Crown Estate Scotland

Collaboration for Environmental Mitigation & Nature Inclusive Design (CEMNID)

NID Suitability Review

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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 the 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 developments in Scotland;

- Summarise good practice[1] environmental mitigation measures that could be deployed using 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 adopted National Planning Framework 4 and emerging policies, including National Marine Plan 2 (NMP2).

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 with input from the Rich North Sea.

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 (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 (current deliverable; A100906-S00-A-REPT-005):
  - Strength, Weaknesses, Opportunities and Threats (SWOT) feasibility analysis of identified options for their applicability to offshore wind in Scotland, and associated NID suitability review focusing on ScotWind option 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 will discuss each of the below NID groups in the Scottish offshore wind context, with particular focus on applicability of NID to ScotWind at a plan level. The SWOT analysis (Section 4), which was derived from the NID information presented in the NID literature review and supplemented with feedback from stakeholder workshops and review by the Rich North Sea, will inform this review of applicability. This deliverable analyses information collated as part of the NID literature review and the SWOT analysis for the following five NID categories:

- Fish hotels/cage-type structures;
- Adapted rock protection measures;
- Reef-type structures and concrete blocks;
- Mattresses; and
- Water replenishment holes.

This deliverable seeks to advance our understanding about the suitability of the identified NID options at a plan level within the ScotWind Plan Option Areas according to approximate geographic regions, and describe the key habitat-forming and policy important species/habitats (as defined in the NID literature review). The NID groups will be discussed in turn according to the local environmental characterisation, with particular emphasis on any site-specific points of interest. Please note, this deliverable does not provide the level of detail required to advise on NID measures at individual offshore wind sites; site specific data would be required for this exercise. Within the conclusion, an analysis of the evidence to support the consenting requirement to implement NID in the marine environment will be presented, alongside recommendations, within the context of the adopted NPF4 and emerging policies within NMP2.

2 SWOT ANALYSIS

2.1 SWOT analysis methodology

SWOT stands for Strengths, Weaknesses, Opportunities and Threats. SWOT analysis aims to provide a discursive, qualitative overview of the benefits and detractors associated with, in this instance, NID. In this context, the SWOT analysis was undertaken against each of the five NID groups seen below. The grouping of identified NID options across the five categories was based on the structure and function of the identified NID options (for details on the grouping of the NID options please see the CEMNID NID literature review):

- Fish hotels/cage-type structures;
- Adapted rock protection measures;
- Reef-type structures and concrete blocks;
- Mattresses; and
- Water replenishment holes.

'Strengths' and 'Opportunities' reflect the 'helpful' features of each NID group. 'Weaknesses' and 'Threats' describe the aspects of each NID group which may be a hinderance or 'harmful' to the use of the NID group in Scottish offshore wind. 'Strengths' and 'Weaknesses' relate to defining characteristics of each NID group, i.e. those which are 'internal' and directly attributable to the NID group. For example, in ecological terms, how the NID group may benefit the environment. 'Opportunities' and 'Threats' reflect any external factors which can be, respectively, 'helpful' or 'harmful' in the context of each NID group. An example matrix is presented in Figure 1.

	Helpful	Harmful
Internal	STRENGTHS	WEAKNESSES
External	OPPORTUNITIES	THREATS

Figure 1 Example SWOT matrix

The SWOT analysis was initially populated using ecological, technical and construction expertise within Xodus. Individuals with backgrounds in benthic ecology, offshore wind consenting, and with commercial experience in various renewable energy industries were then consulted via a number of organised stakeholder workshops in order to further populate the SWOT matrices. The workshop process is explained in Section 2.2. Following this, the SWOT matrices were then reviewed by the Rich North Sea to ensure current and up-to-date knowledge on NID was captured.

A key focus of the SWOT analysis was the consideration of the ecological credentials of the groups of NID options identified, drawing principally from the work undertaken in the NID literature review. Specifically, ecological aspects included the structural complexity such as increased surface area for attachment of sessile species as well as other 3D structures such as ledges and crevices which can also serve as foraging or shelter for various species. Other ecological considerations included spatial applicability of the design both in the context of their deployment across both offshore (turbines) and nearshore/shallower areas (cables), with greater applicability being looked at as favourable attributes. The ecological suitability was also considered from the context of the geographical distribution of ScotWind Plan Option Areas and the types of protected habitats and species likely to be present or could settle in these areas that may be targeted beneficiaries of the NID measures.

The SWOT analysis also took into account important technical considerations such as practicalities in deployment, potential challenges of scaling up the technology, their applicability of floating vs fixed wind platforms and important technical risks that may need to be considered both from a practical, safety and legal perspective.

The outcomes of the SWOT analysis, inclusive of stakeholder input, are described throughout in Section 3.

2.2 Stakeholder workshop

Two workshop sessions took place on 17th and 18th April 2024 in order to capture attendee availability, as each session had limited numbers. This was done to ensure attendees were able to actively contribute and participate in the sessions. The two sessions were run in the same way and covered the same information. The agenda was as follows:

- Introductions and housekeeping;
- Introduction to CEMNID Project;
- Session on mitigation measures (open discussion);
- Session on NID (open discussion);
- Conclusion/wrap up and next steps; and
- AOB.

Representatives from the following organisations were in attendance:

- Crown Estate Scotland;
- Marine Directorate Licensing and Operations Team (MD-LOT);
- NatureScot;
- Joint Nature Conservation Committee (JNCC);
- Scottish Fishermen's Federation (SFF);
- Scottish White Fish Producers Association (SWFPA); and
- Project Steering Group Developer Representatives (BlueFloat, bp, COP, Ørsted, OceanWinds, and ScottishPower Renewables).

3 NID SUITABILITY REVIEW

3.1 Overview of methodological steps

The NID literature review identified NID options that may benefit 14 habitat-forming species and 15 policy-important species in Scotland (Appendix A). The identified NID options may benefit habitats and species through various ways e.g., acting as attachment surfaces for sessile invertebrates, feeding and spawning ground for fish and skates, nursery grounds for fish and shelter for lobsters. For details on the identification of NID options, policy important species in Scotland that may benefit through identified NID, habitats and species ecology (e.g., bathymetric distribution, feeding habits etc) as well as the pathways that the habitats and species may benefit through the identified NID options please see the NID literature review.

The main steps that were followed for the NID suitability review were as follows:

- Identification of the ScotWind Plan Options Areas. For ease of discussion, Scottish waters have been split into four approximate geographic regions which cover all ScotWind Plan Option Areas. The four regions are as follows:
  - West (contains ScotWind Plan Option Areas W1);
  - North West (contains ScotWind Plan Option Areas N1, N2, N3, N4);
  - North East (contains ScotWind Plan Option Areas NE1, NE2, NE3, NE4, NE6, NE7, NE8); and
  - East (contains ScotWind Plan Option Areas E1, E2, E3).
- Identification of key habitats and species in Scottish waters that are likely to benefit from the NID options (e.g., species with relatively wide geographic distribution in Scotland). These key habitats and species were extracted from the list of the 14 habitat-forming species and 15 policy-important species that was compiled as part of the NID literature review. To facilitate the NID Suitability Review the spatial distribution of the habitats and species has been overlaid with bathymetry maps and with the spatial distribution of ScotWind Plan Option Areas. Also, export cable routeing has been considered (from the offshore wind lease sites towards the coast) for facilitating the identification of likely ecological benefits associated with NID cable protection options.
- The habitats and species examined in the NID Suitability Review are listed below:
  - Annex I and Priority Marine Features (PMF) Protected Habitat Stony/ Bedrock Reef and *Sabellaria spinulosa* habitats (Figure 2);
  - Blue mussel, horse mussel and oysters (Figure 3);
  - Atlantic halibut, Atlantic cod, flapper skate, blue skate, and European lobster (Figure 4); and
  - Northern sea fan, sponge communities, pink sea fingers, white cluster anemone, and northern feather star (Figure 5).

  It should be mentioned that the age of the data points showing the spatial distribution of habitats and species in Scotland (see figures below) span from early 1900s (e.g., for Atlantic cod) up to mid/late 2010's. The vast majority of records (>50%) for the features shown in the figures, have been collected after year 2000. It is acknowledged that the incorporation of some relatively old data records may skew (to a rather minor extent). The actual present geographic distribution of habitats and species. Information about the sources of information used for the geographic distribution of habitat-forming and policy-important features are embedded in each figure.

- Identification of Special Areas of Conservation (SACs) and Nature Conservation Marine Protected Areas (NCMPAs) in Scottish waters. To facilitate the NID Suitability Review the spatial distribution of the SACs and NCMPAs has been overlaid with bathymetry maps and the spatial distribution of ScotWind Plan Option Areas (Figure 6). While some reference has been made throughout to specific designated sites, each site is designated for a different set of features which will be affected variably by different NID options. It is important to consider site-specific information, inclusive of relevant conservation objectives, feature sensitivity and supporting conservation evidence and advice when examining the suitability of NID measures.

The compiled information on the a) structure of the measures contained in the five NID categories, b) spatial allocation of ScotWind Plan Option Areas, c) ecology of key habitats and species in Scottish waters, d) bathymetric and geographic distribution of these habitats and species, e) technical/financial/regulatory aspects associated with each of the five NID categories and f) SWOT analysis of the NID categories, have facilitated the assessment of the suitability of NID categories for ScotWind Plan Option areas. The figures presenting this information are shown below. It should be mentioned that the examination of the habitats and species distributions indicate a relatively higher prevalence of habitat-forming and policy-important features in the west coast than the east coast of Scotland. However, there is still potential for likely ecological benefits for NID options in the east coast of Scotland for features such as Annex I reefs (Figure 2), blue mussel and horse mussel beds (Figure 3), European spiny lobster, Atlantic cod, Atlantic halibut, flapper skate and blue skate (Figure 4). It is acknowledged that records for a number of species and habitats do not directly overlap ScotWind sites, however, as mentioned previously, the identification of likely ecological benefits takes into account into account export cables routeing form the wind lease sites towards the coast. On this basis there may still be potential for overlap between developments and habitat and species geographic distribution.

