razorbill and guillemot). Some behavioural observations were made on gannet flight paths. It should be considered that these results are inconclusive as to the significance of any effects on these species other than the structures presenting a degree (albeit small) level of obstruction.

Overall, there would have appeared to be no significant effects based on the monitoring evidence but due to lack of information on the mitigation deployed, no comment can be made as to whether this influenced the apparent outcome.



Table 18 Post-construction monitoring survey findings for North Hoyle Offshore Wind Farm

RECEPTOR	SUMMARY OF FINDINGS	CITATION
Physical environment	<ul style="list-style-type: none"> Sites within the wind farm array and in control areas have shown both increases and decreases in sediment coarseness; There is no trend suggesting that wind farm construction, cable burial or adjustment of hydrodynamic forces due to piles present are responsible for the changes in sediment type; Presence of drill cutting mounds to the south of each pile, and some minor scouring to the north of piles. Further mounds relate to rock armouring around the J-tubes and have variable volume and form; Scour estimates for the combined wave and tide case equate well to the observed scour depths which were within the design estimate at less than 0.5m. 	May (2005). Post-construction Results from The North Hoyle Offshore Wind Farm.
Benthic ecology	<ul style="list-style-type: none"> Findings between pre- and post-construction do not indicate a change in habitat. the results from the 2004 survey suggest that characteristics of the Irish Sea assemblages identified after the initial 2001 survey have been retained. 	
Marine mammals (cetaceans)	<ul style="list-style-type: none"> There is no evidence suggesting long-term distributional changes of any cetacean species when comparing sightings before and after wind farm construction. However, systematic effort-related observations are not available. 	
Marine mammals (seals)	<ul style="list-style-type: none"> Anecdotal records of both grey seal and harbour porpoise within the operational wind farm area show that individuals visit the wind farm site and forage within it. 	
Ornithology	<ul style="list-style-type: none"> Sandwich terns and gannet showed variable responses to the wind farm, with some evident deviation of flight around the wind farm, and some flight through the farm though not statistically significant. Gannets entering the wind farm appear to respond to the turbine blades by lowering their flight height. Cormorant use the two meteorological masts for drying out or roosting on at high tide; this happens between foraging trips. Cormorants increasingly also roost on the turbine transition piece gantries. Larger numbers of guillemot and razorbill were recorded on transect sections outside the wind farm, indicating potential avoidance, although this was inconclusive. 	



3.5.7 Robin Rigg Offshore Wind Farm

Robin Rigg Offshore Wind Farm in the Solway Firth. The site is comprised of 60 turbines and an offshore sub-station. Construction of the offshore wind farm and its associated cabling began in December 2007 and the site became full commercial operation in April 2010. Please note, at the time of writing, the EIAR of the Robin Rigg Offshore Wind Farm is not publicly available, so data on mitigation deployment is limited. The only information on associated mitigation measures is a statement around piling mitigation that indicated “Mitigation should be used to avoid startle/alarm responses in response to the onset of piling activities.” That was stated in the year 1 monitoring report (Walls *et al.*, 2012).

In accordance with the consent from Scottish Ministers under Section 36 of the Electricity Act 1989, a Marine Environment Monitoring Programme (MEMP) was developed to record any changes to the local physical and ecological environment as a result of the construction of the wind farm. This included monitoring requirements for a number of ecological parameters including non-migratory fish (over three operational years), birds (over five operational years) and marine mammals (over two operational years) detailed in Table 19 (Walls *et al.*, 2012, 2013; Canning *et al.* 2013 and Nelson *et al.*, 2015). This monitoring data provides an insight into the possible impacts on these receptors over the course of the development.

Surveys focussing on non-migratory fish species were carried out during collation of baseline information, and during construction and post-construction periods. The post-construction surveys of non-migratory fish did not show any significant impacts to the assemblages. There was observation of lower catch abundances during construction, but this may have been circumstantial and not necessarily attributed to the construction activity itself. Overall, there were no discernible changes identified including any effects to the mobile sand habitat present in this area (Walls *et al.*, 2013).

From boat-based visual surveys, it was determined that generally birds were not deterred or displaced by the wind farm. It is notable that the blade air gap for this wind farm was 35 m. It was recorded that the birds generally flew below the rotor blades which adds some weight to the effectiveness on the minimum blade height mitigation that has been well documented elsewhere in this review (Nelson *et al.*, 2015).

