Marine Net Gain: A Proof-of-Concept Assessment of Experimental Metric Calculations and Approaches Utilising Walney Extension Wind Farm as a Case Study

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Executive Summary

To tackle the joint aspirations of expanding the offshore renewable energy sector and assisting marine nature recovery, the UK Government is currently developing a new policy titled "Marine Net Gain". This policy will require developers to leave marine biodiversity in a measurably better state than they found it at the start of development, and is similar to the Biodiversity Net Gain policy, which was developed for terrestrial and intertidal environments.

Biodiversity Net Gain relies on a metric (The Biodiversity Metric 3.1, Natural England) to calculate the value of biodiversity attributable to a development in the form of habitats lost, degraded, added or improved through the development. Several challenges arise when applying this approach and the net gain concept to the marine environment, including but not limited to the scarcity of knowledge on the current condition of UK marine habitats, strategies to restore them, and mobile species whose response to developments may not be captured by habitat impacts alone. With Marine Net Gain policy currently in the early stages of development, solutions to these uncertainties are still emerging.

This report uses data from Walney Extension Offshore Wind Farm to generate three offshore wind farm "scenarios" which were tested against an experimental marine version of Natural England's Biodiversity Metric, to highlight some of the advantages and challenges of using a metric to calculate biodiversity value of marine environments, as well as some of the more general challenges of implementing Marine Net Gain policy. Two versions of this metric were tested within the report, with one metric including a "strategic significance" factor which increased the value of a habitat if it was located within an area of particular importance to biodiversity, for example a Marine Protected Area. An additional metric was used to calculate impact of a development on species.

A summary of each scenario and the key challenges addressed within each trial is outlined below:

Scenario 1: A hypothetical area of seabed with the same area as Walney Extension, to maintain consistency with other scenarios. Trials run within Scenario 1 demonstrated the function of the test MNG metric by altering different habitat parameters and observing the impact on a habitat's biodiversity value. Results from this scenario demonstrated the functionality of the metric and highlighted that the scales used to quantify habitat importance and condition, as well as categorise the type of habitat were very broad. This prevented distinctions between habitats that differed in importance or condition on a slighter, yet significant scale, as well as preventing habitat classification to a fine enough scale to appropriately describe the biodiversity present.

Scenario 2: A true-to-life case study using the area and location of Walney Extension Offshore Wind Farm. This scenario aimed to quantify the total biodiversity loss attributed to Walney Extension and estimate how much marine habitat restoration would be required for a modern-day wind farm to achieve net gain. The trials modelled restoration using different restoration

strategies, and identified challenges with these calculations and approaches. The need for finer scales was reinforced by the results of Scenario 2 trials, which demonstrated that all three habitats present within Walney Extension were calculated to have identical biodiversity values per hectare, despite significant variation in the likely biodiversity supported by each habitat. The biodiversity value of the maximum impacts consented for Walney Extension was calculated to be approximately 3 times larger than the biodiversity value of the area actually impacted by construction; this poses important questions around what stage of a development's consenting or construction process should be included in Marine Net Gain calculations.

Attempting to achieve a net gain through different habitat restoration strategies demonstrated that restoring the same area of the same habitats originally impacted by development would not achieve net gain, owing to the lack of reliable restoration strategies. This was described by a "delivery difficulty" multiplier included in metric calculations which reduces the value of a habitat restoration effort as the difficulty of delivering it increases. Achieving net gain through simulating pressure reduction on an area of the site, for example implementing an exclusion area from anchoring and bottom towed fishing gear, proved to be feasible, posing questions surrounding whether pressure reduction could be considered as a contribution towards Marine Net Gain. Restoration of habitats with existing restoration strategies, such as blue mussel and horse mussel beds, resulted in a net gain; however, areas of restoration required were unnaturally large and impractical, and would not necessarily confer a beneficial increase in biodiversity on the site, as the habitats restored differed significantly from those impacted by development.

Scenario 3: A hypothetical offshore wind farm using Walney Extension's array area, but placed in the North Sea 18.78km off of the Great Yarmouth coast, containing complex habitats (*Sabellaria spinulosa* reef) and mobile species (sandwich tern (*Sterna sandvicensis*), harbour seal *(Phoca vitulina)* and grey seal (*Halichoerus grypus)*). Attempts at achieving Marine Net Gain through restoration within Scenario 3 were met with similar results to Scenario 2 and were exacerbated by the inclusion of a highly important habitat, *Sabellaria spinulosa* reef. These results highlight the potential necessity for trading rules within the metric (as seen in the Biodiversity Metric 3.1), which would prevent the substitution of a habitat for a considerably different habitat. However, the lack of effective restoration strategies for the majority of marine environments would make it unfeasible to require restoration of similar habitats to those impacted by development. Regarding the need for research and development of new and more effective marine habitat restoration techniques, the possibility of including research efforts as a Marine Net Gain contribution was discussed, though the quantification of such efforts would fall outside of the scope of the metric used in this report.

Efforts to quantify the impact of a development on mobile species found within Scenario 3's location found that the current metric only accounts for mortality of individuals, and is unable to characterise accurately the direct and indirect impacts of a development on a species (such as behavioural changes and loss of mating opportunities). The creation of a model specific to developmental impacts on species populations such as the type used in ecological population modelling, was suggested as an alternative method for quantifying and predicting these impacts.

Beyond the recommendations already noted, it is recommended that a "time to restoration" multiplier be added to the metric, to account for the difference in the likelihood of delivery that is conferred by completing or beginning restoration before beginning a development.

To enable a smooth transition into Marine Net Gain policy, developers and stakeholders should be involved in the development of a metric, to improve familiarity and understanding of the metric's approach to calculating Marine Net Gain.

It is recommended that internship partners, alongside other relevant and interested stakeholders, discuss:

- The feasibility and practicality of including within a metric:
    - Finer habitat classification scales, habitat importance scales and habitat condition scales
    - Ecological models to calculate species impacts
    - Trading rules to ensure restoration of habitats with similar biodiversity
- The appropriate stage of the consenting or construction process to implement Marine Net Gain requirements
- The generation and collation of data necessary for gaining a greater understanding of marine biodiversity, habitat condition and developmental impacts
- The current most effective method for improving marine biodiversity alongside offshore developments, until a fully developed Marine Net Gain policy is released.

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Abbreviations

Abbreviation	Definition
BAP	Biodiversity Action Plan
BEIS	Department for Business, Energy & Industrial Strategy
BNG	Biodiversity Net Gain
BOCC	Birds Of Conservation Concern
BU	Biodiversity Units
CMS	Construction Method Statement
CPUE	Catch Per Unit Effort
CSIP	Cable Specification and Installation Plan
DCO	Development Consent Order
Defra	Department of Environment, Food and Rural Affairs
DMA	Danish Maritime Authority
EIA	Environmental Impact Assessment
EMS	European Marine Site
eNGO	Environmental Non-Governmental Organisation
ES	Environmental Statement

ESAS	European Seabirds At Sea
GBF	Gravity Based Foundation
GIS	Geographic Information System
Ha	Hectares
HPMA	Highly Protected Marine Area
HRA	Habitat Regulation Assessment
INNS	Invasive Non-Native Species
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union on the Conservation of Nature
JNCC	Joint Nature Conservation Committee
KRA	Key Resource Area
MCAA	Marine and Coastal Access Act
MCZ	Marine Conservation Zone
MFI	Marine Futures North West Internship
MHSOD	Marine Habitats and Species Open Data
MMO	Marine Management Organisation
MNG	Marine Net Gain
MPA	Marine Protected Area
NASA	National Aeronautics and Space Administration
NE	Natural England
NGO	Non-Governmental Organisation
NOAA	National Oceanic and Atmospheric Administration
NSIP	Nationally Significant Infrastructure Project
NTZ	No-Take Zones
OSPAR	Oslo/Paris convention for the Protection of the Marine Environment of the North-East Atlantic
OSS	Offshore Substation
OWF	Offshore Wind Farm
RE	Rochdale Envelope
SDG	Sustainable Development Goal
SPA	Special Protected Area
TCE	The Crown Estate
TCPA	Town and County Planning Act
TG	Technology Group
TWT	The Wildlife Trusts
UK	United Kingdom
UN	United Nations
WTG	Wind Turbine Generator
WWF	World Wide Fund for Nature

1. Introduction

As global anthropogenic pressures have increased, biodiversity has experienced significant declines in both terrestrial and marine environments. The growing demand for resources and the need for sustainable growth has been made evident in recent years, as has the need for a push towards nature's recovery. In the United Kingdom (UK), Marine Net Gain (MNG) policy has been drafted by Defra (Department of Environment, Food and Rural Affairs) as a mechanism to ensure sustainable growth of sub-tidal developments alongside the recovery of marine biodiversity. This will be similar to the existing terrestrial and intertidal policy of Biodiversity Net Gain (BNG), which requires developers to incur a 10% "net gain" on biodiversity which can be attributed to the development. BNG uses a metric to quantify the biodiversity value of both the development's impact and restoration efforts; the use of a metric for MNG policy has been discussed within Defra's 2022 consultation, though there are numerous challenges associated with using this approach in the marine environment. This report aims to investigate how an MNG metric may be used to calculate biodiversity impact and restoration alongside the benefits or drawbacks this may have. In order to understand how MNG policy would be effective for the UK marine environment, a better understanding of marine habitat loss and the growth of sub-tidal development is necessary.

1.1 Overview of habitat loss in the UK

UK seas cover an area of 885,430km^2 (Benjamins, 2010; Joint Nature Conservation Committee, 2022) and support numerous ecologically rich habitats and species. In line with global trends of decline, the UK has experienced considerable losses of its marine and coastal habitats in recent centuries. Reasons for this decline are linked to the increasing intensity and impact of anthropogenic activity on the oceans, causing further biodiversity loss and fragmentation of key habitats (Pawar, 2016).

Coastal and marine habitats of significant importance are listed as Marine Priority Habitats within the UK Biodiversity Action Plan (BAP) (originally published in 1994 and updated in 2011) (JNCC, 1994). Some of the main habitats included within this plan are kelp forests, seagrass meadows, saltmarshes, biogenic reefs and maerl beds; each of these habitats confers significant biodiversity value on the local marine or coastal environment but has been subject to substantial declines that have affected ecosystem function and service provision of these marine areas (Appendix A: Table 32). Notable examples of habitat loss in the UK include that of seagrass meadows, a once abundant habitat along the UK coastline which have been estimated to have lost 44% coverage in the last 90 years, with losses over a longer timespan potentially reaching losses of 92% (Green et al., 2021). Similar to seagrass meadows, kelp forests which once dominated the coastal marine environment in the UK have experienced estimated declines of 96% since 1987 in some areas e.g. Sussex (Rewilding Britain, 2022; Williams et al., 2022). Substratum abrasion of Maerl beds in the UK has been recorded to reduce the amount of live maerl by 70% with no evidence of recovery within 4 years (Hall-Spencer and Moore, 2000). Biogenic reefs, like *Ostrea edulis* beds, have also been subject to declines; *O. edulis* beds once dominant in the North Sea have declined by 95% since the 1800s (Laing, Walker and Areal, 2006; Perry, Tyler-Walters and Garrard, 2020; Robertson et al., 2021). These losses are often difficult to quantify accurately, owing to a lack of historical coverage data and the inaccessibility of many marine habitats.

1.1.1 Causes of UK habitat loss

In order for an ecosystem to function, it must have a diverse population that provides both functional redundancy and ecosystem resilience (Biggs et al., 2020; Jurburg and Salles, 2015). Functional redundancy refers to the number of species, both flora and fauna, that share a similar or identical role in the function of an ecosystem. If diversity decreases, the number of species performing a function within the ecosystem decreases, consequently reducing the functional redundancy and weakening the resilience of an ecosystem (Biggs et al., 2020; Jurburg and Salles, 2015). This makes it more susceptible to damage from external pressures which in can cause a positive feedback loop that degrades and reduces the biodiversity of the ecosystem.