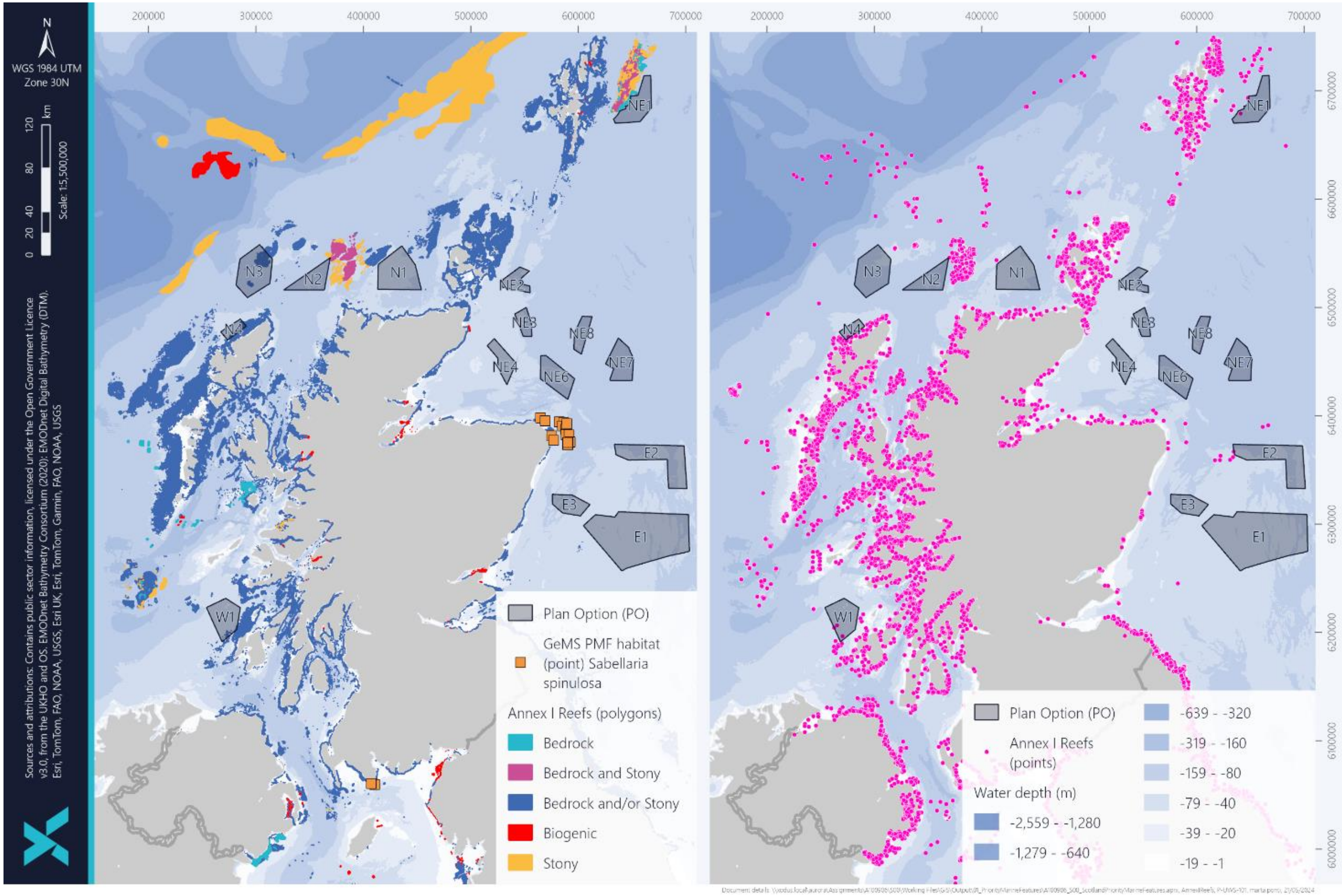

Figure 2 Distribution of reefs shown alongside ScotWind Plan Option Areas. (GEMF: Geodatabase of Marine features adjacent to Scotland)

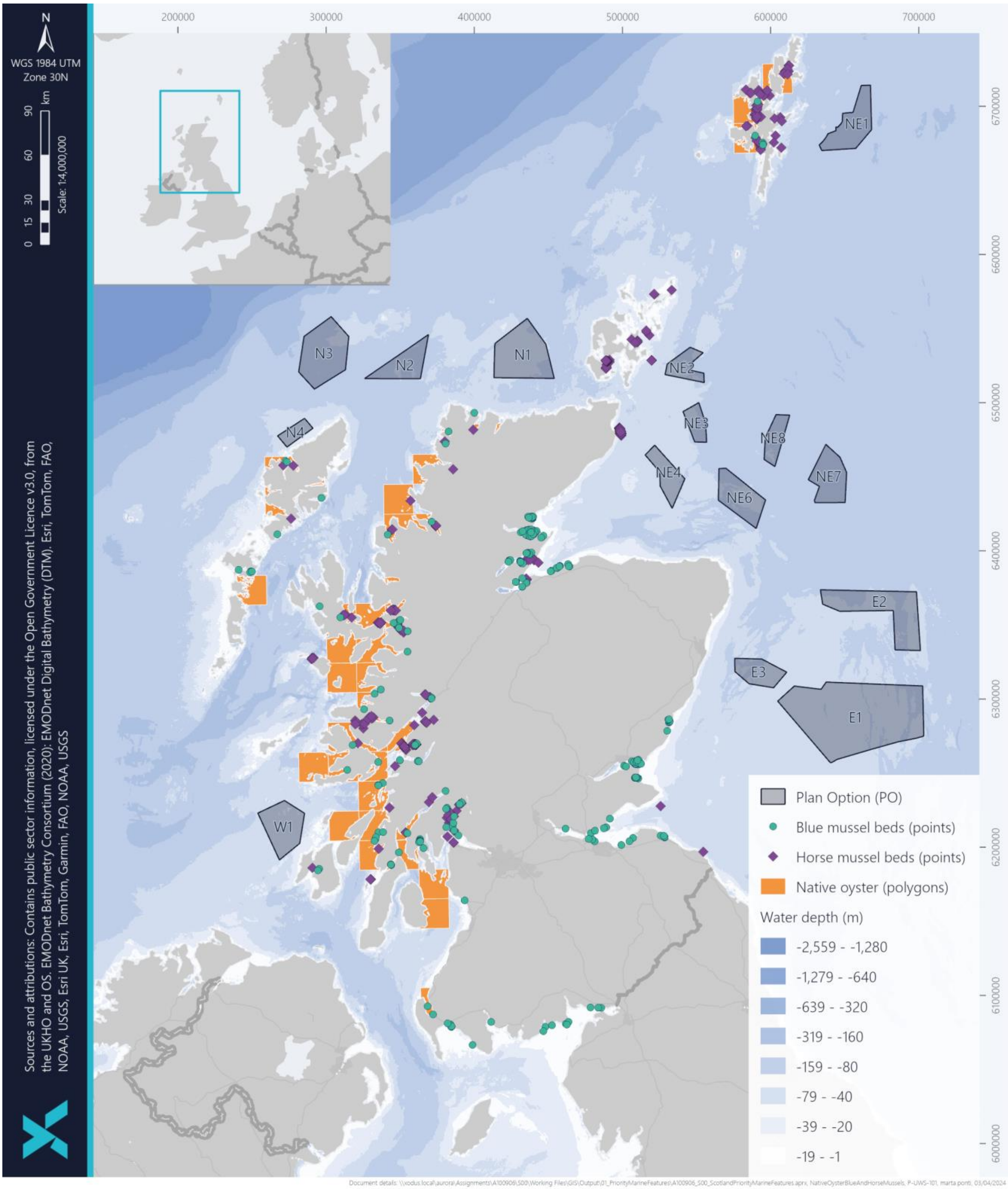

Figure 3 Distribution of blue mussel, horse mussel and oyster shown alongside ScotWind Plan Option Areas

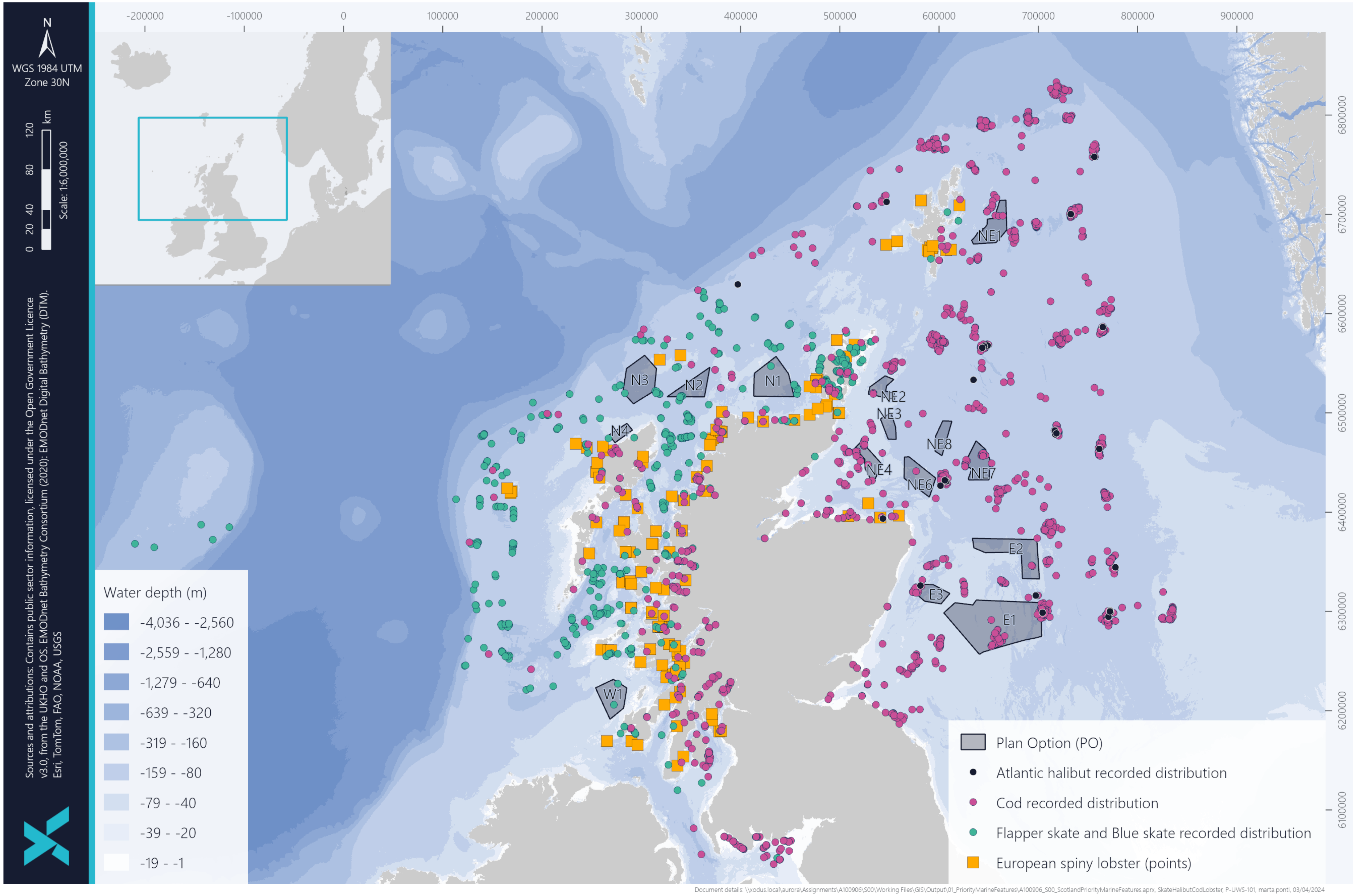

Figure 4 Distribution of Atlantic halibut, Atlantic cod, flapper skate, blue skate, and European lobster shown alongside ScotWind Plan Option Areas