For marine mammals a key finding to come from monitoring during construction was that levels of underwater noise measured at the beginning of the soft start procedure are likely to be below the levels that would cause lethal effects but were likely to illicit a strong behavioural response i.e. animals would flee the area to reduce their exposure to the noise (Canning *et al.*, 2013). Furthermore, the monitoring found that while harbour porpoise abundance in the project area dropped during the construction phase they returned in significant numbers above pre-construction levels during the operational phase. This is a significant finding and adds confidence on the likely effectiveness of the soft start procedure for piling.



Table 19 Post-construction monitoring survey findings for the Robin Rigg Offshore Wind Farm

RECEPTORS	SUMMARY OF FINDINGS	CITATION
<p>Fish and shellfish / Benthic ecology / Physical environment</p>	<ul style="list-style-type: none"> • The species captured in the non-migratory fish surveys are typical of Irish Sea estuarine environments; • Analyses showed that significant change had occurred between survey periods and season; • Catch abundance of fish, invertebrates, brown shrimp and whiting reduced following the commencement of construction, particularly in construction year one (February 2008 to February 2009); however, very little construction activity took place during this period; therefore, it is difficult to attribute this change to construction activity; • Low correlation between species assemblages and distance from site for both fish and epibenthic assemblages suggests wind farm presence is not driving change within the Solway Firth; • No evidence of change to the mobile estuarine sand bank system present in the Solway Firth. 	<p>Walls <i>et al.</i> (2013)</p>
<p>Ornithology</p>	<ul style="list-style-type: none"> • No significant negative effects from construction and operation of the Robin Rigg offshore wind farm on the 11 key avian receptors outlined in the Marine Environmental Monitoring programme were detected, validating the predictions outlined in the EIAR; • There was evidence to suggest that razorbills and guillemots were not displaced from the Robin Rigg offshore wind farm during operation and there was some evidence of habituation to the wind farm; • Modelled provided strong evidence that kittiwakes and herring gulls did not exhibit macro-avoidance and were not displaced from the Robin Rigg offshore wind farm during operation; • The majority (c. 94%) of gannets, kittiwakes, herring gulls and great black-backed gulls flew below turbine rotor height above the sea (<35 m) across the entire study area. Therefore, collision risk for these four species is negligible at the Robin Rigg. 	<p>Nelson <i>et al.</i> (2015)</p>
<p>Marine mammals</p>	<ul style="list-style-type: none"> • Results indicated a possible impact on harbour porpoise abundance – with numbers of porpoise dropping (though not significantly) from pre-construction to the construction phase, and then increasing significantly during the operational phase; • With regards to noise, in most cases the noise associated with the operational turbines was not detectable above background noise levels; • The levels of underwater noise measured during operational year one were sufficiently low that lethal, physical injury and auditory damage to marine species (fish and marine mammal) will not occur. 	<p>Canning <i>et al.</i> (2013)</p>



3.5.8 Summary of monitoring report reviews

An inherent principle of the consenting envelope process is to maintain the flexibility within the project design to allow more detail design to occur post-consent. However, given that environmental monitoring surveys are developed and undertaken only after the project design has been refined and finalised, there is some difficulty when reviewing monitoring reports in isolation and trying to understand the efficiency of mitigation measures.

From the perspective of Beatrice wind farm, it would appear that there was steer through the determination process that drove more stringent monitoring commitments and further consideration to mitigations and stakeholder engagements. These included timing and duration of piling activities and cable burial requirements, all of which would be currently deemed current good practice in minimising impacts.

There were very limited conclusions to derive for the monitoring undertaken at Moray East, due to the limited data available, which is likely due to its relatively recent construction. The data on marine mammal presence during the piling activity seemed to be inconclusive on whether the mitigations deployed such as ADD and soft start were effective. However, the fact that no mammals were sighted during these activities indicates at least that there was avoidance while they were being deployed prior to ramp up of impact piling.

The extensive seabird monitoring at Aberdeen Bay wind farm suggests that there was no major issues with collision risk based on the design parameters that were employed for that particular wind farm, which would appear not to have specifically included collision risks within embedded mitigation. However, the results here should be taken with some caution as this is specific to a particular wind farm and specific location. Similar reports of negligible impacts on seabirds were made from boat based seabird monitoring surveys at Robin Rigg. Proximity to breeding colonies, the species present and their associated flight behaviour in the relation to the wind farm area are all important considerations for appropriate mitigation.