An increased demand for natural resources has followed the exponential increase in the global human population, at a rate which has placed considerable pressure on the natural world. Marine biodiversity has decreased globally due to a variety of anthropogenic stressors. Within the last century anthropogenic activity has caused ocean warming (resulting in species loss and migration e.g. Sand eel species - *Actinopterygii* sp.), sea level rise (putting pressures on coastal and intertidal habitats), ocean acidification (weakening calcium carbonate ecosystem engineers), marine debris (causing entanglement or ingestion leading to bioaccumulation), invasive species introduction (outcompeting native species), overexploitation (key species decline which can lead to trophic cascade) and habitat destruction (removing recruitment zones for species) (Küpper and Kamenos, 2018). Due to the range of stressors the marine environment is subject to and the ability for stressors to combine, there is no simple solution to restore the UK's marine biodiversity.

In concert with habitat loss, habitat fragmentation is a notable threat to species survival (Laurance et al. 2002; Sekercioglu et al. 2002; Chapter 5). When areas of habitat are lost, it can disconnect them and create smaller areas that are not connected. This can occur naturally, but for most cases in the marine environment it is a result of anthropogenic activity. In some cases, habitat fragmentation can lead to a reduction in the habitat's diversity.

1.1.2 Decline of species populations in the UK

Biodiversity decline has impacted individual species around the UK. For example, overexploitation from 118 years of industrial overfishing has led to increased vulnerability of species population within the UK, notably on Atlantic cod (*Gadus morhua)* and sand eel (*Ammodytes)* species (Carroll et al., 2017; Proffitt, 2004; Thurstan, Brockington and Roberts, 2010). Recent studies from 2018 reported that only 10% of management measures on Marine Protected Areas (MPAs) were being implemented in full (Environmental Audit Committee, 2019). Additionally, set objectives had not been met for under half of Marine Conservation

Zones (MCZs) in English waters by 2021 (WWF, 2021). This lack of management and enforcement on protected areas has caused further declines to species populations and the marine environment upon which they depend.

Invasive species introductions pose a further threat towards native habitats and biodiversity through direct and indirect interactions. Direct interactions, such as increased predation and competition from the invasive species introduced, combined with indirect interactions, such as spread of disease, can cause functional redundancy and an ecosystem's functional decline (NOAA Fisheries, 2018). Invasive species are typically introduced by human interactions with the marine environment; for example, Airoldi et al., (2015) found that the development of marine infrastructure on sandy sediment favours non-indigenous species, as the introduction of a hard substrate into a soft-substrate dominated area affects the species which can dominate the habitat.

1.2 Protecting the marine environment

The main mechanism implemented to counteract biodiversity loss within the marine environment is the creation of MPAs (however defined). Previously, the UK relied on voluntary MCZs prior to 1981; more than 20 were established but were not systematically selected (Stevens et al., 2014). Since 1981, the Government created Marine Nature Reserves but it was not until policy shifts at a European level that a network of MPAs dedicated to conserve marine habitats and species were formed. These European Marine Sites (EMS) are required under European Law but the effectiveness of these have been questioned. As of 2022, 38% of UK waters are protected by MPAs (Joint Nature Conservation Committee, 2022). Research by Oceana (2021), a conservation Non-Government Organisation (NGO), into the effectiveness of these MPAs discovered 97% were subject to bottom trawling. Bottom trawling is a destructive fishing practise that impacts habitats found on the seabed and the local biodiversity. This is not to say MPAs are ineffective; No-Take Zones (NTZ), a type of MPA, have been proven to benefit both the marine environment and, after several years, the Catch Per Unit Effort (CPUE) for fisheries that operate nearby (Kerwath et al., 2013; Marshall et al., 2019). Strict enforcement of areas such as NTZs could result in an increase in fish biomass of 600% within that area (WWF, 2018; WWF, 2021). In July 2022, a consultation from Defra was released on the creation of five Highly Protected Marine Areas (HPMAs) in English waters. These areas will aim to promote nature recovery by "prohibiting extractive, destructive and depositional uses and allowing only non-damaging levels of other activities to the extent permitted by international law" (Department for Environment, Food & Rural Affairs, 2022), enabling the natural recovery of habitats within the HPMA.

1.2 Offshore development in the UK

1.2.1 Shift towards sustainability

Until as recently as 1991, renewable energy only accounted for 2% of national energy production in the UK (National Grid, 2022). The use of fossil fuels in the last 200 years, alongside habitat degradation of important carbon sinks, has raised atmospheric carbon dioxide content by 50% with carbon dioxide concentrations being at 419 parts per million in 2022 (NASA, 2022; Friedlingstein et al., 2022). Scientific research and advice have led to global recognition of the need for change. The Intergovernmental Panel on Climate Change (IPCC) 2016 Paris Agreement agreed that, in order to ensure a sustainable future, global temperatures must be kept below a 1.5-2°C increase compared to pre-industrial levels (IPCC, 2016; Mugo, 2021 and UNFCC, 2016). To achieve this, all countries are required to transition their economies to be based upon sustainable methods. This was enforced further in 2018 with the IPCC releasing a report stating that by 2050, countries need to achieve “Net Zero” carbon emissions to have a 50% chance of controlling global warming (IPCC, 2022; Department for Business, Energy & Industrial Strategy, 2022). “Net Zero” with regards to carbon refers to the amount of carbon emissions that are removed from the atmosphere being equal to those emitted by anthropogenic activity (National Grid, 2022). In response to the agreement, 12 countries around the globe passed legislation to achieve “Net Zero” by 2050 including the UK (IPCC, 2022).

Following the IPCC climate agreement, the 2030 Agenda for Sustainable Development was adopted by all United Nations (UN) member states in 2015 (United Nations, 2022). This agenda sets out 17 Sustainable Development Goals (SDGs), which aim to tackle the most urgent global environmental and socioeconomic issues. An SDG progress report is produced annually to note progress towards both IPCC targets and SDG goals. By transitioning to renewable energy sources, the UK is keeping in line with the “Affordable and Clean Energy” SDG (SDG 7); more specifically, the goal of building a sustainable future (SDG 7.2.1) (Thomas, 2021).

1.2.2 Increase of offshore wind developments in the UK

The UK has experienced a rapid growth in renewable energy since 1991; since the early 2000s, The Crown Estate (TCE) have completed three rounds of Offshore Wind Farm (OWF) leasing to support OWF development and in turn support the growth of sustainable energy production. This led to the UK becoming a global leader in offshore wind energy as early as 2014 (Kern et al., 2014). In 2020, the UK produced 43% of its energy from renewable energy, with wind energy (both offshore and onshore) providing 26% (National Grid, 2022). This displays the rapid transition towards renewable energy with wind and solar set to increase significantly between 2022 and 2030. The most recent round, “Round 4”, aims to add a further 8GW of power generated from OWF. Round 4 and future leasing rounds are aiming to produce 50GW of energy in the UK by 2030 as set out in the UK Governments “10 Point Plan for a Green Industrial Revolution” (HM Government, 2020; HM Government, 2022). This comes in line with the Government's push towards OWF power generation and reducing the consenting time in order to achieve the 50GW target (The Crown Estate, 2022). These targets continue past 2030, aiming for 100% of electricity to come from zero-carbon generation by 2035 and the UK being “Net Zero” by 2050 (National Grid, 2022). This will be achieved through the increase in offshore wind developments alongside emerging technologies (tidal stream, tidal range, floating solar, floating wind and wave power). With the fast transition from non-renewables to renewables and a large demand for renewable energy being placed on the marine environment, there needs to be effective, strategic management for subtidal development to minimise impact to the marine environment.

1.2.3 Need for effective policy for offshore developments

To ensure sustainable use of our seas for energy production, change is needed in policy to enforce protection of the marine environment. Current policy revolves around mitigating impacts upon the natural environment and in cases where mitigation cannot occur then compensation is required; this is done by completing Environmental Impact Assessments (EIA), Habitat Regulation Assessments (HRA) and implementing the mitigation hierarchy (Figure 1). However, no policy currently exists that requires a developer to incur a net benefit on marine biodiversity.

Under the 2009 Marine and Coastal Access Act (MCAA), developments are required to apply for marine licenses through the Marine Management Organisation (MMO) (Marine Management Organisation, 2022). As OWF are considered to be Nationally Significant Infrastructure Projects (NSIPs), the Planning Act (2008) provides a framework when applying for a Development Consent Order (DCO). This gives consent to the developer to construct an OWF with the Department for Business, Energy & Industrial Strategy (BEIS) as the regulator. The MCAA then enables the deemed Marine Licences to be granted with the DCO, providing consent for the offshore aspect of an OWF. Once this has been granted consent, the MMO become the regulator. The MMO considers the economic, social and environmental impacts alongside the associated effects of a development. If it is deemed that the project will have significant effects upon the environment, The Marine Works Regulations (2007) require an EIA to be undertaken before a license is granted (Marine Management Organisation, 2022). Alongside this, the MMO will undertake a HRA to assess the impacts a development may have on protected European and Ramsar Sites under the Conservation of Offshore Marine Habitats and Species Regulations (2017); also known as the Habitats Regulations (Marine Management Organisation, 2022).

The mitigation hierarchy, as stated in section 15, paragraphs 174-188 of the National Planning Policy Framework (2012), is implemented to mitigate any adverse effects that may occur on the site's integrity. The hierarchy consists of four main elements: avoidance, minimisation, restoration and offsets (Figure 1).

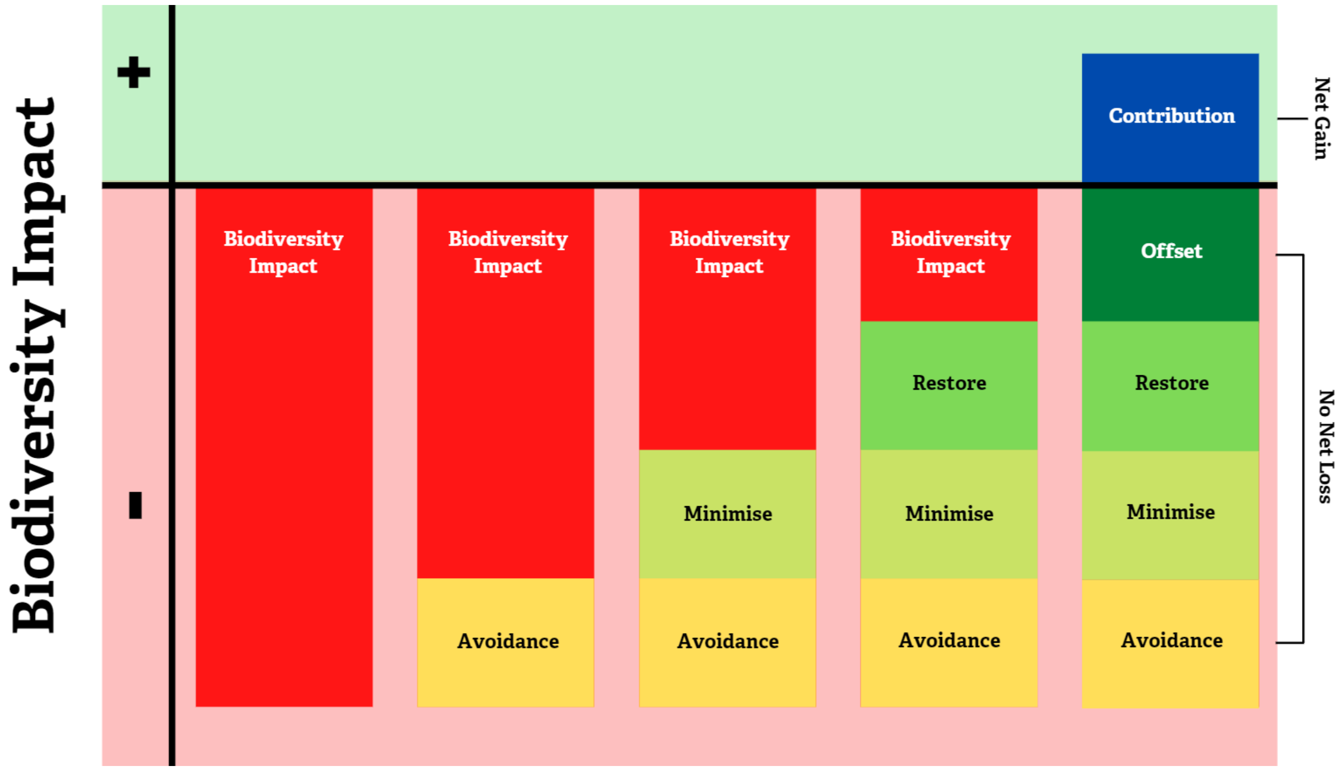

Figure 1: *The stages of the Mitigation Hierarchy displayed visually. To achieve a 'No Net Loss' to the site's biodiversity all four steps should be taken. To achieve 'net gain' additional 'contributions' have to be made. Figure adapted from Natural England, 2021.*