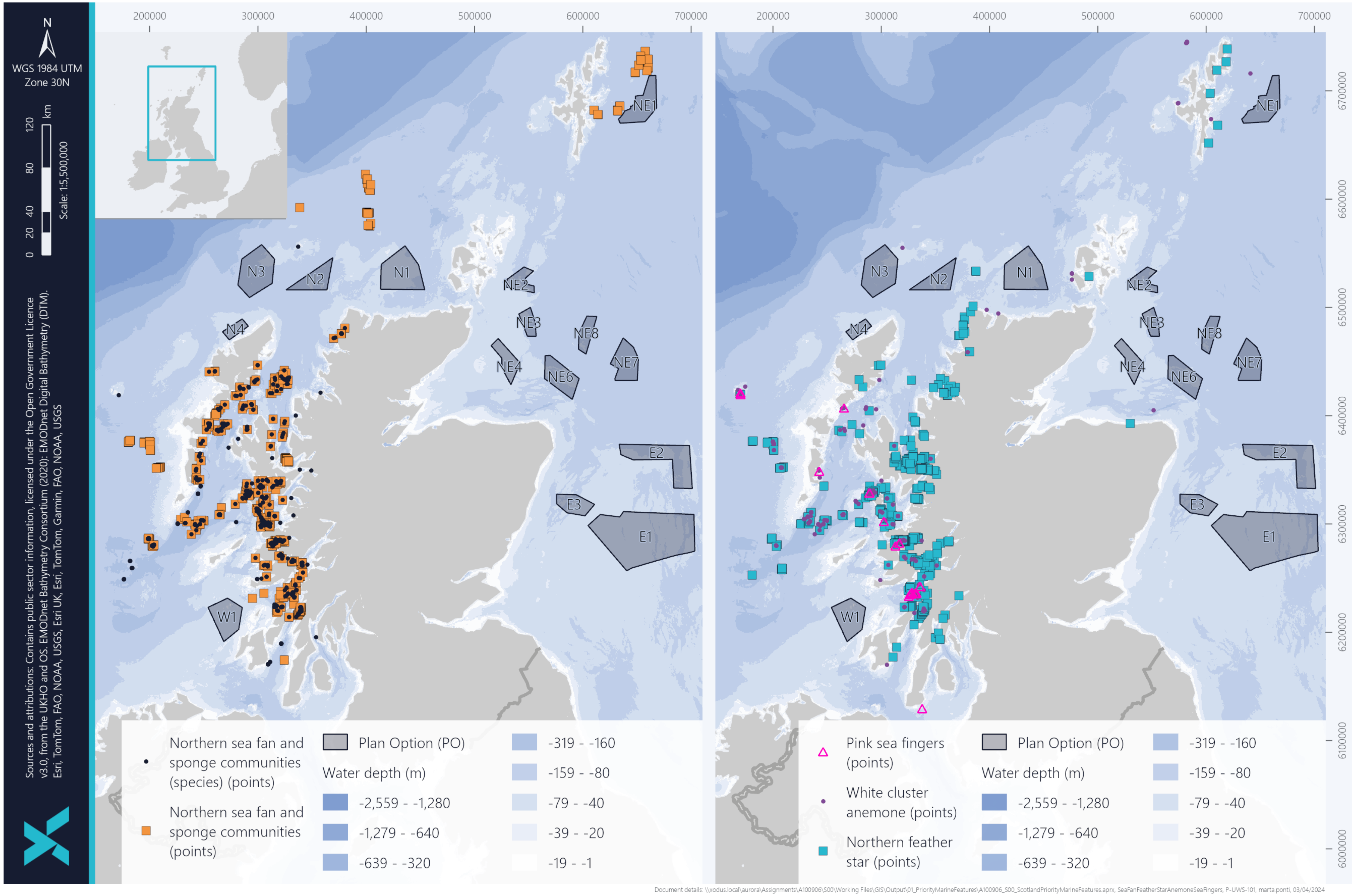

Figure 5 Distribution of northern sea fan and sponge communities, pink sea fingers, white cluster anemone, and northern feather star shown alongside ScotWind Plan Option Areas

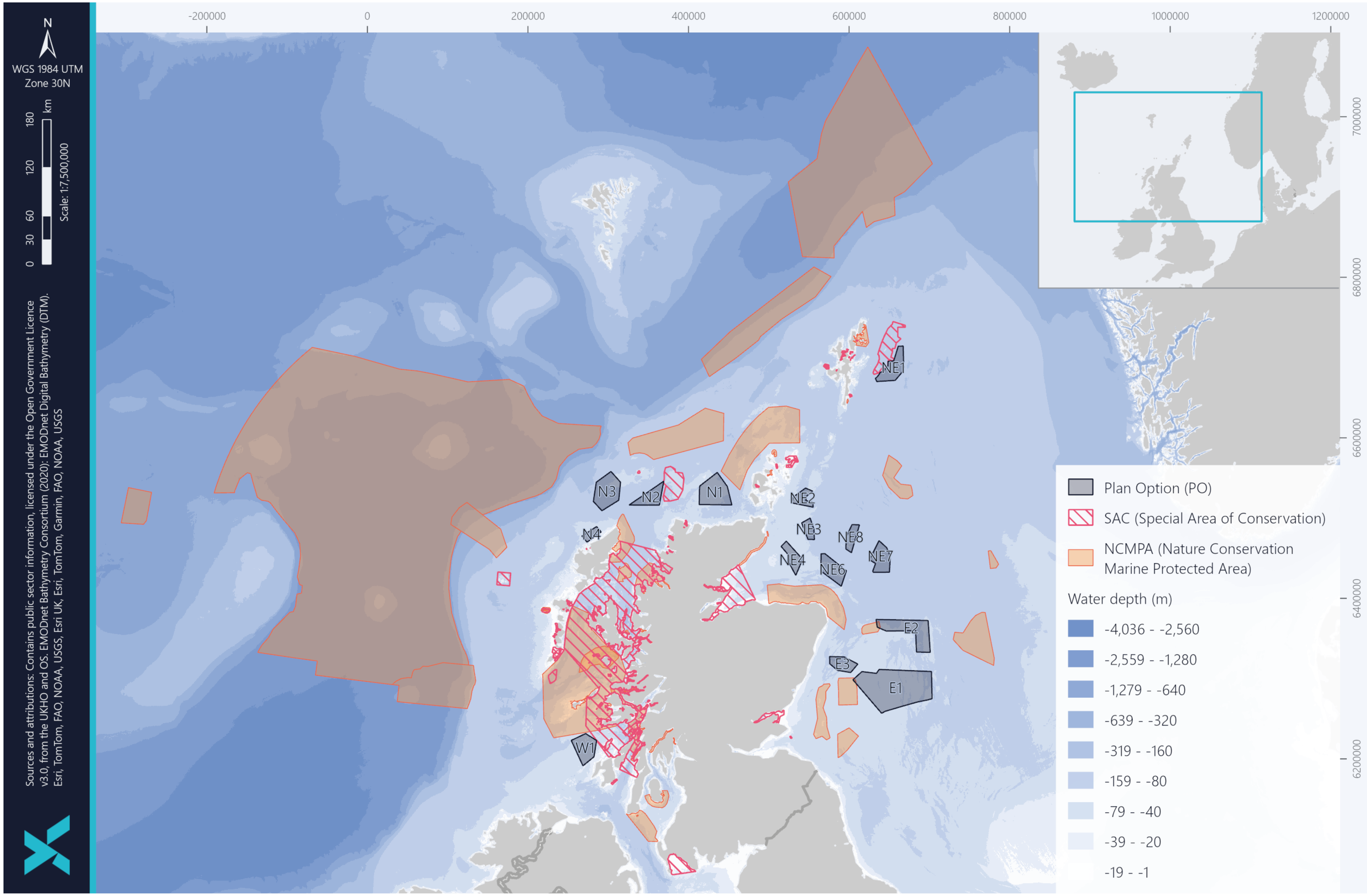

Figure 6 Designated sites shown alongside ScotWind Plan Option Areas

3.2 SWOT analysis

The detailed outcomes of the SWOT analysis are presented in Section 4. The common points across all five categories of NID options are summarised in Table 1 below. In addition, a summary of key points with respect to each NID group is presented throughout Section 3.3. In particular, Section 3.3 aims to link the information gathered in the NID literature review with the SWOT analysis and wider Scottish offshore wind context. Discussion has also been provided at a high level on the implications of NID on the ScotWind Plan Option Areas.

While the focus of the NID suitability review is on ScotWind, the discussion presented herein aims to be of a sufficiently high level that findings can be applied more broadly to offshore wind in Scotland, such as Innovation and Targeted Oil and Gas (INTOG) areas.

Finally, it should be noted that the identification of NID options for ScotWind Plan Option Areas does not guarantee their ecological success. The ecological performance of the identified NID options has not yet been tested in practice in Scotland and therefore any evidence of success that has been noted in this review is based on other geographies. Ecological failure is one of the major risks that have been identified in previous reports regarding NID options in offshore wind farms (e.g., Hermans *et al*., 2020; MRAG, 2023). This, and other risks will be addressed in turn throughout Section 3.3.

Table 1 Key common strengths, weaknesses, opportunities, and threats across all five NID categories

STRENGTHS
Can increase habitat complexity and thus support biodiversity enhancement – to an extent, this applies across all NID measures.
NID measures requiring installation of hard substrate or rock (adapted rock protection; modified mattresses) could supplement or act as introduced stony reef habitat. This could support a variety of species and habitats identified as being of conservation value in Scottish water.
Demersal fish species may benefit through the provision of feeding grounds and shelter (fish hotels; adapted rock protection; reef structures-concrete blocks; modified mattresses; water replenishment holes).
Many of the NID measures have high spatial applicability – range can extend from the offshore wind array area all the way to nearshore (along the cable route), therefore benefitting a wide range of fauna and flora across a variety of water depths.
OPPORTUNITIES
Can be added onto existing structure (fish hotels; adapted rock protection; water replenishment holes).
Potentially applicable to both fixed and floating wind structures (fish hotels; adapted rock protection, reef structures-concrete blocks; modified mattresses).
WEAKNESSES
No long-term monitoring to determine the actual effectiveness of the NID measure in situ (knowledge gaps and unknown). This applies to most available NID options.
The location/area-specific environmental conditions need to be examined when considering the effectiveness of the NID options and interactions with other sea users. This applies to most available NID options.
Unlikely to be suitable in areas with protected soft sediment habitats (adapted rock protection; reef structures-concrete blocks; modified mattresses).
THREATS
It is likely that ecological benefits will disappear after the asset is decommissioned. This applies to most available NID options, with the potential exception of the adapted rock protection measures due to technical challenges.
Degradation of NID options over time and release of potentially harmful material in the environment (fibres, plastic, other contaminants) (e.g., adapted rock protection filter bags; reef structures-concrete blocks; modified mattresses).
Potential to contribution to the spread of invasive and non-native species (INNS) and diseases. This applies to most available NID options.
Spatial exclusion for fishing and other activities; snagging hazards in arrays where fishing might be possible (fish hotels; adapted rock protection; reef structures-concrete blocks; modified mattresses).
Financial risks associated with the implementation of insurance cover. This applies to most available NID options.