Overall, there was evidently a lack of accessible monitoring and post-consent data for operational windfarms with only six developments identified where post-construction environmental monitoring reports readily available for review. Monitoring data that was available focussed on selected receptors essentially to corroborate the residual impacts assessed in the respective EIARs; and little could be derived to provide context to the effectiveness of the individual measures deployed. Indeed, in many cases there was no obvious specific mitigations deployed. As such, it was generally considered that the monitoring results did not indicate how successful a single mitigation measure was. Instead, monitoring data targets receptor/s that shows its status of the in-combination effects of a project that incorporated a suite of mitigation measures at a particular time. The post-construction survey monitoring results would generally appear not to show significant changes from baseline conditions. In some places, the extent of some key conservation species such as *Sabellaria* had increased, however it was inconclusive whether any of these outcomes were actually a result of effective and successful mitigation measures. Similar gaps were evident for seabirds and fish and marine mammals. The Reports from the Robin Rigg Wind Farm of negligible, if any observable effects in seabirds provided some merit for a minimum rotor blade height at 35 m, at least for this particular site.

The monitoring data to date also only provides a relatively short term picture of status and there remains the uncertainty of longer term impacts in combination with climate change and increase in marine developments generally and other pressures to receptors such as avian flu. It was noted that pre-, during and post-construction



monitoring can be informative for construction activities which have a temporary impact such as piling and associated effects can be compared, as was the case at Robin Rigg.

Nonetheless monitoring across the whole life cycle, including post decommissioning as set out in UK National Policy Statement (UK Government, 2023) will help determine the legacy of effects and should feed into an adaptive mitigation management process so that that mitigation can be brought in to potentially ameliorate effects that have been shown to be greater than initially expected through monitoring. Furthermore, monitoring data can also be used to inform decisions about mitigations that can potentially have beneficial effects, if any through interactions such as NID.



4 DISCUSSION AND CONCLUSIONS

This literature review took a holistic approach to consider mitigation measures broadly across publicly available documents relating to offshore wind farms covering a range of physical, biological, and environment receptors the intention was to aid in determining appropriate mitigation measures that can be incorporated into a Good Practice Library that will be appropriate for offshore wind developments in Scotland. By doing this, the review intended to take important steps towards achieving key aims of the CEMNID Project, namely to:

- Provide a clearer understanding of how to apply the mitigation hierarchy in offshore wind development, including consideration of embedded measures and design decisions; and
- Summarise good practice environmental mitigation measures available to deploy through the mitigation hierarchy.

This review process has set out wide ranging lists of mitigation Measures relating to specific receptors and categorised them according to the mitigation hierarchy outlined in Section 2.4. The process has involved the identification of mitigation measures driven by UK and international policy, included those in existing Scoping reports / EIARs as well as further consideration for those which are promising but have not yet become deployed in the UK offshore wind sector at the time of writing.

An important finding was that many of the mitigations that were encountered in the review process were Primary mitigations what were inherent in the design of the development and a consequence of standard practices. Examples of these are approaches such as cable burial principles, minimising rock protection as low as reasonably practicable and ensuring turbine spacing is such that it minimises entanglement or collisions with marine fauna. In these cases, where this mitigation is proposed, the driver is most often engineering design and/or cost effectiveness rather than the environmental benefit. Nonetheless, where relevant, such measures have been retained on the lists in this review and considered mitigations in their own right on the basis that (where relevant), they do represent good practices that generally result in an environmentally beneficial outcome. It is proposed that retaining these measures as embedded environmental mitigations will help to ensure such measures are committed to and carried through to executing the project.

One of the emerging findings is the importance of developers' early engagement with regulators and SNCBs. This early engagement should incorporate discussions about possible significant effects that may arise from offshore wind farms and what should be done to mitigate those effects. On the contrary, late stakeholder engagement, can significantly reduce the capacity to implement further mitigation into the design. Moreover, the early consultation and consideration of avoidance mitigation in the early planning phases can significantly improve the environmental performance of a project (as well as realise cost savings and help deliver a smooth consenting process). This was an important theme found throughout the review.