1.3 Introduction to Net Gain

1.3.1 Aims and objectives of Biodiversity Net Gain Policy

In 2018, the UK Government proposed a new approach to terrestrial developments in an effort to tackle the ongoing ecological crisis alongside the increasing demand for new infrastructure in the UK (Environment Act 2021). This approach, titled BNG, aimed to ensure that biodiversity was left in a measurably better state at the completion of a new development, in comparison to before the development was commenced. This requirement applies to all terrestrial and intertidal (down to the Mean Low Water Mark) developments under the Town and County Planning Act 1990 (TCPA) and to terrestrial NSIPs (Planning Advisory Service, 2021). As an additional requirement to existing habitats and species protections achieved through the mitigation hierarchy (Figure 1), developers will be required to ensure that any in-scope new developments deliver a 10% gain in biodiversity over the course of the development, through the restoration or enhancement of sites beyond mitigation measures (Environment Act 2021). This will become mandatory two years after the 2021 Environment Act.

1.3.2 The Biodiversity Net Gain Calculator

For terrestrial environments, the biodiversity value of an area is calculated using habitat as a proxy. The biodiversity loss of any given habitat, measured in Biodiversity Units (BU), is calculated by the area of habitat that is subjected to a reduction in condition, reduction in distinctiveness or complete loss, multiplied by the original condition, habitat distinctiveness (importance) and strategic significance of that habitat (Figure 2). Natural England (NE) has developed a Biodiversity Metric by which to calculate this value, which assigns values to each of these four categories based on empirical research. By this method, more distinctive (important), more strategically significant habitats and/or habitats that are in a more pristine condition prior to development have a higher biodiversity value. By combining the BU of each habitat that is lost to the development, the total biodiversity loss for a site can be calculated (Figure 3).

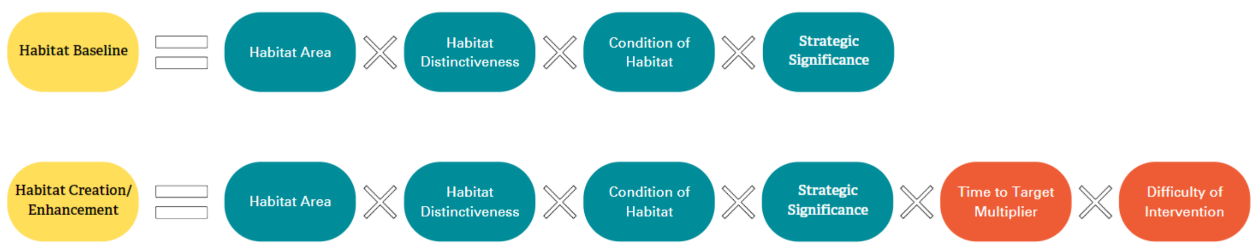

Figure 3: *Longhand calculation of the BNG metric. The blue multipliers are positive (scores >1) and the red multipliers are negative (scores <1). If the creation/enhancement is off-site then another negative multiplier is added, distance from onsite base*

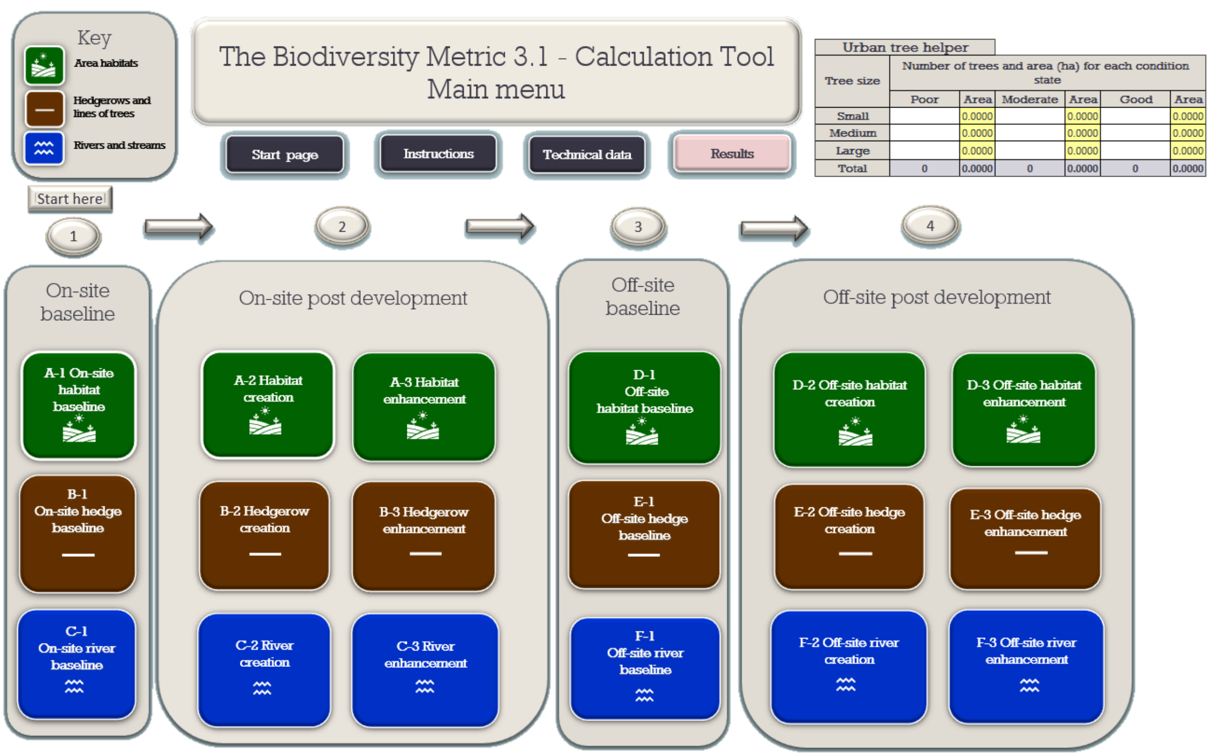

Figure 2: *The overall view of the BNG Metric 3.1. The main area used is the habitat calculator (green) which includes both terrestrial and intertidal habitats. Figure sourced from the BNG Metric 3.1 (Natural England, 2022).*

The mechanisms for delivering a net gain in biodiversity within the BNG 3.1 Metric are proposed as delivering gains on-site (i.e. within the footprint of the development site) through, for example, landscaping or green infrastructure, off-site through new habitat creation or enhancement or purchasing biodiversity units that reflect biodiversity gains made through large-scale strategic habitat creation/enhancement projects. Another option is the purchasing of statutory credits, which could be used to achieve the necessary number of BU for a net gain. However, it is worth noting that the purchasing of statutory credits (a system not yet in place) is to be used as a final resort when BNG cannot be achieved through on-site and/or off-site delivery.

When calculating the biodiversity value of habitat delivery (through the creation or enhancement of a habitat), the BNG metric takes the change in condition, distinctiveness and strategic significance of the delivered habitat into account, as well as adding risk multipliers for time taken to achieve delivery and difficulty, risk of achieving successful delivery or spatial risk (Figure 3). As well as providing a more comprehensive prediction of the biodiversity value of a delivered habitat, the risk multipliers also encourage restoration efforts that can be completed in advance of development and are therefore a more accurate measure of the actual habitat creation/enhancement that is attributable to a project. However, this comes with potential challenges where uncertainties surrounding the success of a habitat restoration project severely reduce the value of a habitat, thereby necessitating disproportionately large areas of habitat to be delivered in order to achieve BNG targets. If the habitat delivery has already been commenced prior to the onsite impact (perhaps as part of a large-scale restoration project) this brings down the uncertainty and correspondingly the amount of delivery required.

1.3.3 Challenges with BNG and the marine environment

The delivery of biodiversity net gain in the terrestrial and intertidal environment is solely assessed through the removal/degradation and creation/enhancement of habitats. Applying an identical method to the marine environment is quickly met with several significant challenges, primarily consisting of:

1. **Lack of data in the marine environment and uncertainties around the condition of marine habitats**: The condition of marine habitats and their importance to biodiversity is poorly understood. A large proportion of the existing data comes from case studies or empirical data from small areas of the seabed. Making accurate predictions of the biodiversity value of a habitat that is to be removed or replaced is therefore more difficult and liable to error and broad approximation.
2. **Difficulty of accessing marine habitats:** the previously stated issue of a lack of knowledge surrounding marine habitats, particularly those offshore, is broadly due to the inability to access or assess them without expensive and specific equipment. The most frequent contact that these environments encounter is usually anthropogenic substratum abrasion (de Bettignies et al., 2021; Krumhansl et al., 2016). This issue persists into current efforts to monitor and conserve the seabed and will likely present

an issue when attempting to deliver habitat creation or enhancement under net gain requirements.

3. **Mobile species:** the biodiversity present within a marine environment cannot always be accurately represented by the habitat present on the seafloor. Key species such as marine mammals and seabirds are known to be impacted by offshore developments (Bailey, Brookes and Thompson, 2014; Brandt et al., 2011; Fox and Petersen, 2019), but unless their presence is either intrinsically linked to the presence of an impacted habitat, or accounted for separately to habitat impact, the impact of a development on these "mobile" species' populations will go unaccounted for.

Defra's "Consultation on the high level Principles of Marine Net Gain" ran from June 2022 to September 2022 and allowed developers, conservation organisations and other interested parties to share views on the direction of MNG policy. Questions within the consultation focused on which developments should be included in MNG policy, what should be included as a part of MNG (i.e. which features of the environment should be included as well as what sort of restorative/generative measures should count towards biodiversity gains) and what approach to use when calculating biodiversity losses and gains.

With responses to the consultation delivered at the end of September 2022, there are still several areas of uncertainty for users of the marine environment surrounding what MNG policy will ultimately look like, though each sector undoubtedly has its own priorities for the emerging policy. As a result, the policy is open to considerable change as it develops over the coming years.

1.4 Aims and Objectives:

To highlight the priorities and potential barriers to calculating and implementing MNG, this report utilises the data from an existing OWF to test a simple prototype marine metric inspired by Natural England's BNG 3.1 metric and highlight how achievable MNG could be under the various versions of the policy. By simulating a wind farm's construction and operation on both actual and hypothetical seabed areas, this report aims to present recommendations that could be made towards the ongoing development of a calculation and the MNG policy. Additionally, it will discuss how best to achieve/accomplish this by using examples from existing research or projects currently underway. Within this, this report identifies where partner organisations of the Marine Futures North West Internship (MFI) could best take a role in delivering mutually beneficial targets for renewable energy and marine recovery as effectively and synergistically as possible.