3.3 Review of NID in Scotland

3.3.1 Fish hotels / cage-type structures

Ecological / Regional Suitability

The SWOT results for fish hotels/ cage-type structures are presented in full in Section 4. Here, a summary of key points with respect to the ecological suitability of the NID group are presented with reference to the Scottish context. Some of the key benefits and detractors of this NID group are discussed here.

The cage type structures can be generally considered as add-on (e.g., the cod hotel). These add-on NID options are associated with the foundation infrastructure itself and as such, their spatial applicability will be limited to offshore areas rather than cable routes. Therefore, any potentially targeted species that have a distribution restricted to the coast or shallower waters are unlikely to benefit from this NID option. NID add-on options such as the cod hotel and the Biohut are designed to support increased aggregations of locally present fish, including key policy-relevant and commercial species such as Atlantic cod. However, while the cod hotel for instance aims to target cod, there are limits to the specificity of the NID options. Therefore, it is not possible to determine exactly which species will be benefitted by these NID options. Apart from Atlantic cod other fish species may benefit from cage-type structures such as ling (adults are encountered most commonly in waters between 100-400 m in depth and found all around the Scottish coastline and in offshore areas) or saithe (demersal species encountered from 37 to 364 m and found all around the Scottish coast and in offshore waters) but success cannot be guaranteed without prior testing and monitoring. In addition to geographic location, it is likely that water depth and the location of these NID options, in the water column will be the key factors in determining which locally present fish species may benefit and may include pelagic species although research would need to be undertaken to confirm the potential ecological benefits to such species.

In the case of Atlantic cod, this species has a very wide distribution in Scotland and can be expected to be present within any of the ScotWind Plan Option Areas (Figure 4). Consequently, implementation of these measures across any of the ScotWind Plan Option Areas may feasibly benefit cod.

It is noteworthy that given that add-on NID options such as the cod hotel and Biohut will be physically off the seabed, any associated species that are strictly benthic in nature are unlikely to be supported by these options. However, benthic habitats may still be indirectly influenced by these add-on structures through organic enrichment associated with the biological growth which could potentially have an impact on productivity and community composition in the local area. It is with noting that these add-on measures, while not being benthic in nature may be an advantage for instance in areas where there are protected sedimentary habitats such as in the central North Sea where need for rock minimisation may make other available NID options less attractive.

A risk, or concern, potentially associated with this NID group is that of the potential for larger species to get stuck within the holes/structure. However, the size of these structures is likely to be too small to pose a risk to larger predators, such as seals. The potential for seals becoming stuck within possible NID is discussed further in Section 3.3.5.

The fish hotel can also be deployed as a standalone unit, attached on the seabed. In this way, both PMF fish (e.g., Atlantic cod) and PMF invertebrate species (e.g., northern feather star) could benefit from the presence of fish hotels. It should be mentioned though that available knowledge about the ecological performance/success of fish hotels is limited so far and more research is needed. Atlantic cod has a very wide distribution in Scotland and can be expected to be present at any of the ScotWind Plan Option Areas while sessile invertebrates such as the northern feather star could benefit from the deployment of these stand-alone units in the North West geographic areas of the ScotWind Plan Option Areas.

Technical Suitability

There are some technical challenges associated with these type of add-on structures that must be considered upon their incorporation into wind turbine designs. These challenges are outlined in full in Section 4.

Where fish cage designs are pre-installed, there are practical risks associated with transportation and lifting activities. During these times, any external add-on structures run the risk of being damaged themselves or damaging the wind turbine itself. Damage during transport and installation activities is more likely to be associated with add-ons attached to fixed structures.

While NID options of this type do have the potential for incorporation in floating technology designs, the dynamic nature of the environment with which floating structures must contend presents a significant challenge as it introduces a higher stress on welding points which would attach the add-on NID to the floating structures. The Les Éoliennes Flottantes du Golfe de Lion (EFGL) project, in collaboration with Principle Power, installed a total of 16 Biohut structures on one of their three floating turbines. Generally, an increase in the biodiversity of species in and around the cages was reported and no invasive species were observed.[2] Aside from positive ecological benefits, the installation of these Biohuts on floating structures in water depths of 70-100 m, suggests there is opportunity for incorporation of these measures in ScotWind. Despite potential technical concerns regarding structural integrity, the use of fish hotels and cage-type structures in a floating wind context is not to be dismissed.

Furthermore, add-ons would contribute to increased drag on the main structure, which is typically undesirable in the structural design. Generally, any weld points are deemed a weakness on any structure (fixed or floating), and these are typically kept to a minimum. Therefore structurally, incorporation of add-on designs could increase risk of failure at these weld points. These weld points would also need to be designed to ensure they are accessible for monitoring inspections and maintenance (i.e. cleaning) which will take place over the operational life of the structure, thorough routine O&M activities using an ROV or potentially specialist divers, through to decommissioning.

As insurance risk is typically higher for floating wind infrastructure compared to fixed technologies, due principally to the relative newness of the technology, the insurance period for floating wind structures is significantly shorter than for fixed designs. This presents another hurdle for the uptake of these add-on designs within floating wind as an increase in risk is likely to make developers reluctant to take such design changes forward. It was also noted that even during operation, floating structures may have to be towed for maintenance purposes, and moving these structures could lead to any accumulated biological growth falling off or require pre-cleaning. This ultimately negates the

[2] https://www.principlepower.com/projects/les-eoliennes-flottantes-du-golfe-du-lion

potential benefit of the add-on NID options. Transportation of infrastructure to ports may also facilitate the spread of invasive and non-native species.

Fish hotels and other cage-type structures intend to increase biomass and facilitate growth of marine communities. The associated increase in marine growth will itself bear additional weight which adds to the risk of the structural integrity. As discussed previously, the stress placed on welds, particularly on floating structures, is already great. Therefore, the implication of any additional biomass would have to be factored in during the design stage to ensure risk of failure is minimised.

Despite these technical challenges, it was considered that add-on structures designs could theoretically be applied to floating wind structures, with the most practical and acceptable method likely to be to retrospectively attach the structures after the windfarm has been deployed, using staps rather than welds. This would make for easier installation, management, and maintenance.

While the ecological benefits associated with fish hotels/cage-type structures are discussed above, the use of this NID may encourage fish to aggregate. It is also worth noting that while fish hotels and cage like structures have been discussed above as add-on designs, these could theoretically be deployed as stand-alone NID measures without need for attachment to wind turbine structures. In the case that these are standalone, they are still considered NID and may be incorporated into seabed infrastructure design and supplement cable protection for instance. For instance, oyster gabions are considered to be standalone measures. However, due to their size and weight, when used alone they may not be very robust and may need some kind of attachment.

Where the presence of fish aggregation devices such as fish hotels are deployed directly on the seabed, they are likely to increase the potential for a snagging incident to occur and such additional man-made structures should be added to navigation maps as a hazard. However, where these structures are incorporated into existing infrastructure as ‘add-ons’ they will have an inherently lower snagging risk as they will be within the safety zones of the offshore wind infrastructure.

3.3.2 Adapted rock protection measures

Ecological / Regional Suitability

The full suite of Strengths, Weaknesses, Opportunities and Threats associated with adapted rock protection measures are provided in Section 4. Some of the key points are discussed here with reference to the Scottish context and the ScotWind Plan Option areas.

The adapted rock protection will create a varied hard substrate habitat that predominantly will benefit benthic species that are likely to colonise such substrates. The structural complexity of having larger boulders with high relief from the seabed as well as smaller cobbles and boulders will mimic similar naturally occurring habitats akin to Annex I stony reef which can be expected to support a relatively high biodiversity. This can include a number of lower trophic levels such as filter feeding organisms. For example, the PMF species northern feather star, northern sea fan and white cluster anemones can use adapted rock protection NID options as an attachment surface. Due to the expected distribution of these species, northern feather star and white cluster anemones can potentially benefit from adapted rock protection NID options in the North West, North East and West regions of the ScotWind Plan Option Areas (Figure 5). Northern sea fan can potentially benefit from these NID options in the West and North West regions of the ScotWind Plan Option Areas (Figure 5).

The crevices and variety of surfaces are likely to attract mobile species too including crustaceans and fish, many of which can be PMFs, or listed under another policy framework. One of the mobile species that can benefit from these NID options is the European spiny lobster which could potentially use openings and crevices provided by filter units and basalt bags, as a shelter. The European spiny lobster can potentially benefit from this NID option in West, North West, North East and East regions of the ScotWind Plan Option Areas. Another mobile species that can potentially benefit from adapted rock protection NID options is Atlantic cod. For example, juvenile cod may use basalt bags as a shelter in West and East regions of the ScotWind Plan Option Areas. Adult Atlantic cod may also benefit from the adapted rock protection NID options such as the filter units feeding on the epifauna colonising these NID options. Atlantic cod has wide distribution in Scotland seas and thus it is likely that adult specimens can benefit from adapted rock protection NID options deployed across all ScotWind Plan Option Areas.

As adapted rock protection NID options can be deployed in offshore regions as well as more inshore areas, associated with cable installation, there is the potential that a very wide range of species, including biogenic habitat forming species may be associated with this measure. The range in deployment also means that there will potentially be a variety of different hydrodynamic conditions, sheltered areas, and tide swept conditions that this NID measure can be deployed in with differing outcomes, all of which are potentially beneficial. However, it is likely that most benefit from this type of NID would be derived from its deployment in places where rocky substrates are already known to be present. In these cases, the introduction of new substrate or habitat can essentially extend and potentially even improve the suitability of the habitat for characteristic species of the area.

Geographically, the ScotWind Plan Option Areas with the highest likelihood for having reef-like habitats are in the West and the North East regions, as well as near the shore where rocky outcrops may be found (Figure 2) (this is discussed further within Section 3.3.3). It is these regions that will likely have potential to benefit from adapted rock protection measures. However, this does not mean to suggest that positive outcomes may not be realised in other areas.