A key emerging finding in compiling the list of mitigation measures across Scoping reports and EIARs was that in almost all cases these were essentially embedded mitigations in the respective projects that fell within existing, established guidance and policy criteria for offshore wind developments in UK/Scottish waters. As such, it is proposed that these would generally be incorporated into the Good Practice Library as part of the CEMNID Project. In particular,



avoidance mitigation measures were generally applicable to both fixed and floating designs and thus considered appropriate to ScotWind projects going forward.

The review has revealed that the mitigation measures adopted by projects at EIA stages were refined through the determination and post consenting process all relate to avoidance and minimisation methods that are broadly in line with the industry standard practices. At present, there has been very limited restoration and offsetting measures featured in the mitigation plans for UK projects, with only one or two clear examples identified. Following the mitigation hierarchy beyond avoidance and minimisation to include restoration and offsetting measures is therefore something for consideration for new ScotWind projects.

One of the mitigation measures that seems to be successful so far for mitigating impacts on seabirds is the application of a minimum gap between rotor blades and sea surface. This measure has been mentioned in several EIAs examined in this report as well as evidenced through the Aberdeen Bay and Robin Rigg offshore wind farm post-construction and operational monitoring outputs. It would seem that there remains some degree of technical uncertainty on the achievable gap that can be obtained by floating structures, although 35 m (MSL) has been proposed by two proposed floating wind developers. The blade clearance for installed demonstrator floating windfarms at Hywind and Kincardine achieved 26- to 22 m respectively.. It should be taken into account that the air gap that is achievable for any offshore wind farm (fixed or floating) is dependent on project specific conditions including as the water depth.

It is noted that there were some potential future considerations for physical effects of offshore wind structures on hydrographic fronts and water mixing for which no particular mitigation was identified. This may be something to consider cumulatively in future planning.

A number of innovative/novel mitigation measures are available in the literature (see Section 3.4). While these measures have generally not yet been tested in Scotland, especially on a commercial basis, their effectiveness and applicability to the region is somewhat unknown. This is especially true when considering additional noise abatement options that go beyond the standard protocols for piling that are current standard practice. However, there is evidence that these may have some real potential and be incorporated into a suite of good practice measures to be considered for offshore wind in Scotland. It was considered that measures for noise abatement for piling such as big bubble curtains and Hydro Sound Dampers (HSD) have promise for applicability in Scottish waters and would provisionally be considered for incorporation into the Good Practice Library. Furthermore, low order deflagration for UXO has now been successfully deployed at a Scottish Site (Moray West windfarm) and is therefore a proven method that generates considerably lower noise than a UXO detonation. Seabird collision risk mitigation such as remote sensing detection and shutdown/slowdown technologies and painting of turbines may have the potential to significantly reduce impacts of ScotWind projects where sensitivities of seabirds are particularly high. It is proposed that these innovative measures will be further screened against the objective criteria for the next step to develop the Good Practice Library. This is further discussed in Section 4.1.

Another key point that has emerged is that each single mitigation measure should not be regarded as a measure that solely reduces negative effects it may create potential negative effects too. This finding is relevant to both innovative/alternative measures as well as to standard practices. For example, painting turbine blades black to avoid collision risk with seabirds may have negative impacts for landscape. Also, the use of ADDs (a measure that is regarded as "standard practice") may also have some negative impacts on marine mammals through the introduction



of noise in the marine environment. These points emphasise the need for a more holistic consideration for mitigation measures across multiple receptors. Furthermore, based on the discussions with developers it seems that a description of the positive and negative effects/challenges associated with mitigation measures would be beneficial. This could help them in the selection of appropriate mitigation measures for their developments. Identification and selection of appropriate mitigation measures may also benefit from knowledge gathered from other industries (e.g., oil and gas, shipping, aquaculture). In the view of other industry learnings, the offshore Oil and Gas Industry, in particular, can be drawn on from which a wealth of experience has been gained through entire project lifecycle of offshore infrastructure projects from construction through to operation and decommissioning. There are parallels that have been identified with regard to design and removal considerations for FPSOs and floating wind structures for instance as well as the parallels between Pipeline and cable installation considerations with regards to approaches for mitigation and monitoring.