The following aims were chosen to achieve this:

Aim 1: Create hypothetical scenarios which reflect key partner questions and ambitions

Objectives:

- Obtain impact data from a recent OWF development
- Calculate the predicted impact upon underlying habitats
- Host workshop(s) around the structure of the metric and how the scenarios will be implemented
- Input habitat impact data into the simple metric to determine habitat value
- Highlight partner ambitions with different scenarios/trials

Aim 2: Identify advantages and challenges associated with each scenario in the metric

Objectives*:*

- Run various trials within each scenario, highlighting partner ambitions
- Compare various trials to highlight functions of the simple metric
- Compare scenarios to highlights challenges that may have occurred

Aim 3: Provide solutions to problems identified to improve understanding of the metric

Objectives*:*

- Research around problems identified
- Discuss any problems with partners to obtain opinions
- Identify solutions that will benefit partner organisations

Aim 4: Detail partner roles in MNG surrounding a metric

Objectives*:*

- Produce a list of recommendations to improve the metric calculations
- Produce a list of recommendations on how each partner should approach MNG
- Raise questions for the partners to answer about the future of MNG

2. Methodology

2.1 Use and functions of MNG metric

2.1.1 Basic rundown of metric function

To explore the potential MNG scenarios presented in this report, a simple metric calculation was developed. This was required to investigate potential methods for calculating the valuation of preintervention habitats (the baseline habitat before it is developed on) as well as the value of any habitat delivery interventions (habitat creation or enhancement). This early iteration of a metric was based on a simplified version of the BNG metric and had two versions. Figure 4 displays Version A of a metric for both habitat preintervention valuation and habitat delivery valuation. Figure 5 displays Version B of the metric which includes strategic significance for both habitat preintervention and delivery valuation. The key difference between the two versions was the inclusion of strategic significance. The metric habitats that were included in the analysis were based upon the BAP Marine Habitats and artificial habitats alongside key species that interact with marine developments (coastal birds and marine mammals). The metric calculation included a habitat section and a species section. Both sections had a habitat/species value (habitat/species that would be impacted) and a delivery value (restoration of habitats/species to achieve a net gain). The calculator took both sections and produced the results that displayed the overall BU and the overall net gain/loss of the trial.

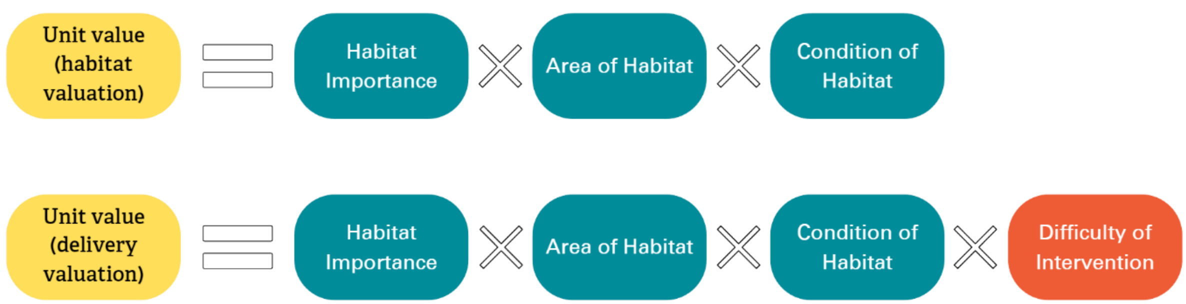

Figure 5: *MNG metric Version A multipliers used to calculate habitat unit value.*

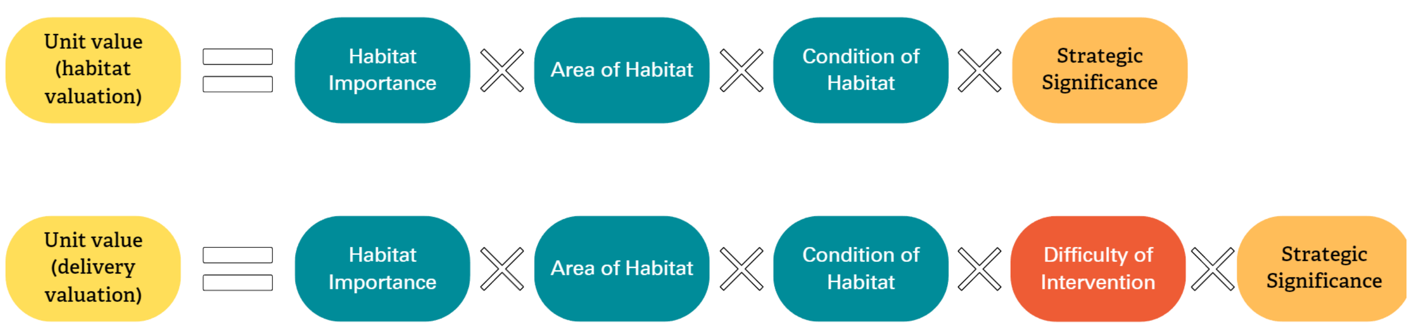

Figure 4: *MNG metric Version B multipliers used to calculate habitat unit value.*

Each trial was run through both versions of the metric to compare results. The area, condition and significance of each habitat were input into the habitat valuation. This would calculate the "BU" or the worth of the habitat that would be expected to be lost. To achieve net gain, this value had to be less than that of the delivery value. The threshold to achieve net gain was not determined but instead suggested to follow the BNG principle of a 10% overall biodiversity value increase over the predevelopment value.

The metric developed to measure species gains and losses functioned slightly differently to the habitat calculation. Instead of habitat area, the species metric uses the size of the species population (Figure 6). The impact status of the species metric (a measure of the effect of pressures on a species population) had the same set of multipliers as the condition multiplier in the habitat metric. Unlike the habitat calculation, this only has one version which does not consider strategic significance. The species calculation was only used for Scenario 3 that aimed to look at a complex mix of habitats and species.

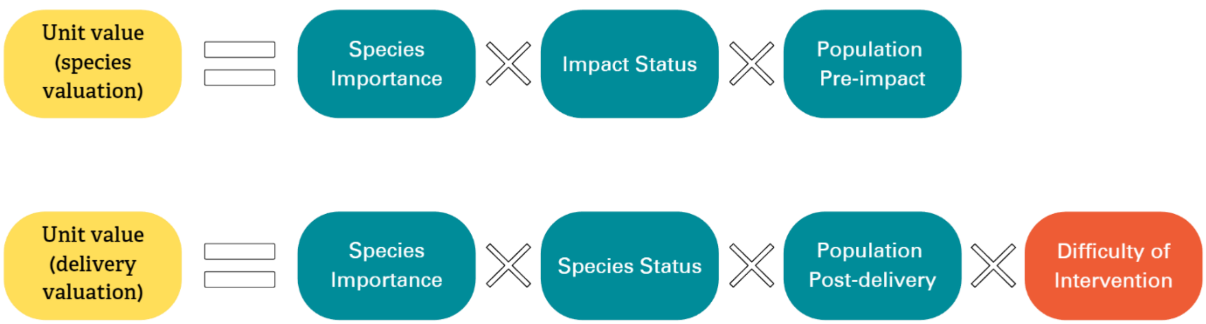

Figure 6: *MNG species metric, this is calculated separate to the habitat metric.*

2.1.2 Metric scores and example run through

Each multiplier of the metric had a weighted scale of numerical values, which were created solely for this report (Table 1). The habitat importance function had three scores that could be selected: "less important", "important" and "very important". The importance of a habitat had a large weighting on the final number of BU produced. The condition of the habitat also had three scores: "likely pristine", "likely moderately impacted" and "likely very impacted". This is likely to be determined through risk-based or vulnerability assessments in the future, though no specific thresholds have yet been determined. The multipliers for this function were not as high as the importance but still increased the habitat value overall. Strategic significance, which was only included in Version B, had two scores: high or low strategic significance. Again, this increased the habitat value but not at the same scale as importance or condition. Finally, for habitat delivery, the difficulty of positive intervention had four scores: "easy intervention", "evidence that it is possible", "moderately difficult" and "very difficult". This was a negative multiplier that had a bigger impact on the habitat value the more difficult it was to create.

Table 1: *The multipliers and associated scores of the metric that were used throughout this report.*

Habitat Importance	Multiplier	Condition of Habitat	Multiplier	Strategic Significance	Multiplier	Difficulty of Positive Intervention	Multiplier
Very important	6	Likely pristine	3	High strategic significance	1.3	Easy intervention	1
Important	4	Likely moderately impacted	2	Low strategic significance	1	Evidence that it is possible	0.67
Less important	2	Likely very impacted	1			Moderately difficult	0.33
						Very difficult	0.1

For example, if 10 ha of "likely pristine", "highly strategic" subtidal chalk was to be impacted by a development it would have a habitat valuation of 180 BU using Version A or 234 BU using Version B (equation below). This is due to subtidal chalk being a very important habitat within the metric. The following equation calculates the BU:

$$6(importance) \times 3(condition) \times 10\ (area) = \mathbf{180}\ (Version\ A) \times 1.3(strategic) = \mathbf{234}\ (Version\ B)$$

If the same parameters are input into the habitat delivery calculator to achieve net gain, difficulty of positive intervention is involved:

$$6(importance) \times 3(condition) \times 10\ (area) \times 0.1(difficulty) = \mathbf{18}(Version\ A)\ \times 1.3(strategic) = \mathbf{23.4}(Version\ B)$$

As shown in the equation above, the delivery difficulty multiplier of 0.1 reduces the BU to 10% of the habitat preintervention value. This multiplier considers the risk of creating pristine subtidal chalk; with no evidence to support the restoration of that habitat it is considered very difficult to positively intervene. Unlike the BNG 3.1 metric, there is no function within the MNG test metric which considers the inability to restore irreplaceable habitats. As shown in the example, the use of strategic significance can cause the habitat preintervention value and habitat delivery value to increase.

Habitat preintervention and habitat delivery values are then combined to calculate the overall net gain. This is done by dividing the change in habitat value by the total loss of habitat value. Change in habitat value is the total gain of habitat value (habitat delivery valuation) minus the total loss of habitat value (habitat preintervention valuation). By calculating this both versions of the metric result in a 90% net loss (equations below). This example would therefore not achieve a net gain.

Version A:

$$\frac{(18\ (habitat\ delivery) - 180\ (habitat\ preintervention))}{180\ (habitat\ preintervention) \times 100} = \mathbf{-90\ \%}$$

Version B:

$$\frac{(23.4\ (habitat\ delivery) - 234\ (habitat\ preintervention))}{234\ (habitat\ preintervention) \times 100} = \mathbf{-90\ \%}$$

2.2 Selection and creation of scenarios

To address the aims and objectives of this report, a number of trials were tested against three scenarios (representations of OWF developments); these trials and scenarios were developed following conversations with the MFI partners. Each trial aimed to address a different aspect of an MNG metric (Table 2). Walney Extension OWF was chosen as the case study for this report, owing to it being a relatively recent, large and fully constructed wind farm in the Irish Sea, the focal area for the internship.

Scenario 1 aimed to introduce the concept of an MNG metric and maintain simplicity in the inputs. Scenario 1 used the area of Walney Extension OWF to maintain consistency throughout the report. Although using the area, the main aim was to show how different MNG metric multipliers impacted the overall BU score. For this reason, both the location and habitats impacted upon were completely hypothetical.

Scenario 2 used Walney Extension OWF's area and its true location as a realistic case study by which to trial the MNG test metric (Figure 7 and 8). The purpose of Scenario 2 was to estimate how much restoration would be required for a modern-day wind farm to achieve net gain and identify associated challenges.

Scenario 3 used Walney Extension's array area and was placed in the North Sea, 18.78km off of the Great Yarmouth coast (Figure 7). This site was selected based on its location within a Key Resource Area (KRA) for wind energy (Figure 9), as well the presence of complex habitats (Figure 10) and species (Figure 11) that could complicate the use of a metric. This location contained *Sabellaria spinulosa* reef and the mobile species sandwich tern (*Sterna sandvicensis*), harbour seal *(Phoca vitulina)* and grey seal (*Halichoerus grypus)* were present, which would be impacted if a wind farm were built in this area.