Installation of these alternative rock protection measures in the vicinity of mobile sediments may exasperate winnowing of the surrounding sediment, which in turn may cause OWF infrastructure stability issues. Addressing any possible issues with the stability of the OWF may require further rock protection as maintenance. This process can be continuous. As such rock material is typically kept to a technical minimum, as part of standard mitigation practices and avoidance where possible (in the case of soft sediment habitats) is normally the approach. Therefore, adapted rock protection NID options are not always going to be the most suitable NID option where soft sediment habitats are present and indeed may be protected themselves. The suitability of these (or any) NID options would therefore need to consider site specific physical and biological parameters to determine their appropriateness. Considering technical challenges associated with the removal of rock protection material at the end of a project's lifecycle it is likely that rock protection material will be decommissioned in situ and thus any likely ecological benefits associated with this NID option will remain in place.

Technical Suitability

It is envisioned that adapted rock protection measures can be deployed on top of, or incorporated within, routine scour protection or cable rock armour. The modified rock protection NID can be used in place of, or in addition to, traditional rock protection to provide a more natural and varied top rock layer (for more information on the adapted rock protection measures please see CEMNID "NID literature review"). A practical advantage for this measure is that it can technically be deployed from the same rock deployment vessel that would be undertaking the rock dumping activity, providing some cost advantages. However, the deployment method may have to be modified to account for larger rock grades that will provide a greater complexity of rock habitat than the more uniform rock berm of smaller rock grades typically installed for cable protection. Similarly, the material utilised in this adapted rock protection can likely be obtained from typical quarry suppliers (depending on the type of material considered each time) which reduces the need for additional sourcing considerations.

There will likely always be a requirement within projects/developments for use of rock as protection or mitigation against scour. Therefore, in technical terms, there are minimal risks associated with adapted rock protection measures from a design perspective. In terms of vessel requirements, it is assumed that installation of alternative rock protection would be a process similar to installation of traditional rock. While there may be a slight increase in vessel time associated with the deployment of adapted rock protection measures, this type of NID option would likely have good potential for a positive environmental outcome.

Where some of the other NID groups may need to be removed at the time of decommissioning, rock placement is typically decommissioned in situ owing to technical difficulties associated with its removal. Consequently, of all the NID groups, adapted rock protection measures are unlikely to be recoverable, and by remaining in perpetuity have the potential for much longer term impacts and integration into the surrounding environment.

It should be acknowledged that some forms of adapted rock protection involve the deployment of rocks contained within filled bags. This aims to allow a greater degree of flexibility with regard to the method of deployment (i.e. these can be accurately deployed using a winch rather than reliance on fall-pipe vessel). While the material utilised in these measures may be adapted or changed over time, at the time of writing, it is understood that some bags are made from polyester mesh. This particular methodology would be discouraged due to the addition of plastic material to the marine environment and concerns about the long term release of microplastics. It is also important to note that the benefit of the bags is lost if they are made from a material impervious to fauna.

3.3.3 Reef-type structures and concrete blocks

Ecological / regional Suitability

As noted within the SWOT (Section 4), the artificial reef structures have a high overall structural complexity that is predicted to increase the potential for higher biodiversity and productivity with the potential to support higher trophic levels. This includes ledges, holes crevices and textures to the surfaces increasing thus the availability of surfaces/microhabitats. In this way they can increase the variety of organisms likely to colonise. The increased relief above the surrounding seabed also makes this NID option more akin to natural reefs in its form, compared to other NID forms such as the water replenishment holes.

Concrete blocks and other reef-type NID structures such as 3D printed reefs mainly serve either as optimised scour protection layer or stand-alone units. The applicability to deploy offshore all the way to the nearshore along cable routes is a large advantage. Reef-type structures and concrete blocks NID options may benefit both sessile and mobile species. As regards the sessile, organisms like mussels, northern sea fan, northern feather star, white cluster anemones and *Sabellaria spinulosa* could use these NID options as an attachment surface. Northern feather star and white cluster anemones can potentially benefit from reef-type structures and concrete blocks in the North West, North East and West regions while northern sea fan can potentially benefit from these NID options in the West and North West regions of the ScotWind Plan Option Areas (Figure 5). Mussels may use reef-type structures and concrete blocks as an attachment surface in East regions of the ScotWind Plan Option Areas (Figure 3). Reef cubes may act as an attachment surface for *Sabellaria spinulosa* in East regions of the ScotWind Plan Option Areas (Figure 2).

Mobile organisms such as fish may also benefit from reef-type structures and concrete blocks. For example, Atlantic cod may use these NID options (e.g., 3D printed reefs, reef cell modules) as a feeding ground and shelter. Atlantic cod has wide distribution in Scotland seas and thus it is likely that adult specimens can benefit from adapted rock protection NID options deployed in West, North West, North East and East regions of the ScotWind Plan Option Areas (Figure 4).

Universal to most NID groups, but perhaps most pertinent to measures which aim to encourage reef formation, is the potential for introduction of INNS. Installation of any material on the seabed runs the risk of introducing other species. Particularly in an instance where the creation of reef may encourage colonisation of non-native species, particularly in an area not previously exposed to hard substrate.

Suitability of reef-type structures and concrete blocks will vary across space. In areas where sediment substrates of conservation value are present, it is deemed to be unfavourable to introduce further hard substrate the seabed which would further reduce any likelihood of recovery of such habitats. The mitigation hierarchy to avoid or minimise permanent seabed disturbance and shift in substrate type (from soft to hard substrate) will likely rule out the deployment of such NID options, especially where the sediments occur inside marine protected areas where conservation objectives are prioritised. Therefore, it is considered that potentially suitable areas for deploying artificial reef-like structures are areas that are well known to have already reef-like seabed hosting the target species identified (see the NID literature review and Section 3.1 above) and where such designs can augment habitats that already have stony substrates. In the context of Scottish offshore wind areas, this would approximately equate to North and North East regions of the ScotWind Plan Option Areas, especially N1, N2, N3 and N4, as well as NE1, the latter which is in close proximity to the Protected Area Pobie Bank SAC, designated for Annex I reef. The thoughtful sighting of these types of NID measures will likely result in the most successful outcomes. There may also be application of such designs for the restoration of degraded rocky habitats, although the CEMNID project does not specifically focus on restoration or offsetting measures.

Universal across almost all NID groups, is a body of evidence in support of the ecological benefits. While there are often pilot/small-scale or coastal schemes which evidence the efficacy of NID measures, there is a lack of commercial scale evidence, particularly in the UK. While this applies to many of the NID options, there are increasingly international efforts to incorporate and monitor NID in offshore wind. RWE have recently deployed a pilot study in the Baltic Sea to incorporate artificial reefs in their Swedish Kårehamn wind farm. A baseline survey was undertaken in 2023 and monitoring will take place over the coming years.[3]

Technical Suitability

These artificial reef-type structures can come in a variety of shapes, from cuboid blocks to spheres or more complex shapes such as tetrahedrons. Their customisability and adaptability are among the key benefits of these measures, which was noted in the SWOT (Section 4). These NID measures are generally made out of concrete. These are deployed directly on the seabed either onto existing substrata or on top of rock protection. These can be placed in the immediate vicinity of infrastructure to act as scour protection, potentially placed over mooring structures of floating wind designs and can also be installed along cable routes over conventional rock protection.

Where concrete blocks aim to perform the same function as traditional rock protection measures, a key difference is in the nature of the material. Where traditional rock protection typically comprises granite, or another highly inert strong erosion-resistant rock, concrete may not have the same tried and tested durability, particularly when manufactured into a unique/alternative shape. While not unique to NID, concrete can break down and release contaminants into the environment. However, use of low toxicity concrete could be implemented to minimise this risk.

Vessel requirements should be considered and will largely depend on local water depths. Where these reef-type structures have been deployed under trial conditions in the UK, they were installed from the back of a vessel using winches in relatively shallow depths. Vessel specifications may differ to those typical construction vessels which will be carrying out the installation works. This is particularly so for larger reef-type or concrete block designs.

Another important technical consideration is the recoverability of these structures. These artificial reefs are not generally designed to be removed so if extensive re-deployment of reef blocks is required, this could come at considerable cost. It is noted that the regulatory position on installing infrastructure in the offshore environment is that installed infrastructure must be designed to allow full removal. Potential marine licensing challenges may appear

[3] https://www.rwe.com/-/media/RWE/documents/07-presse/rwe-offshore-wind-gmbh/2024/2024-05-22-rwe-tests-artificial-reefs-at-offshore-wind-farm-in-the-baltic-sea.pdf

for these stand-alone structures due to not being part of design envelope. However, this in itself has implications on the long term success of the NID – such structures are intended to facilitate habitat growth which would be undone upon removal.

A further potential technical challenge is likely to be interactions with other users of the sea, particularly fishing vessels, and especially bottom trawling gear. These types of NID can be deployed in areas associated with installed cables, alone or in combination with traditional protection measures, so could be theoretically laid anywhere from shallow subtidal all the way to the offshore windfarm. Consequently, implications on local fishing interests and other users of the sea (particularly in shallower water depths) should be considered, although the incorporation of NID measures in these areas will not necessarily have additional impact on fisheries in those case where infrastructure (e.g., cable protection material) is already present. Furthermore, where this NID encourages fish to aggregate, this may be capitalised on by the fishing industry and in doing so may increase the chances of snagging.

3.3.4 Mattresses

Ecological / Regional Suitability

The ecological suitability is of mattress designs is much the same as for other hard substrate type designs as discussed under adapted rock protection (Section 3.3.2) and reef type structures (Section 3.3.3). The SWOT for this NID group is found in full in Section 4. These structures provide reef-like qualities that will attract associated epifaunal communities, which will vary depending on the geographic location and bathymetric and hydrographical conditions. These modified mattress structures may be easier to deploy and recover when compared to other NID designs deployed on the seabed, though these will generally have a lower relief from the seabed than reef-like structures or concrete blocks. The spaces between the concrete components of the mattresses can potentially backfill with sediment, thus providing a patchwork of habitat substrates and thus increase habitat complexity.

Mattresses may benefit both sessile and mobile species through various pathways e.g., attachment surface, feeding ground, shelter, spawning ground. Sessile species such as mussels, oysters, northern feather star, northern sea fan and white cluster anemones may use mattresses as an attachment surface. Northern feather star and white cluster anemones can potentially benefit from mattresses in the North West, North East and West regions while northern sea fan can potentially benefit from these NID options in the West and North West regions of the ScotWind Plan Option Areas (Figure 5). Mussels may use mattresses as an attachment surface in East regions of the ScotWind Plan Option Areas and oysters in the West regions (Figure 3).