It was noteworthy on reflection that decommission mitigation was not widely described and effectively absent of the review of management plans and EIARs. This may be considered further for offshore wind farms in Scotland, particularly as there can be a distinct difference in approaches and legacy between fixed and floating structures. Lessons on decommissioning practices can be taken from the oil and gas industry from which there are lots of parallels for the offshore sectors. In particular structure removal (excavating and cutting piles below seabed) have similar principles and are demonstrated to work. Similarly, decommissioning of pipelines have similar consideration to cable infrastructure, particularly if buried or rock protected and 'in situ' decommissioning is considered. Of particular relevance to ScotWind, decommissioning of FPSO vessels have similarities in principle to floating wind structures particularly with mooring recovery. Benefits of reverse installation techniques to remove suction piles for instance have been realised as effective measures that would apply to floating wind designs where this design is suitable.

Literature review and stakeholder engagement have highlighted need for accessible and transparent monitoring data but also the limits of what this data can tell us about that performance of mitigation measures. Overall, it seems that there is lack of monitoring with regards to mitigations measures, and therefore a lack of understanding as to whether measures are cost effective or successful. Furthermore, in the case that mitigation measures are not successful it is not clear if adaptation should follow, or if altogether alternative approaches should be sought. In terms of monitoring, stakeholders indicated that the following information regarding monitoring data; analysed results and type of analysis undertaken should become publicly available.

The lack of accessible monitoring and post-consent data is apparent in that only four post-construction environmental monitoring reports were sourced for review. Monitoring data that was available focussed on selected receptors and didn't tell a full picture. Generally, it was considered that the monitoring results did not indicate how successful a single mitigation measure was. Instead, monitoring shows the status of a receptor(s) as a result of the in-combination effects of a project that incorporated a suite of mitigation measures at a particular time. It is considered that the monitoring data may be used to indicate whether a mitigation measure has been useful or not based on whether any effects (positive or negative) have been recorded. However, it is not always obvious if different results would have been recorded in the absence of the mitigation measure, so it is not always clear-cut. The post-commissioning survey monitoring results would generally appear not to show significant changes from baseline conditions. In some places the extent of some key conservation species such as *Sabellaria* had increased, however it was inconclusive whether any of these outcomes were actually a result of effective and successful mitigation measures. Similar gaps were evident for seabirds, fish, and marine mammals. The monitoring data to date also only provides a



short term picture of status and there remains the uncertainty of longer term impacts in combination with the uncertainties of climate change and increase in marine developments generally and other pressures to receptors such as avian influenza.

Stakeholder engagement has shown that contract competition is one of the parameters that can hinder the success of mitigation measures. For example, for UXO clearance there is a novel method called low order deflagration. There is evidence that this method works (including deeper waters with NatureScot being keen that developers move towards low order deflagration) but there is only one supplier for this method at the moment which could increase cost to the developers.

Developing a robust regulatory process that drives environmental recovery and restoration is an area that is still in early development and further thinking should take place on that.

4.1 Next Steps

The next step in the CEMNID Project, which follows on from this literature review, is to develop a Good Practice Library suitable for Scottish offshore wind projects that is based on objective criteria.

As outlined in the methodology (Section 2), objective criteria were proposed to examine whether the identified mitigation measures in this review could be considered to represent industry good practice. Following this literature review, the objective criteria for defining the Good Practice Library has been refined further in Table 20.

Table 20 Objective criteria proposed for inclusion into the Good Practice Library (these were considered in the order listed)

OBJECTIVE CRITERIA		DEFINITION
1	Policy/Current Industry Practice	Is the mitigation measure included in UK policy and/or routinely used as Current Industry Practice?
2	Technical	Has the measure been technically proven to be applicable to Scottish offshore waters?
3	Unintended consequences ⁷	Does the mitigation measure have any potential unintended environmental consequences?

⁷ A third criterion of 'unintended consequences' was considered and noted during the screening process, but this was actually not used as a differentiator for screening in/out any particular mitigation measure. This is because such unintended consequences are likely to arise on a specific case by case basis and are therefore unpredictable and should not be used as a criteria to screen all mitigation measures against.