Table 2: *List of the trials completed within each scenario. Some trials had sub-trials that focused on specific details (see section 3.0).*

Scenario 1	Scenario 2	Scenario 3
Trial 1.1: Habitat importance	Trial 2.1: Walney Extension biodiversity loss	Trial 3.1: Impact v. intervention
Trial 1.2: Habitat condition	Trial 2.2: Biodiversity gain from incidental reef creation	Trial 3.2 Impact v. intervention with existing restoration
Trial 1.3: Habitat delivery difficulty	Trial 2.3: Intervention required to meet net gain (existing restoration) – strategic significance excluded	Trial 3.3: Species impacts
Trial 1.4: Strategic significance	Trial 2.4: Intervention required to meet net gain (existing restoration) – strategic significance included	
Trial 1.5: Strategic significance impact v. intervention	Trial 2.5: Pressure reduction as an intervention for MNG	
Trial 1.6: Impact v. strategic significance intervention	Trial 2.6: Consented impacts v. actual impacts of Walney Extension	

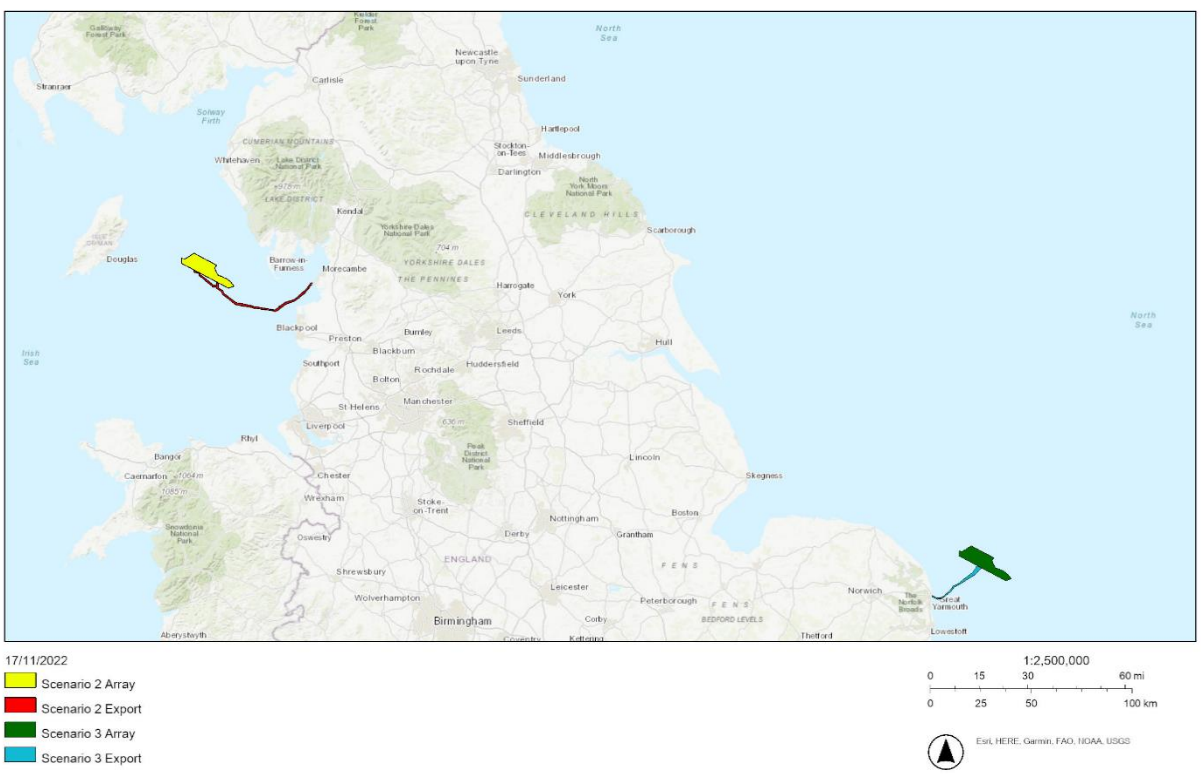

Figure 7: *Locations of Scenario 2 and 3. Figure produced using ArcGIS Online software.*

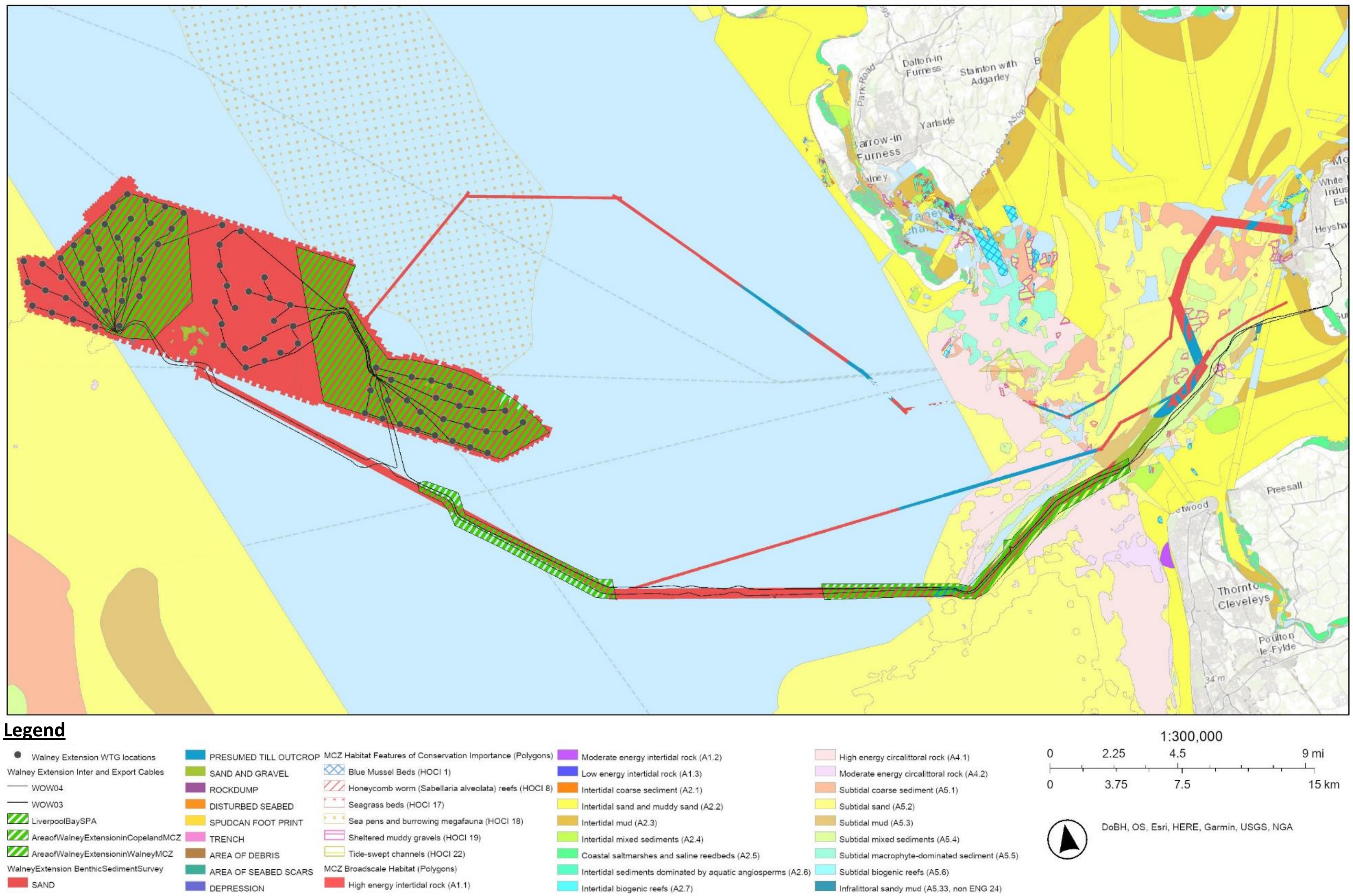

Figure 8: *Location of Scenario 2 with habitat, MPA, WTG, inter-array and export cable layers. Feature layers were created to delineate each individual habitat type located within Scenario 2, to calculate the total area of each habitat that would be impacted on through development. The MPA area located within the Walney Extension array was created as an additional feature layer for the same purpose. This figure was created using ArcGIS Online Software and containing habitat (NE and JNCC, 2022; DONG Energy, 2011), windfarm (DONG Energy, 2011; The Crown Estate, 2022) and MPA (JNCC,2020) locations.*

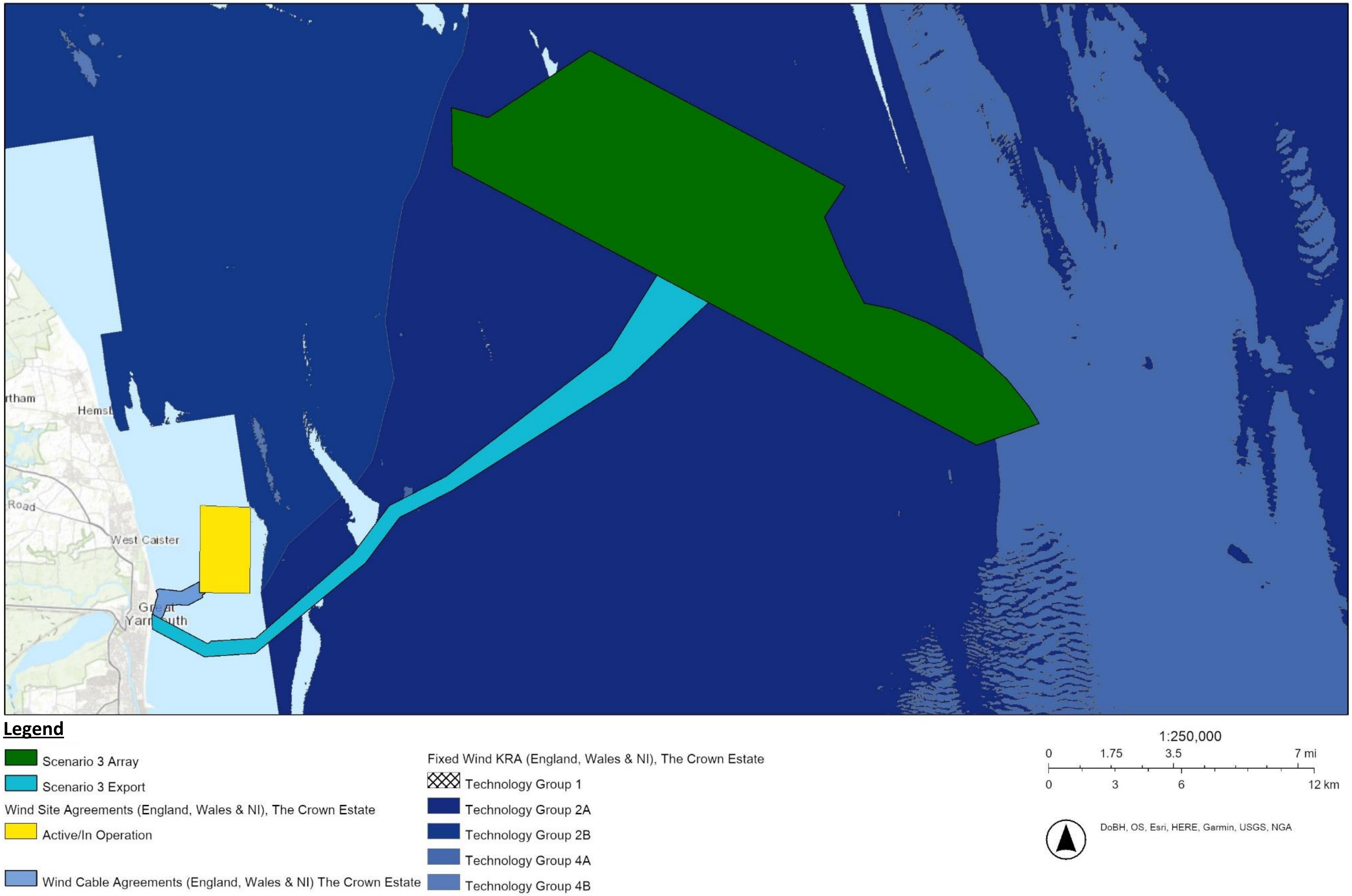

Figure 9: *Location of Scenario 3 with Fixed wind KRA area, array and export cable layers. Scenario 3 is located within the fixed wind KRA technology group 2B; areas suitable for monopile foundations. This figure was created using ArcGIS Online software and containing information on fixed offshore wind KRAs (The Crown Estate) and Windfarm parameters (DONG energy, 2011; The Crown Estate, 2022)*