Mattresses can also support feeding grounds for demersal fish e.g., Atlantic cod and Atlantic halibut and skates. Atlantic cod has wide distribution in Scotland seas and thus it is likely that adult specimens can benefit from mattresses deployed in West, North West, North East and East regions of the ScotWind Plan Option Areas (Figure 4). Atlantic halibut may utilise mattresses deployed in East regions as a feeding ground (Figure 4). Flapper/blue skates have relatively wide distribution in Scotland's seas and thus they may use mattresses deployed in West, North West, North East and East regions of the ScotWind Plan Option Areas as a feeding ground (Figure 4).

Mattresses may also support spawning grounds for skates. Flapper/blue skates have relatively wide distribution in Scotland's seas and thus they may use mattresses deployed in West, North West, North East and East regions of the

ScotWind Plan Option Areas as a feeding ground. Mattresses may also be used as a shelter from European spiny lobster in West, North West, North East, and East regions of the ScotWind Plan Option Areas (Figure 4).

In the case of mattresses, there is perhaps a slight disadvantage ecologically in that the structural complexity such as prominence above the seabed, and provision of crevices, and ledges etc. may be restricted in comparison to the NID options designs mentioned above. Nonetheless, there is good evidence from research such as the work undertaken by the INSITE research programme (https://insitenorthsea.org/) that mattresses in the offshore environment do have higher associated epifaunal organisms and attract aggregations of demersal fish species. This latter point does not necessarily prove an increased productivity but there is a suggestion this may be a benefit. The applicability of mattresses to be potentially used across the whole range of cable depths is something that can be considered when NID measures are being looked at for a site.

Technical Suitability

The key technical risks associated with mattresses are in relation to snagging potential – a commonality with mattresses of traditional specification. Additionally, some of the components of more flexible mattresses (generally polypropylene) are undesirable for introduction into the marine environment. These concerns were raised within the SWOT (Section 4) and are considered further here.

The modified mattresses are deployed to provide the function of cable protection but with an added increase in structural complexity to conventional methods. The deployment of alternative mattresses may be different to that of standard protection measures, particularly in terms of vessel specifications. However, installation duration may be similar, so overall there may be an opportunity for installation of alternative mattresses.

In terms of risk, mattresses are a known hazard to bottom trawling fishing gear so this would need to be considered for deployments of this type. Use of mattresses could also have an implication on the potential insurance cover for such an installation and associated financial risk over the lifetime of the development (and perhaps beyond). Decommissioning requirement would also need to be considered. It is worth noting that the mattress design may theoretically be easier to decommission than other hard substrate designs mentioned above (although the integrity of structures is known to deteriorate over time so this is no guarantee).

As discussed previously in Section 3.3.2, there are undesirable impacts associated with installation of infrastructure containing plastics. Therefore, it is encouraged that any designs used are free of plastics. It is known that many conventional concrete mattresses in the offshore industry feature polypropylene rope and this should be discouraged in an NID design.

3.3.5 Water replenishment holes

Ecological / Regional Suitability

Water replenishment holes are exclusively associated with fixed offshore wind structures where holes are made within the foundation of the wind turbine structure. A key benefit of water replenishment holes is in their provision of shelter and ground for settlement by marine species (Section 4). Work is currently being undertaken by Vattenfall in conjunction with the Rich North Sea and Royal Netherlands Institute for Sea Research (NIOZ) within the Hollandse Kust Zuid windfarm. This windfarm is located within the Dutch North Sea, and the study aims to determine to what extent the inside of the turbine foundations can be used by marine life to settle within and use as shelter and a feeding ground. Atlantic cod may benefit from the holes in the monopile through provision of shelter. Atlantic cod has wide distribution in Scotland seas and thus it is likely that adult specimens may benefit from water replenishment holes in infrastructure deployed West, North West, North East and East regions of the ScotWind Plan Option Areas (Figure 4). The scour protection inside of the turbine foundation will add habitat complexity, offering settlement opportunity (e.g., sessile filtering feeding species), shelter and feeding grounds for a wide array of species.

A potential concern with regards to the employment of water replenishment holes, is the potential for seals (or other larger marine species) to become stuck in the holes. Anecdotally, this has been known to occur in the North Sea in J-tubes (which are associated with flexible umbilicals and cables). There has been recorded video footage of occurrences of seals swimming in and out of a monopile foundation via the water replenishment holes within the Dutch North Sea. However, the entrance to these holes is relatively large (and ellipsis of 96 cm by 32 cm) so there is no expectation for this to be a considerable concern. To date there are no reported instances of seals becoming stuck within water replenishment holes,

Furthermore, the diameter of the holes can be tailored to avoid this altogether and there is no clear evidence to suggest that this is a major risk factor associated with the NID. However, it would be advisable that if implementing use of water replenishment holes, proximity to seal haul outs or densely populated areas of seals is considered. This is perhaps less of a concern for ScotWind Plan Option Areas located in deeper waters where floating infrastructure is generally proposed and where the presence of seals is likely to be much lower.

Technical Suitability

Technical considerations associated with water replenishment holes, as identified by the SWOT, are considered in Section 4. Water replenishment holes were initially devised as a method of minimising material corrosion by ensuring that the water within is continually refreshed, and reducing formation of scour, as the holes allow water to flow through the structure unimpeded. Consequently, it is not anticipated that there are any considerable technical associated risks.

3.4 Summary of evidence associated with the ecological performance of NID options

Aiming to advance understanding of the ecological performance of NID options, a summary of the available evidence is provided below (Table 2). This evidence has been gathered from various areas across the globe. A comprehensive presentation of this evidence can be found in Table 2 of the CEMNID NID literature review.

While Table 2 presents published literature in support of NID, there are numerous projects which have incorporated NID measures, and which are currently collecting monitoring data to outline NID efficacy and progress. These have been referred to throughout preceding sections as appropriate.

Table 2 Summary of available ecological information from the deployment of identified NID options

NID CATEGORY	NID OPTION	AREA	MAJOR POINTS
Fish hotels/cage-type structures	Biohut	Docks and pontoons in the French Mediterranean coast	• Bouchoucha *et al.* (2016) tested the potential benefit of Biohuts to increase the value of docks and pontoons as commercial fish nursery grounds. Average abundances on added Biohut habitats were twice as high as on nearby bare surfaces, suggesting that increasing the complexity of the vertical structures can enhance their suitability for juvenile rocky fishes.
Fish hotels/cage-type structures	Oyster tables	Netherlands	• Research from the programme Rich North Sea at the Blauwwind wind farm (Borsele III & IV Netherlands) has shown a survival of 96% of European flat oyster a year after placement of the oyster tables; • Didderen *et al.* (2019) monitored a number of (technical and ecological) parameters with deployment of oyster tables. Rich life around, and at, the introduced structures were observed including pout (*Trisopterus luscus*), edible crab (*Cancer pagurus*), anemones and starfishes.
Reef-type structures and concrete blocks	Reef cube	Subtidal zone in Devon, UK	• Hickling *et al.* (2022) evaluated the effects of different construction materials on the development of macrofouling communities on Reef Cubes. They found no significant differences in species richness, species diversity, total biomass, calcareous mass and live biomass between the different material types; total live cover was significantly different across different construction materials. Differences were also found in terms of epibenthic community composition across different construction materials. • Findings suggest that alternative construction materials could be satisfactory substrates for the development of epibenthic communities on Reef Cubes.

NID CATEGORY	NID OPTION	AREA	MAJOR POINTS
Reef-type structures and concrete blocks	Reef cube	North Sea	• Kardinaal (2021) evaluated the effects of Reef Cube deployment on the potential enhancement of reef associated fishes and benthic communities. • There was enhanced abundance of a number of species, including Ross worm (*Sabellaria spinulosa*), common mussel (*Mytilus edulis*), oysters (*Ostrea edulis* and *Crassostrea gigas*), brown crab (*Cancer pagurus*) and European lobster (*Homarus gammarus*), pouting, common dab, red mullet, gobies, common dragonet, starfish, serpent stars and velvet crabs.
Modified mattresses	ECO Mats®	Port Everglades, Florida	• Sella *et al.* (2021) investigated deployment of Ecological Articulated Concrete Block Mattresses and compared them against adjacent artificial structures and smooth surface concrete blocks. • Findings showed that the mattresses increased the richness and diversity of sessile assemblages and the abundance of mobile species.
Adapted rock protection measures	Adapted grading armour layer (scour protection)	Dutch North Sea	• Lengkeek *et al.* (2017) reviewed literature on ecology of scour protection. • The number of species on conventional scour protection material that is currently deployed in the North Sea is relatively low compared to other artificial hard substrates. They concluded that scour protection in Dutch offshore wind farm offers the potential for improving local ecology.
Adapted rock protection measures	Adapted grading armour layer (scour protection)	Offshore areas in the North Sea	• Mirta *et al.* (2020) reviewed of available information and showed that that scour protection layers host diverse and abundant faunal communities; • In situ experiments in the C-Power offshore wind farm (Belgium) showed that combining different rock sizes had positive effects on species richness and biomass of the community colonising the scour protection.
Adapted rock protection measures	Adapted grading armour layer (scour protection)	Offshore areas in the Dutch North Sea	• Kingma *et al.* (2023) examined the effect of substrate material and grading of the scour protection on benthic biodiversity. • The study revealed a significant positive relationship between available substrate surface (pebble size) and taxonomic richness

4 SWOT MATRICES

The below sections present the SWOT matrices in full across each of the five NID groups. It should be noted that the information presented in each of the SWOT matrices has been derived from the stakeholder engagement workshop. This information has been subject to editing in order to ensure consistency and objective presentation of the information. The matrices formed the basis of the discussion within the preceding sections.