Discussion with developers, the CEMNID Project steering group, and the suite of mitigations identified from offshore wind projects Scoping Reports, EIARs and monitoring reports, suggest that the vast majority of mitigation measures that were in practice in the industry are generally in line with standard industry practice and underpinned by the policies and guidance in place at the time of writing. However, this review revealed that there is very limited information on the efficiency of these mitigation measures which is particularly relevant for those mitigations where demonstrating a clear correlation with the reduction of pressure source and the effect (if any) on the receptor would be invaluable. The available monitoring data primarily centred on specific receptors, serving mainly to validate the residual impacts evaluated in the respective EIAs. Consequently, there was limited insight that could be derived to provide additional context regarding the effectiveness of the individual measures implemented. It is suggested that a conservative approach is taken to ensure all embedded mitigation practices (i.e. those meeting the for two criteria in Table 19) are presented within the suite of options for consideration for future projects, where applicable. Where deemed relevant, embedded primary or tertiary mitigation measures which would appear to be driven by other technical or financial reasons will be included in the Good Practice Library where it is considered that they represent good industry practice. However, as discussed in this review, aspects relating to existing mitigation practice may also have undesired consequences that should be factored into decision making of a developer.

The potential innovative mitigation measures highlighted in Section 3.4 will not necessarily meet the first two criteria outright but they may be implied in policy without being explicitly identified. These innovative measures will be subjected to the criteria based on their merits and screened in or out of the Good Practice Library. Consideration will be taken into account for mitigation measures used in combination which may result in better outcomes than each measure in isolation.

Taking into account this review, it is therefore proposed that the approach for a Good Practice Library as a three step process that follows mitigation hierarchy and subject to objective criteria:

- Relevant avoidance measures that are embedded in current practice and outlined in current policy, practice and guidance;
- Relevant minimisation measures that are embedded in current practice and is outlined in policy and guidance; and
- Promising avoidance or minimisation measures that are deemed to meet good practice objective criteria but may not be tested in UK waters or embedded in UK policy or guidance.



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APPENDIX A

Table 21 List of offshore wind farm projects in Scotland and England examined for management plans and mitigation measures

PROJECT TITLE	TYPE	PROJECT STATUS	DOCUMENT EXAMINED	COUNTRY	YEAR THAT DOCUMENT WAS SUBMITTED
Salamander Offshore Wind Farm	Floating	Non-operational	Scoping Report	Scotland	2023
Beatrice Offshore Windfarm	Fixed Bottom (Commercial)	Operational	Environmental Impact Assessment Report	Scotland	2018
Moray East	Fixed Bottom (Commercial scale)	Operational	Environmental Impact Assessment Report/Piling Strategy	Scotland	2014
Moray West	Fixed Bottom (Commercial scale)	Non-operational	Environmental Impact Assessment Report/Piling Strategy	Scotland	2018
Neart na Gaoithe (NNG)	Fixed bottom (Commercial)	Non-operational	Environmental Impact Assessment Report	Scotland	2018
Kincardine Windfarm	Floating (Demonstrator Project)	Operational	Environmental Impact Assessment Report	Scotland	2016
Hywind Windfarm	Floating (Demonstrator Project)	Operational	Environmental Impact Assessment Report	Scotland	2013
Aberdeen Bay Wind Farm	Fixed Bottom (demonstrator Project)	Operational	Environmental Impact Assessment Report	Scotland	2011
Seagreen Alpha and Bravo Offshore Wind Farms	Fixed bottom	Operational	Environmental Statement	Scotland	2012
Pentland Offshore Wind Farm	Floating	Non-operational	Environmental Impact Assessment Report	Scotland	2022
Morven Offshore Wind Farm	Fixed bottom	Non-operational	Scoping Report	Scotland	2023
Muir Mhòr Offshore Wind Farm	Floating	Non-operational	Scoping Report	Scotland	2023

Collaboration for Environmental Mitigation & Nature Inclusive Design (CEMNID)

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PROJECT TITLE	TYPE	PROJECT STATUS	DOCUMENT EXAMINED	COUNTRY	YEAR THAT DOCUMENT WAS SUBMITTED
Berwick Bank Offshore Wind Farm	Fixed bottom	Non-operational	Environmental Statement	Scotland	2023
MarramWind Offshore Wind Farm	Floating	Non-operational	Scoping Report	Scotland	2023
Caledonia Offshore Wind Farm	Fixed/Floating	Non-operational	Scoping Report	Scotland	2022
West of Orkney Wind farm	Fixed	Non-operational	Environmental Impact Assessment Report	Scotland	2023
GreenVolt	Floating	Non-operational	Environmental Impact Assessment Report	Scotland	2022
Hornsea Project Four	Fixed	Non-operational	Environmental Statement	England	2021