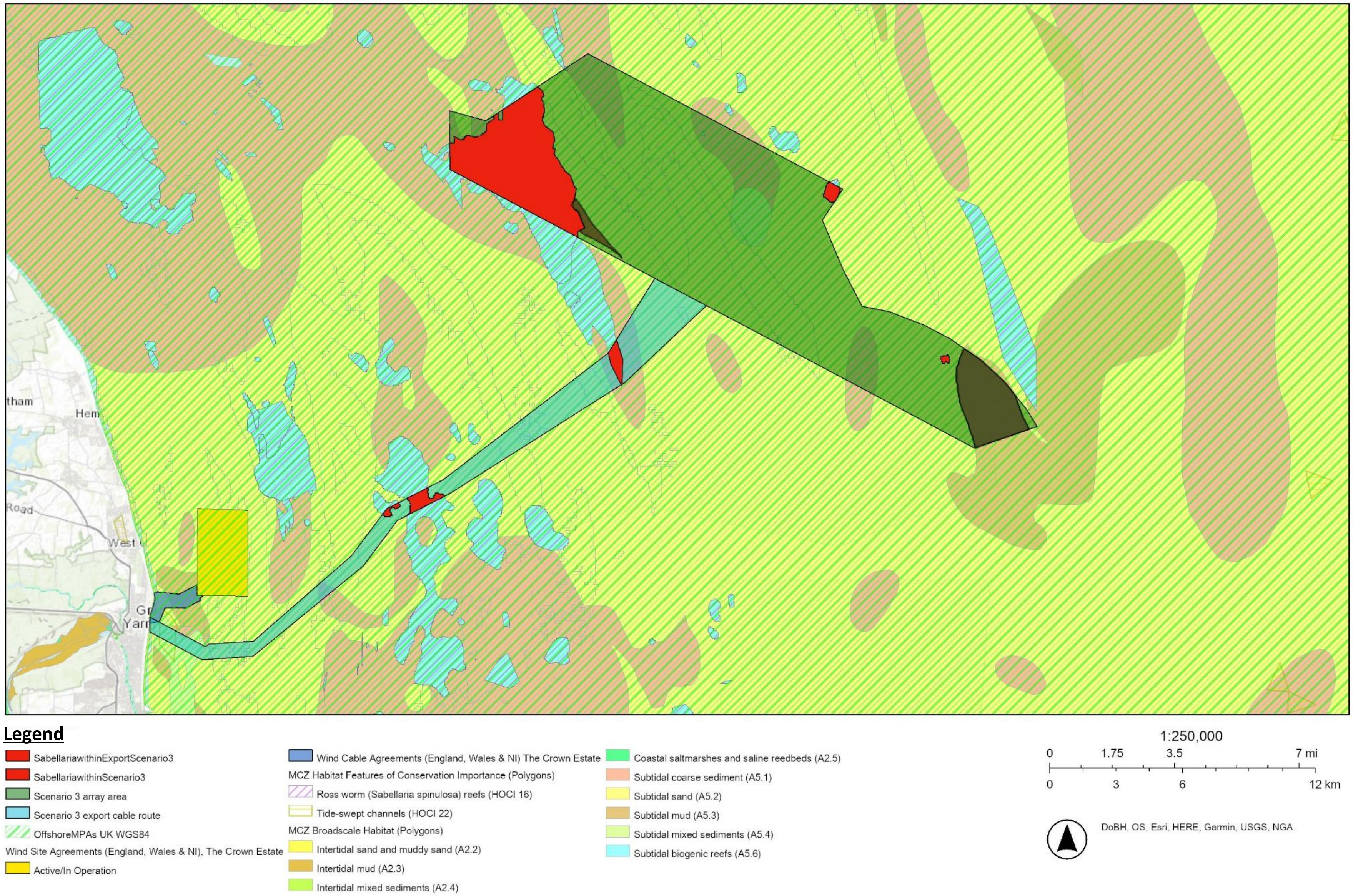

Figure 10: *Location of Scenario 3 with habitat, MPA, array and export cable layers. Habitats located inside of Scenario 3's area had feature layers created to calculate the total area that may be impacted by development. All of Scenario 3 was within an MPA. This figure was created using ArcGIS Online software and containing habitat (NE and JNCC, 2022), windfarm (TCE, 2022) and MPA locations (JNCC, 2020)****.***

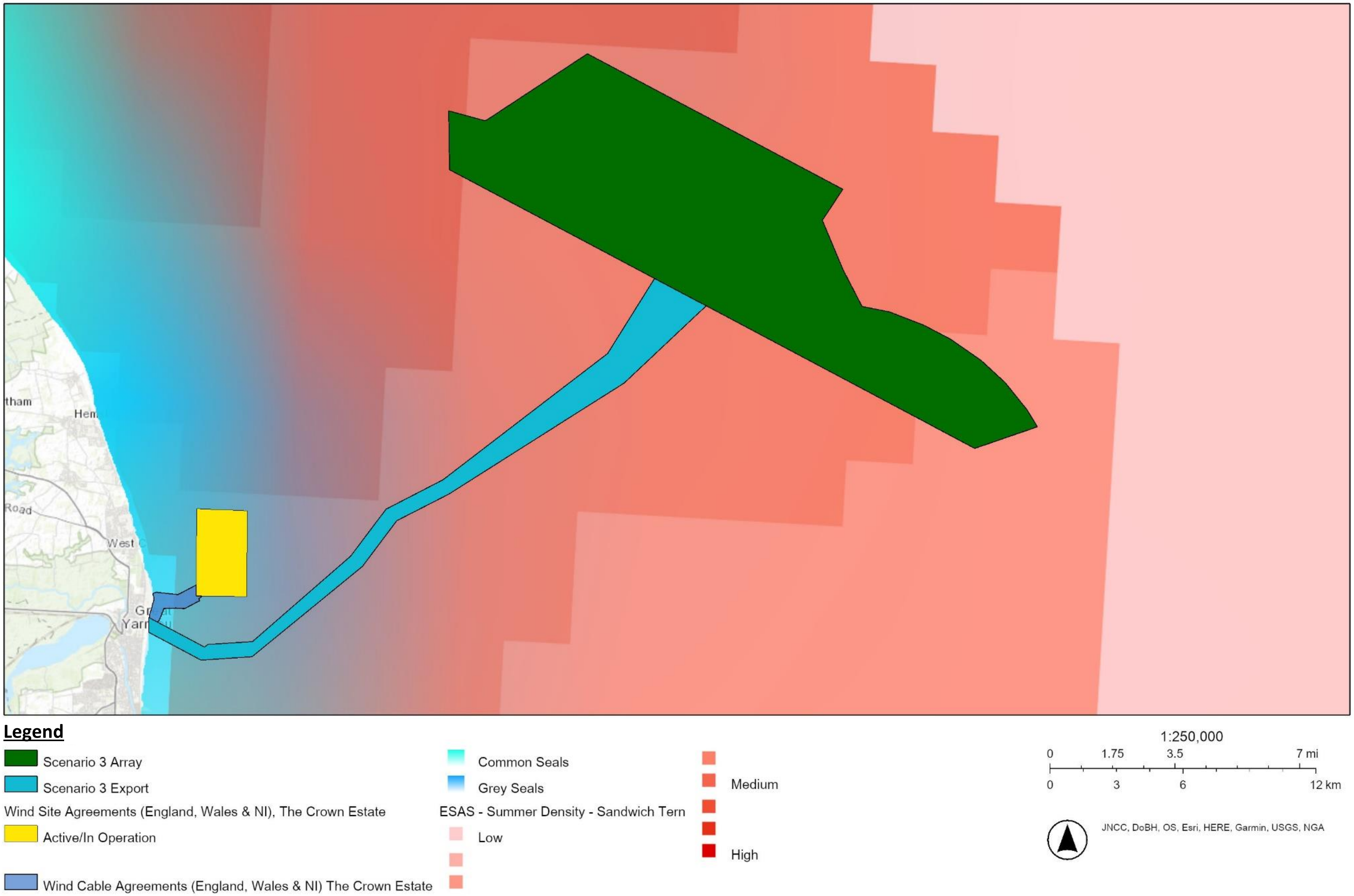

Figure 11: *Location of Scenario 3 with species distribution. Pinniped distribution around typical haul-out locations (nearest being Scroby Sands) and S. sandvicensis density calculated by ESAS. This figure was created using ArcGIS Online software and containing species (SCOS, 2021; ESAS and JNCC 2021) and windfarm (TCE, 2022).*

2.3 Scenario data collection

Scenario 1 was metric-based and did not involve using GIS software. Scenarios 2 and 3 used feature layers on ArcGIS Online to determine the parameters that were inputted into the metric. Open access data from TCE on the locations of operational OWFs around England, Wales and Northern Ireland were used to display the location, size and export cable route of Walney Extension OWF. The locations of inter-array cables, export cables and Wind Turbine Generators (WTGs) were sourced from publicly available Ørsted data. Marine habitat data was sourced from the Marine Habitats and Species Open Data (MHSOD) map layer (Natural England and Defra, 2021) and public benthic data (DONG Energy, 2011).

2.3.1 Walney Extension

To maintain a realistic approach to MNG, this report used data from a large wind farm that had been consented and developed recently. Ørsted constructed Walney Extension OWF in 2018 with a power output of 659 MWh generated from 87 WTGs. With permission from Ørsted, data for this report was obtained from the following documents:

- Environmental Statements (ES);
- Construction Method Statement (CMS) for transmission assets (export cables and substations);
- Cable Specification and Installation Plan (CSIP) for both transmission and generator assets (array cables, turbine foundations and WTG);
- GIS shapefiles to determine the environmental impact this development had on the marine environment.

To obtain the consented impacts for Walney Extension, data was extracted from the Walney Extension ES. The ES contains the parameters which were used to construct Walney Extension. The maximum parameters of these processes are stated within the Rochdale Envelope (RE). The RE approach was developed to provide developers a degree of flexibility in design options when applying for consent on a project (Ezeocha, 2016), as the final details of a project are not known at the time an ES is required. The RE is large to ensure maximum consented impacts are not exceeded, which can result in the prosecution of a developer. Data was extracted from the Walney Extension RE on the following sections of an OWF development:

- WTG - the number of WTGs alongside the different foundations:
    - Monopile foundation - diameter, seabed area take per monopile, total seabed area take.
    - Gravity Based Foundation (GBF) - diameter at seabed, conical cross-sectional area, seabed area take per GBF. total seabed area take.
    - Steel jacket suction caisson foundation – number of legs, leg diameter, caisson diameter, seabed are take per jacket, total seabed area take.
    - Steel jacket piled foundation – number of legs, leg diameter, pile diameter, seabed area take per jacket, total seabed area take.
- Offshore Substations (OSS) – the number of OSS alongside the different foundations:

  - Piled foundation – pile diameter, number of piles per jacket, seabed area take per jacket.
  - GBF – seabed footprint, legs per jacket, area of seabed for levelling/preparation, seabed area take per GBF.
  - Suction caissons foundation – caissons per leg, caissons diameter, seabed area take per jacket.
- Inter-array cables – total length of inter-array cables, width of cable trench, width of seabed affected per cable, footprint of rock placement required at crossings, footprint of surface laid cables rock placement.
- Export cable – number of cable systems, length of cables, width of seabed affected per cable, area of seabed affected per cable (width multiplied by length), rock placement footprint for surface laid cables, cable protection excluding crossings footprint, cable crossings rock placement footprint.