4.1 Fish hotels / cage-type structures

STRENGTHS (+)	WEAKNESSES (-)
Potentially applicable to offshore fixed and floating wind structures, and along/as part of cable protection.	Needs to be incorporated into early design/during procurement (depending on NID measure).
Potential to benefit across all life stages of a species.	Could affect structural integrity of the structure it's attached to (potential engineering considerations).
Potential to attract higher trophic levels - especially aggregations of fish.	Potential increase in biomass needs to be accounted for during design, but biomass hard to predict.
Suitable for a variety of species and habitats identified as being of conservation value in Scottish waters.	Uncertainty surrounding biomass during cleaning/decommissioning.
No direct impact on the seabed (i.e. no habitat lost/replaced).	Ecological benefit of measures which are incorporated into structural design is limited to operational life.
Evidence of successful deployment in the marine environment	Potentially lower structural complexity (biodiversity benefit) compared to other NID groups.
Could be used as a stand-alone measure away from infrastructure.	Uncertainties regarding approach to monitoring, ease of access etc.
Depending on NID specifics, could be easier to remove during decommissioning.	Incorrect placement on the seabed could cause sediment winnowing and lead to scour.
Can be used in combination with other NID measures.	If add-ons become detached over time this results in dropped objects/fouling of the seabed.
Can be installed/incorporated during operational phase (assuming consent).	As a stand-alone, this fundamentally represents introduction of additional man-made structures into the environment.
OPPORTUNITIES (+)	**THREATS (-)**
Can be incorporated during design.	No long term monitoring to determine the actual effectiveness *in situ*.
Can be added on to existing structures.	Potential threat of encouraging spread of INNS due to creation of new habitat.
Could benefit species of commercial importance and value.	Risks not being accepted by engineers due to the incorporation of additional welds (as an add on).
Potential for coexistence with static fisheries gear.	Unlikely that the design company will accept the cost of any design alterations.
Potential for cooperation with academic community - opportunity for research.	Potential marine licensing challenges if not accounted for within Project Development Envelope.
Potential opportunity for reuse of these structures on subsequent projects.	Potential risk of entanglement or larger species getting stuck.
Deployment close to existing infrastructure will have a minimal exclusionary impact on fishing activity.	Impact on insurance is likely a key financial risk.
If at a relatively small scale, this could generate opportunities for local manufacture/secondary steel market.	Potential snagging risk where located on the seabed.
Overhead costs likely more favourable if tested as a prototype or in a demonstrator project.	Strategic placement of NID to maximise ecological benefit may incur additional logistical and financial implications.
	Potential for increased costs of any particular design intricacies when scaled commercially.
	Attachments (like add-ons) present an additional risk during onward transportation (risk of breakage).
	Possibility that removal of attachments will be required to allow maintenance access, negates any positive benefit.

4.2 Adapted rock protection measures

STRENGTHS (+)	WEAKNESSES (-)
Potentially applicable to offshore fixed and floating wind structures, and along/as part of cable protection.	Uncertainty surrounding biomass during cleaning/decommissioning.
Potential to benefit across all life stages of a species.	Unlikely to be suitable for areas of soft sediment habitats (especially within sites designated for sediments).
Potential to attract higher trophic levels - especially aggregations of fish.	Design might include plastic/other components - undesirable to add these into the marine environment.
Suitable for a variety of species and habitats identified as being of conservation value in Scottish waters.	Lack of clarity on composition of these alternative materials.
Creates increased structural complexity (ledges and crevices).	Uncertainty surrounding structural integrity of alternative materials - possibly not as robust as traditional protection measures.
Directly beneficial to lower trophic levels and sessile epifauna in particular.	Degradation over project lifetime might necessitate additional maintenance/replacement considerations within marine licensing process.
High spatial applicability; therefore, may benefit a range of species across a range of water depths.	Carbon footprint of materials to develop these NID measures and subsequently transport them independently.
Could be used as a standalone measure away from infrastructure.	Similar to reef-type structures and concrete blocks but with a more limited profile therefore potentially less ecologically beneficial.
Can be used in combination with other NID measures.	
Deployment likely in line with typical rock protection timescales.	
Elevation from seabed is a key measure of 'reefiness'.	
Does not need to be directly attached or designed directly into a structure.	
Could be used to supplement traditional rock protection - dual purpose as potential protection measure.	
Can be installed/incorporated during operational phase (assuming consent).	

OPPORTUNITIES (+)	THREATS (-)
Can be added on to existing structures.	No long term monitoring to determine the actual effectiveness *in situ*.
Could benefit species of commercial importance and value.	Potential threat of encouraging spread of INNS due to creation of new habitat.
Opportunity to enhance installation activities which are already taking place (e.g. traditional rock placement).	Potential marine licensing challenges if not accounted for within Project Development Envelope.
Potential for streamlining vessel requirements - activity in line with traditional rock placement durations.	Reluctance to add more material than necessary along cables and undesirable to detract from cable burial requirements.
Rock type could be adapted to fit local environmental conditions.	Potential risk of entanglement or larger species getting stuck.
Deployment close to existing infrastructure will have a minimal exclusionary impact on fishing activity.	Impact on insurance is likely a key financial risk.
Likely minimal risk to foundation design therefore increased potential for design acceptance.	Potential snagging risk where located on the seabed, NID potentially compromises 'overtrawlability'.
	Strategic placement of NID to maximise ecological benefit may incur additional logistical and financial implications.
	OFTO divestment requirements depend on justification of protection measure costs - unless potentially more expensive alternative measures are required via consent, there is little incentive to invest in NID.
	Uncertainty surrounding decommissioning process, removal would result in any benefit being lost.
	Potential for increased costs of any particular design intricacies when scaled commercially.
	Potential for increased vessel requirements associated with novel installation methods.

4.3 Reef-type structures and concrete blocks

STRENGTHS (+)	WEAKNESSES (-)
Potentially applicable to offshore fixed and floating wind structures, and along/as part of cable protection.	Uncertainty surrounding biomass during cleaning/decommissioning.
Potential to benefit across all life stages of a species.	Unlikely to be suitable for areas of soft sediment habitats (especially within sites designated for sediments).
Potential to attract higher trophic levels - especially aggregations of fish.	Design might include plastic/other components - undesirable to add these into the marine environment
Suitable for a variety of species and habitats identified as being of conservation value in Scottish waters.	Lack of clarity on composition of these alternative materials.
Creates increased structural complexity (ledges and crevices).	Uncertainty surrounding structural integrity of alternative materials - possibly not as robust as traditional protection measures.
Directly beneficial to lower trophic levels and sessile epifauna in particular.	Degradation over project lifetime might necessitate additional maintenance/replacement considerations within marine licensing process.
High spatial applicability; therefore, may benefit a range of species across a range of water depths.	Incorrect placement on the seabed could cause sediment winnowing and lead to scour.
Evidence of successful deployment in the marine environment.	As a stand-alone, this fundamentally represents introduction of additional man-made structures into the environment.
Could be used as a stand-alone measure away from infrastructure.	Carbon footprint of materials to develop these NID measures and subsequently transport them independently.
Depending on NID specifics, could be easier to remove during decommissioning.	
Can be used in combination with other NID measures.	
Deployment likely in line with typical rock protection timescales.	
Elevation from seabed is a key measure of 'reefiness'.	
Does not need to be directly attached or designed directly into a structure.	
Advertised as highly customisable.	
Can be installed/incorporated during operational phase (assuming consent).	
OPPORTUNITIES (+)	**THREATS (-)**
Can be added on to existing structures.	No long term monitoring to determine the actual effectiveness *in situ*.
Could benefit species of commercial importance and value.	Potential threat of encouraging spread of INNS due to creation of new habitat.
Potential for coexistence with static fisheries gear.	Potential marine licensing challenges if not accounted for within Project Development Envelope.
Opportunity to enhance installation activities which are already taking place (e.g. traditional rock placement).	Policy challenges and a lack of clarity over decommissioning processes.
Potential for cooperation with academic community - opportunity for research.	Question surrounding liability at decommissioning and implications surrounding Crown Estate Scotland seabed agreements.
Potential for application of existing research to draw on (e.g. INSITE), particularly for justification of decommissioning approach.	Impact on insurance is likely a key financial risk.
Opportunity for customisation - alternatives to concrete.	Potential snagging risk where located on the seabed, NID potentially compromises 'overtrawlability'.
Deployment close to existing infrastructure will have a minimal exclusionary impact on fishing activity.	Strategic placement of NID to maximise ecological benefit may incur additional logistical and financial implications.
Advertised customisation which may allow for reduced impacts to commercial fisheries.	Potential nullification of 'overtrawlability' which has repercussions (for the commercial fishing industry) beyond operational life.
Likely minimal risk to foundation design therefore increased potential for design acceptance.	Uncertainty surrounding decommissioning process, removal would result in any benefit being lost.
Overhead costs likely more favourable if tested as a prototype or in a demonstrator project.	Potential for increased costs of any particular design intricacies when scaled commercially.
	Potential for increased vessel requirements associated with novel installation methods.

4.4 Mattresses

STRENGTHS (+)	WEAKNESSES (-)
Potentially applicable to offshore fixed and floating wind structures, and along/as part of cable protection.	Uncertainty surrounding biomass during cleaning/decommissioning.
Potential to benefit across all life stages of a species.	Unlikely to be suitable for areas of soft sediment habitats (especially within sites designated for sediments).
Potential to attract higher trophic levels - especially aggregations of fish.	Design might include plastic/other components - undesirable to add these into the marine environment.
Suitable for a variety of species and habitats identified as being of conservation value in Scottish waters.	Lack of clarity on composition of these alternative materials.
Creates increased structural complexity (ledges and crevices).	Uncertainty surrounding structural integrity of alternative materials - possibly not as robust as traditional protection measures.
Directly beneficial to lower trophic levels and sessile epifauna in particular.	Degradation over project lifetime might necessitate additional maintenance/replacement considerations within marine licensing process.
High spatial applicability; therefore, may benefit a range of species across a range of water depths.	Carbon footprint of materials to develop these NID measures and subsequently transport them independently.
Could be used as a stand-alone measure away from infrastructure.	Similar to NID group reef-type structures and concrete blocks but with a more limited profile therefore potentially less ecologically beneficial.
Depending on NID specifics, could be easier to remove during decommissioning.	
Can be used in combination with other NID measures.	
Deployment likely in line with typical rock protection timescales	
Elevation from seabed is a key measure of 'reefiness'.	
Does not need to be directly attached or designed directly into a structure.	
Could be used to supplement traditional rock protection - dual purpose as potential protection measure.	
Can be installed/incorporated during operational phase (assuming consent).	
OPPORTUNITIES (+)	**THREATS (-)**
Can be added on to existing structures.	No long term monitoring to determine the actual effectiveness *in situ.*
Could benefit species of commercial importance and value.	Potential threat of encouraging spread of INNS due to creation of new habitat.
Opportunity to enhance installation activities which are already taking place (e.g. traditional rock placement).	Potential marine licensing challenges if not accounted for within Project Development Envelope.
Potential opportunity for reuse of these structures on subsequent projects.	Reluctance to add more material than necessary along cables and undesirable to detract from cable burial requirements.
Potential for streamlining vessel requirements - activity in line with traditional rock placement durations.	Impact on insurance is likely a key financial risk.
Deployment close to existing infrastructure will have a minimal exclusionary impact on fishing activity.	Potential snagging risk where located on the seabed, NID potentially compromises 'overtrawlability'.
Likely minimal risk to foundation design therefore increased potential for design acceptance.	Strategic placement of NID to maximise ecological benefit may incur additional logistical and financial implications.
Opportunity for frond mattresses to facilitate sediment accretion in sandier conditions/close to the coast.	OFTO divestment requirements depend on justification of protection measure costs - unless potentially more expensive alternative measures are required via consent, there is little incentive to invest in NID.
	Uncertainty surrounding decommissioning process, removal would result in any benefit being lost.
	Potential for increased costs of any particular design intricacies when scaled commercially.
	Potential for increased vessel requirements associated with novel installation methods.

4.5 Water replenishment holes

STRENGTHS (+)	WEAKNESSES (-)
Potentially applicable to offshore fixed wind structures.	Only applicable to fixed offshore wind structures, many ScotWind projects will be floating.
Potential to benefit across all life stages of a species.	Needs to be incorporated into early design/during procurement.
Potential to attract higher trophic levels - especially aggregations of fish.	Could affect structural integrity of the structure it's attached to (potential engineering considerations).
Suitable for a variety of species and habitats identified as being of conservation value in Scottish waters.	Potential increase in biomass needs to be accounted for during design, but biomass hard to predict.
No direct impact on the seabed (i.e. no habitat lost/replaced).	Uncertainty surrounding biomass during cleaning or decommissioning.
Evidence of successful deployment in the marine environment.	Ecological benefit of measures which are incorporated into structural design is limited to operational life.
Can be used in combination with other NID measures.	Potentially lower structural complexity compared to other NID groups.
No opportunity for creation of scour.	Uncertainties regarding approach to monitoring, ease of access etc.
Likely less impact on commercial fisheries, fewer associated risks and restrictions.	
No additional infrastructure required.	
OPPORTUNITIES (+)	**THREATS (-)**
Can be incorporated during design.	No long term monitoring to determine the actual effectiveness *in situ*.
Could benefit species of commercial importance and value.	Potential threat of encouraging spread of INNS due to creation of new habitat.
Potentially may limit impacts of infrastructure on water column stratification.	Unlikely that the design company will accept the cost of any design alterations.
Potential for cooperation with academic community - opportunity for research.	Uncertainty over potential impact on stratification and other physical processes (which has been identified as a ScotMER evidence gap).
Potential for reduced scour protection requirements due to reduced impact on hydrodynamic processes (the holes allow unimpeded flow of water).	Potential risk of entanglement or larger species getting stuck.
	Impact on insurance is likely a key financial risk.
	Potential for increased costs of any particular design intricacies when scaled commercially.

5 CONCLUSION

This review considered the suitability of each of the five identified NID categories in offshore waters in Scotland, focusing on their applicability to ScotWind based on their technical and ecological attributes. It also summarised the global evidence of the potential ecological benefits of some NID measures, for which information is limited and is still in the process of being gathered within different countries.

It has been shown that each of the NID groups has a series of strengths, weaknesses, opportunities, and threats across technical and ecological aspects – these have been captured in the matrices in Section 4. A summary of common points across the five NID categories in terms of strengths, weaknesses, opportunities, and threats can be seen in Table 1 with subsequent detailed discussion throughout Section 3.3.

The information presented throughout this report is expected to support developers and stakeholders in the selection of promising NID options across ScotWind Plan Option Areas, with reference to specific policy-important habitats and species, and habitat-forming species.

With the aim to support developers and stakeholders in the identification of promising NID options, advice about the process to be followed for the consideration of NID options in offshore wind farms in Scotland, has been developed and can be found in the CEMNID Final Report (A-100906-S00-REPT-007). This advice highlights key principles which must be considered when determining which NID are most suitable for a project. In addition, the advice includes a high-level schedule which highlights where in a project timeline NID might be considered.

It should be mentioned that the available information about NID options globally and in Scotland is limited and thus any recommendations made in this deliverable should not be regarded as a guarantee of the success of NID options. The location and area-specific environmental conditions need to be considered as an important factor that shapes the ecological success of NID options. This also highlights the need for advancing knowledge about the performance of NID options in offshore wind farms in Scotland, which, needs the deployment, testing and monitoring of the ecological performance of NID measures in Scottish waters. Advancing knowledge about the ecological performance of NID measures in Scottish offshore windfarms, as well as the parameters that drive ecological success will be also important in advancing knowledge about the scalability of NID measures across Scottish offshore wind farms.

Throughout the preceding sections, information was provided about the type of species/habitats that may benefit from the NID options (e.g., sessile, mobile) and the service that NID can serve to these features. Summarising the information presented in sections above it seems that all five NID categories may have potential ecological benefits across all the four ScotWind Plan Option areas (i.e., West, North West, North East and East). The main drivers supporting this observation are the following:

- Most of the policy important habitats and species have relatively wide geographic distribution across Scottish waters. This wide geographic distribution enhances the potential overlap between those features and the ScotWind Plan Option Areas. For example, the features Annex I reefs (Figure 2), blue mussel beds, horse mussel beds (Figure 3) as well as the species European spiny lobster, Atlantic cod (Figure 4) and northern feather star (Figure 5) have been recorded across all four ScotWind Plan Option Areas. In addition, native oysters (Figure 3), Atlantic halibut, flapper skate, blue skates (Figure 4), white cluster anemones, northern sea fan and sponge communities (Figure 5) have been recorded in three ScotWind Plan Option Areas.

- Most of the NID categories have high spatial applicability. Specifically, the geographic/bathymetric range of the NID measures a) adapted rock protection, b) reef structures-concrete blocks, and c) modified mattresses can extend from the offshore wind array area all the way to nearshore (cable route), benefitting a relatively wide range of fauna across a variety of water depths (see Section 4); NID measures may benefit areas where sensitive species have disappeared or habitats have been degraded from historic human activities and could support their recovery, restoration and/or support the resilience and recovery of such features that occur in adjacent areas (such as in protected sites).
- Most of the NID categories may provide more than one service (e.g., attachment surface, shelter feeding ground, etc) widening thus the number of features that may benefit. For example, the modified mattresses may serve as an attachment surface for northern feather star in North West Areas, as a feeding ground for Atlantic halibut in East Areas and a spawning ground for skates in West Areas. Detailed presentation of the information about the features that may benefit from each NID category and the relevant services can be seen in Tables 1 and 3 in the CEMNID NID Literature Review (A100906-S00-REPT-003).

With regards to technical aspects, many key considerations are applicable across both fixed and floating technologies (e.g., the technical view that welds are structural weak points and must be accessible for inspection). However, structural soundness is of particular importance when looking at floating structures which exist in a high stress dynamic environment. This has financial and insurance consequences, with potential additional financial burdens for the developer. While NID measures do not intent to be financially or practically limiting, there may be specific vessel requirement associated with the deployment of different NID options. Another key risk to NID deployment is potential for interaction with other users of the sea, some types of NID may come with associated increased snagging risks.

The findings of this deliverable can act as a starting point for the interested parties (e.g., offshore wind farm developers) in identifying and selecting NID options for offshore wind farms in Scotland to support nature-positive development in the marine environment. Scotland's biodiversity strategy sets out our clear ambition for Scotland to be Nature Positive by 2030, and to have restored and regenerated biodiversity across the country by 2045 (Scottish Government, 2022). This strategy has fed into NPF4 which applies to the intertidal, onshore, and offshore elements of offshore wind projects. Some offshore wind developers have responded to meeting the requirements of NPF4 policies 1, 2 and 3 which have a focus on creating more sustainable places, whether this is through mitigation and adaptation to the climate crisis or biodiversity enhancement (e.g. West of Orkney Wind Farm Outline Biodiversity Enhancement Plan submitted in 2024). In a similar vein, the ongoing update to the National Marine Plan (NMP) will require translation of NPF4 policies 1, 2, and 3 into a marine context for NMP2 to ensure both plans are in sync, given jurisdictional overlap in the intertidal zone and have been included as policy ideas to be tested with stakeholders throughout 2024. NID could have a place within these policies within the context of applying the mitigation hierarchy, a focal point within the NMP. NMP2 is due to be in place in 2025 and will apply to all marine sectors.

At a more strategic level and in response to global biodiversity frameworks, tender and investor requirements, developers have been responding and reporting at a corporate level on the need to address net-positive biodiversity impacts. For example, Ørsted's ambition is that all new renewable energy commissioned from 2030 onwards should deliver a net-positive biodiversity impact (Ørsted, 2024) and bp's ambition is to have plans in place for all projects (in scope) to achieve net positive biodiversity impact, with a target for 90% of actions to be delivered within five years of project approval (bp, 2024)[4]. Another example is Scottish Power Renewables which have (through Iberdrola) a goal to have a net positive impact on biodiversity by 2030[5]. These plans could drive investment in nature positive solutions for projects, including NID.

Interested parties should read the CEMNID Final report which proposes an NID framework and provides recommendations (e.g., clear need for further research into, and trialling of, NID Options in Scotland) and discusses the limitations this NID suitability review has encountered.

[4] *In 2023, bp began applying their NPI biodiversity methodology to new, in scope bp projects, such as the Northern Endurance Partnership Development in the UK*

[5] *https://www.iberdrola.com/documents/20125/40552/2030_Biodiversity_Plan.pdf*

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APPENDIX A LIST OF SELECTED POLICY-IMPORTANT HABITATS AND SPECIES

List of policy-important habitats and habitat-forming species

- Blue mussel beds
- Horse mussel beds
- Kelp beds
- *Sabellaria spinulosa* reefs (*Sabellaria spinulosa* on stable circalittoral mixed sediment)
- Tide-swept algal communities
- Kelp and seaweed communities on sublittoral sediment
- Kelp in variable or reduced salinity
- *Ostrea edulis* beds on shallow sublittoral muddy mixed sediment
- *Caryophyllia smithii* and *Swiftia pallida* on circalittoral rock
- Mixed turf of hydroids and large ascidians with *Swiftia pallida* and *Caryophyllia smithii* on weakly tide-swept circalittoral rock
- Submerged fucoids, green or red seaweeds (low salinity infralittoral rock)
- Deep sponge communities (circalittoral)
- Annex I Bedrock reef
- Annex I Stony Reef

List of policy-important species

- Native oyster (*Ostrea edulis*)
- Northern sea fan (*Swiftia pallida*)
- Atlantic halibut (*Hippoglossus hippoglossus*)
- Atlantic cod (*Gadus morhua*)
- Atlantic herring (*Clupea harengus*)
- Flapper skate and blue skate (formerly common skate) (*Dipturus batis* complex)
- Spotted ray (*Raja montagui*)
- Ling (*Molva molva*)
- Saithe (*Pollachius virens*)
- Spiny dogfish / spurdog (*Squalus acanthias*)
- European spiny lobster (*Palinurus elephas*)
- Northern feather star (*Leptometra celtica*)
- Pink sea fingers (*Alcyonium hibernicum*)
- White cluster anemone (*Parazoanthus anguicomus*)
- Dog whelk (*Nucella lapillus*)

For more information on the selection process, the ecology of the selected features and how they may benefit from the identified NID measures, please refer to the CEMNID NID Literature Review (A-100906-S00-REPT-003).