CMS and CSIP reports were used to source the real impact data of Walney Extension. Within these were figures that stated what the impact statistics would most likely look like. The combination of these datasets with marine habitats data (see section 2.1.2) were used to assess marine environmental impacts within the MNG metric.

2.3.2 Marine habitats

Polygon layers of the MHSOD dataset were used to identify habitats that overlap with Scenarios 2 and 3. Feature layers were created to calculate the specific area of each habitat within the OWF array. Habitat data for Scenario 2 specifically was sourced from pre-construction subtidal surveys conducted by DONG Energy in 2011, owing to missing data from the MHSOD dataset. Subtidal surveys of the Walney Extension array and export cable route were completed via benthic grab samples, underwater camera surveys and beam trawling (see Appendix B for more detail).

2.3.3 Offshore wind Key Resource Areas

Offshore wind KRA data were obtained from a GIS feature layer developed by TCE and Everoze, which defined areas of seabed that are suitable for OWF development based on current technology. This dataset is purely based upon suitability to produce wind energy and does not take into consideration other marine users or environmental constraints. The layer identifies areas for different technology groups which are characterised by a set of physical site drivers. From the 13 Technology Groups (TGs) listed, TG-2A and TG-2B were used to determine the location of Scenario 3 as the most relevant groups for technology (Figure 12).

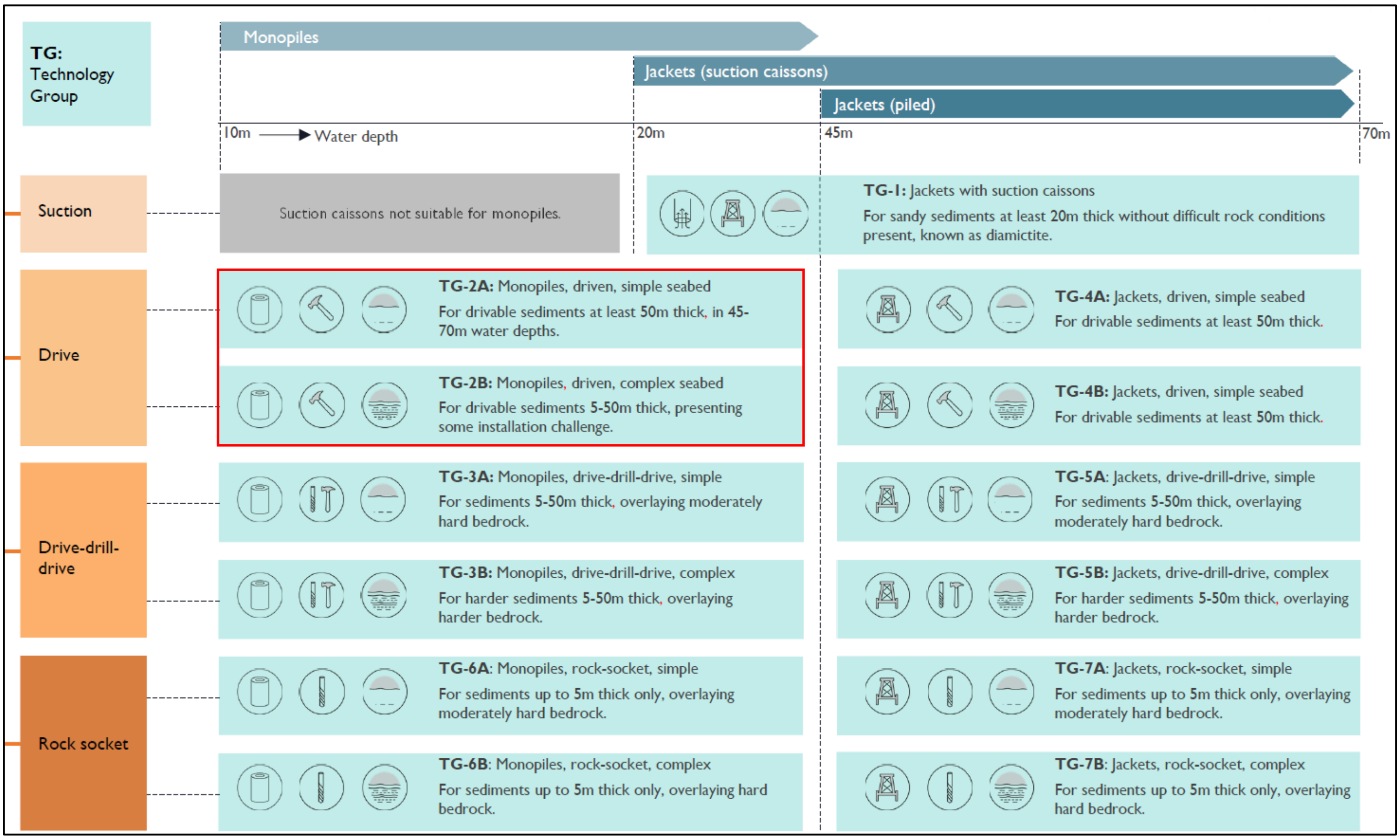

Figure 12*: Technology groups as identified by the report produced by Everoze for TCE (2021). Bedrock hardness increases down the left and depth increases on the top to show how technology groups change. TG-2A and TG-2B are highlighted in red.*

2.3.4 Development impact on habitats

Once the sites had been determined, the parameters obtained from the ES, CMS and CSIP (see section 2.1) was used to calculate the developments impact on each habitat within the development footprint. Due to data constraints, the impact distribution was assumed to be uniform in Scenario 2's export cable and the whole of Scenario 3. The data was organised into a table that listed all the parameters within an OWF that impacted the seabed (see section 2.1).

Scenario 2 had three MPAs within its boundaries: two MCZs that overlaid the array, West of Walney MCZ and West of Copeland MCZ, and one Special Protected Area (SPA) that overlaid the export cable route, Liverpool Bay SPA. Habitats found within an MPA were considered to be of "high strategic significance". Creating feature layers of the MPAs meant that habitat area of "high strategic significance" could be calculated. Habitats that were not found in an MPA were therefore "low strategic significance". The calculations of these habitats were then inputted into the metric.

The inter-array cables and WTG impacts were calculated more accurately due to having the shapefile locations within Walney Extension. The benthic data from Ørsted was used to measure the area of habitats found within the array. Two feature layers, one for West of

Copeland MCZ and one for West of Walney MCZ were created to calculate habitats of “high strategic significance” within the array. Impact per WTG was calculated using data obtained via the ES, CMS and CSIP and multiplied by the total number of WTG within the array to calculate the total impact. The total impact on each specific habitat was calculated by combining the inter-array, export cable, OSS and WTG impacts and considered the strategic significance. These figures were then input into the metric and BU outputs were recorded.

The export cable corridor area was taken from the ES and the realistic impact of the export cable was taken from the CSIP. The impact of the export cable relative to the corridor size was calculated as a percentage. This was used to calculate the impact on the habitats that were found within the export cable corridor (uniform distribution of development impact was assumed). The area of each habitat found in the export cable corridor was measured; this was then multiplied by the percentage of area impacted by export cable laying within the cable corridor. This calculated the rough area that would be impacted upon by development.

Unlike Scenario 2, Scenario 3 was hypothetical and therefore data on the WTG, inter-array and export cable locations were not available. The entirety of Scenario 3 was located within several MPAs (both array and export cable). For this scenario, impact was assumed to have a uniform distribution across the array and export cable corridor shapefile. Shapefiles were created for all the habitats that were within Scenario 3 and the areas were subsequently calculated. For the WTGs, the percentage area of the habitat relative to the whole array was calculated and multiplied by the consented/actual impact for each parameter. The same was done for each habitat against the OSS, inter-array cables and export cables.

2.4 MNG Partner Workshop:

A workshop was hosted on the 4th of October 2022 with representatives from the four MFI partners attending (Ørsted, TCE, NE and TWT). The purpose of this workshop was to inform the partners of the scenarios selected and raise questions surrounding the project (Appendix C).

3. Results

3.1 Scenario 1: Walney Extension area, hypothetical habitats: Exploring a marine metric

N.B.: This is a purely hypothetical scenario for the purposes of comparison between different components of the metric; therefore, the habitats used and their respective areas are also hypothetical and likely to be unrepresentative of a realistic marine development. Realistic habitat areas are covered in Scenarios 2 and 3.

Trial 1.1: Demonstration of habitat importance

Purpose: Demonstrate how a metric could consider habitat importance as a factor when calculating an area’s biodiversity value, and how impacting habitats of differing importance will confer differing values of biodiversity loss.

Test: Dividing the approximate area of Walney Extension OWF (250 hectares) into two habitats of equal area and impact status (likely pristine) but differing importance:

- 125Ha concrete (designated as “less important” in this MNG metric scenario)
- 125Ha Maerl beds (designated as “very important” in this MNG metric scenario)

Metric result:

125Ha of pristine concrete was calculated to have a biodiversity value of 750 BU, in comparison to 125Ha of pristine maerl beds which was calculated to have a biodiversity value of 2250 BU. As all other parameters of the metric were the same for each habitat and strategic significance was not included as a factor in the calculator, the difference in biodiversity value is entirely attributable to the difference in importance of these two habitats.

Table 3: *Parameters considered by the MNG test metric (version A) to calculate the value of each habitat with habitat type (and therefore importance) as the differing value. impact status = the assumed condition of the habitat prior to development.*

Habitat	Habitat importance	Impact status[1]	Area (Ha)	Location value (BU)
Concrete	Less important	Likely pristine	125	**750**
Maerl beds	Very important	Likely pristine	125	**2250**

Trial 1.2: Demonstration of habitat condition

Purpose: To demonstrate how a MNG metric could consider habitat condition (impact status) as a factor when calculating an area’s biodiversity value, and how the same area of habitat with different initial conditions will result in different biodiversity values for each habitat.

Test: Dividing the approximate area of Walney Extension OWF (250 hectares) into two habitats of equal area and importance but different starting conditions prior to developmental impacts:

- 125Ha Maerl beds in “likely pristine” condition
- 125Ha Maerl beds in likely “moderately impacted” condition

Metric result:

125Ha of “likely pristine” Maerl bed habitat was calculated to have a biodiversity value of 2250 BU, in comparison to 125Ha of “likely impacted” Maerl bed habitat which was calculated to have a biodiversity value of 1500 units. As all other parameters of the metric were the same for each habitat, this difference in biodiversity value is entirely attributable to the difference in initial condition of these two habitats prior to development.

Table 4: *Parameters considered by the MNG test metric (Version A) to calculate the biodiversity value of each habitat with habitat condition (impact status) as the differing value.*

Habitat	Habitat importance	Impact status	Area (Ha)	Location value (BU)
Maerl beds	Very important	Likely pristine	125	**2250**

Maerl beds	Very important	Likely moderately impacted	125	**1500**

Trial 1.3: Demonstration of habitat delivery difficulty

Purpose: To demonstrate how a metric could incorporate the uncertainty of success of a restoration intervention by incorporating how difficult it is to create any given habitat into its biodiversity value.

Test: Attempt to achieve net gain in a scenario where a development impacts an area of habitat, then restores an identical area of the same habitat to a better condition; first using incidental reef habitat created by scour protection (low delivery difficulty) and second using subtidal chalk (no known restoration method = high delivery difficulty).

Metric result: As artificial reef is easy to deliver; the metric assumes a 100% probability that the area of artificial reef will be delivered (multiplier of 1). Therefore, by replacing moderately impacted artificial reef with the same area of pristine reef, the new pristine habitat has a higher biodiversity value, is not impacted by a negative delivery difficulty multiplier and confers a net gain in biodiversity value for the artificial reef. Conversely, as subtidal chalk delivery would be much less likely to be successful, the metric confers a delivery difficulty multiplier of 0.1 to the calculation. This results in the biodiversity value of the restored chalk area being considerably lower than the biodiversity value of the impacted chalk area, despite each area being the same size.

Table 5: *A comparison between the biodiversity values of impacted and delivered habitats of the same area for i) artificial reef and ii) subtidal chalk.*

Habitat	**Impact status**	**Area impacted (Ha)**	**Value of impacted area (BU)**	**Habitat**	**Impact status**	**Area restored/ created (Ha)**	**Delivery difficulty**	**Value of created habitat (BU)**	**% change in BU**	**Net gain achieved?**
Artificial reef	Likely moderately impacted	125	**1000**	Artificial reef	Likely pristine	125	**Not difficult (1)**	**1500**	**+50**	**Yes**
Subtidal chalk	Likely moderately impacted	125	**1500**	Subtidal chalk	Likely pristine	125	**Very difficult (0.1)**	**225**	**-85**	**No**

Trial 1.4: Strategic significance demonstration

Purpose: To demonstrate the difference in biodiversity value calculated by the metric of a given habitat when taking strategic significance into consideration. For the purposes of this report, habitats located within MPAs were used as examples of strategically significant habitats, with the awareness that future MNG policy may not allow interventions within MPAs; however, in the current absence of other designations of strategic significance, location within an MPA is a helpful example of where additional biodiversity significance exists for an area based on its location.

Test: Measure the change in biodiversity value of a habitat when strategic significance is included as an additional factor. This trial used 250Ha of sublittoral sand where 125 Ha is inside an MPA (strategically significant habitat) and 125Ha is outside of an MPA (not strategically significant).

Metric result: The metric assumes that an area that is strategically significant has more biodiversity value than an area that is not, and therefore adds a positive multiplier to represent this difference in BU. As a result, the 125Ha of sublittoral sand that is designated as strategically significant was calculated to have a location value of 1300, in comparison to 1000 for the 125Ha of sublittoral sand that was not designated as strategically significant.

Table 6: *Comparison of biodiversity values of sublittoral sand habitats where i) the habitat is in a strategically significant area and ii) the habitat is not in a strategically significant area.*

Habitat	Habitat importance	Impact status	Area (Ha)	Strategic significance	Location value (BU)
Sublittoral sand (non-priority)	Important	Likely moderately impacted	125	High	**1300**
Sublittoral sand (non-priority)	Important	Likely moderately impacted	125	Low	**1000**

Trial 1.5: Strategic significance: strategic significant impact v. intervention

Purpose: To demonstrate the effect of impacting strategically significant habitats and restoring non-strategically significant habitats.

Test: Carry out impacts on the Walney Extension area (250Ha) on two habitats, including strategic significance in their biodiversity value. Demonstrate the difference in value when not including strategic significance in habitat interventions.

Metric result: Due to strategic significance increasing the biodiversity value of a habitat, the value of both impacted habitats increased. As strategic significance was listed as "low" for both restored habitats (Table 8), as well as delivery difficulty conferring a reduction in value, the restored habitat was valued lower in BU than the impacted habitat. Consequently, there was a net loss in biodiversity over the course of the development, and net gain was therefore not achieved in this trial (Table 9).

Table 7: *Habitat impact valuation of Trial 1.5.*

Habitat	Habitat Importance	Impact status	Area (Ha)	Location value (BU)	Strategic significance	Location value (BU) INCLUDING strategic significance
Subtidal Sands and Gravels	very important	Likely moderately impacted	125	1500	High strategic significance	1950
Sublittoral sand	Important	Likely moderately impacted	125	1000	High strategic significance	1300

(non-priority)						

Table 8: *Intervention valuation of Trial 1.5.*

Habitat	Habitat Importance	Impact Status	Area (Ha)	Delivery difficulty	Location value (BU)	Strategic significance	Location value (BU) INCLUDING strategic significance
Subtidal Sands and Gravels	very important	Likely pristine	125	0.67	1507.5	Low strategic significance	1507.5
Sublittoral sand (non-priority)	Important	Likely pristine	125	0.67	1005	Low strategic significance	1005

Table 9: *Trial 1.5 comparison between habitat impacted value and intervention value.*

Habitat type	Impacted biodiversity value	Intervention biodiversity value	Total change in habitat value (BU)	Net gain achieved?
Subtidal Sands and Gravels	1950	1507.5	-737.5	No (-22.69%)
Sublittoral sand (non-priority)	1300	1005		

Trial 1.6: Strategic significance: impact v. strategic significance intervention

Purpose: To demonstrate the effect of impacting non-strategically significant habitats and restoring strategically significant habitats.

Test: Carry out impacts on the Walney Extension area (250Ha) on two habitats, excluding strategic significance in their biodiversity value. Demonstrate the difference in value when including strategic significance in habitat interventions.

Metric result: As the restored habitats were defined as strategically significant, their biodiversity value was increased comparatively to the same habitat of low strategic significance. Despite delivery difficulty conferring a reduction in biodiversity value, the biodiversity value of restored habitats in this trial exceeded that of impacted habitat, thereby delivering net gain.

Table 10: *Habitat impact valuation of Trial 1.6.*

Habitat	**Habitat Importance**	**Impact status**	**Area (Ha)**	**Location value (BU)**	**Strategic significance**	**Location value (BU) INCLUDING strategic significance**
Subtidal Sands and Gravels	very important	Likely moderately impacted	125	1500	Low strategic significance	1500
Sublittoral sand (non-priority)	Important	Likely moderately impacted	125	1000	Low strategic significance	1000

Table 11: *Intervention valuation of Trial 1.6.*

Habitat	Habitat Importance	Impact Status	Area (Ha)	Delivery difficulty	Location value (BU) no strategic significance	Strategic significance	Location value (BU) INCLUDING strategic significance
Subtidal Sands and Gravels	very important	Likely pristine	125	0.67	1507.5	High strategic significance	1959.75
Sublittoral sand (non-priority)	Important	Likely pristine	125	0.67	1005	High strategic significance	1306.5

Table 12: *Trial 1.6 comparison between habitat impacted value and intervention value.*

Habitat type	**Impacted biodiversity value**	**Intervention biodiversity value**	**Change in habitat value (BU)**	**Total change in habitat value (BU)**	**Net gain achieved?**
Subtidal Sands and Gravels	1500	1959.75	459.5	766.25	Yes (+30.65%)
Sublittoral sand (non-priority)	1000	1306.5	306.5		

3.2 Scenario 2: Walney Extension area, Walney Extension location: “true-to-life” scenario

Trial 2.1: Calculation of biodiversity unit loss as a result of Walney Extension

Purpose: To demonstrate the biodiversity value of the habitat impacted by Walney Extension’s construction, as an example of how an OWF’s biodiversity impact would be calculated by the test metric in its current iteration.

Test: Approximations of the area of each habitat which was impacted by Walney Extension have been run through the metric to calculate the estimated biodiversity value of each impacted habitat.

2.1.1: Strategic significance excluded

Metric results: Habitats impacted by Walney Extension were subtidal sands and gravels mud habitats in deep water and estuarine rocky habitats. The condition of each habitat before development was assumed to be moderately impacted. The total biodiversity value of the habitat impacted by Walney Extension was calculated to be 3016.644 BU.

Table 13: *Habitat impact valuation of Trial 2.1.1.*

Habitat	Habitat importance	Impact status	Area (Ha)	Biodiversity value (BU)
Subtidal sands and gravels	Very important	Likely moderately impacted	248.426	2981.112
Mud habitats in deep water	Very important	Likely moderately impacted	2.151	25.812
Estuarine Rocky habitats	Very important	Likely moderately impacted	0.81	9.72

2.1.2: Strategic significance included

Purpose: To define any habitat within Walney Extension that lay within an MPA as strategically significant and demonstrate the difference in biodiversity value when strategically significant habitat is considered.

Test: Separated each of the three habitats present in Walney Extension into areas of high and low strategic significance, based on how much of each habitat lay in an MPA, and calculated biodiversity value for each area.

Metric results: The total biodiversity value of the habitat impacted by Walney Extension when strategic significance was included as a factor was 3493.9986 BU, in comparison to 3016.644 in the trial which did not account for strategic significance.

Table 14: *Habitat impact valuation of Trial 2.1.2.*

Habitat	Habitat importance	Impact status	Area (Ha)	Strategic significance	Biodiversity value (BU)	Total BU
Subtidal sands and gravels	Very important	Likely moderately impacted	130.577	High	2037.0012	3451.1982
			117.849	Low	1414.188	
Mud habitats in deep water	Very important	Likely moderately impacted	1.289	High	20.1084	30.4524
			0.862	Low	10.344	
			0.73	High	11.388	

Estuarine Rocky habitats	Very important	Likely moderately impacted	0.08	Low	0.96	12.348

Trial 2.2. Demonstration of biodiversity gain: incidental reef creation

Purpose: To demonstrate the biodiversity value gained through incidental reef creation on the scour protection of Walney Extension turbines, and whether this confers a net gain to the site.

Test: Calculated the area of artificial reef created on Walney Extension and its biodiversity value, and compared this to the biodiversity value loss of Walney Extension using version A of the metric (no strategic significance included). Version A was used in this instance as incidental reef creation was deemed to be incapable of being strategically significant in any scenario, owing to the lack of targeted delivery of beneficial habitat that it currently delivers.

Metric results: Although the incidental reef creation from Walney Extension conferred some biodiversity value to the site (665.106 units), this was not enough to confer an overall gain in biodiversity alone and the site still resulted in an 80.96% loss of biodiversity (BU).

Table 15: *Habitat impact valuation and intervention valuation of Trial 2.2.*

Impacts						
Habitat	**Habitat importance**	**Impact status**	**Area (Ha)**	**Strategic significance**	**Biodiversity value (BU)**	**Total BU**
Subtidal sands and gravels	Very important	Likely moderately impacted	130.577	High	2037.0012	3451.1982
			117.849	Low	1414.188	
Mud habitats in deep water	Very important	Likely moderately impacted	1.289	High	20.1084	30.4524
			0.862	Low	10.344	
Estuarine Rocky habitats	Very important	Likely moderately impacted	0.73	High	11.388	12.348
			0.08	Low	0.96	
Habitat delivery						
Habitat	**Habitat importance**	**Impact status**	**Area restored/ created (Ha)**	**Delivery difficulty**	**Value of created habitat (BU)**	**Total change in BU**
Artificial reef	Important	Likely pristine	42.635	Not difficult (1)	665.106	665.11 – 3493.99 = -2828.88 = -80.96% loss in biodiversity

Trial 2.3. Demonstration of intervention required to meet net gain using existing restoration strategies (strategic significance excluded)

Purpose: To demonstrate the area of habitat creation required (using habitats with known restoration strategies) to confer a net gain onto the Walney Extension development under conditions where strategic significance is not considered.

Test: Calculate the area of horse mussel and blue mussel beds required to achieve a net gain, whilst including the gain in biodiversity conferred by the incidental reef creation.

Metric results: The biodiversity value of the impacted habitat from Walney Extension without accounting for strategic significance totalled 3016.64BU. BU gained by incidental reef creation totalled 511.62BU. In order to achieve net gain, 140 hectares of "likely pristine" Horse Mussel beds totalling 1688.4BU and 140 hectares of "likely pristine" Blue Mussel beds totalling 831.6BU were added to the trial as planned restoration. These interventions totalled 3031.62BU, resulting in a gain of 14.98BU and a 0.5% net gain of biodiversity.

Table 16: *Biodiversity values for impacted habitats from Walney Extension.*

Habitat impacts				
Habitat	**Habitat importance**	**Impact status**	**Area (Ha)**	**Biodiversity value (BU)**
Subtidal sands and gravels	Very important	Likely moderately impacted	248.426	2981.112
Mud habitats in deep water	Very important	Likely moderately impacted	2.151	25.812
Estuarine Rocky habitats	Very important	Likely moderately impacted	0.81	9.72

Table 17: *Biodiversity values for hypothetical planned habitat restoration/intervention using habitats with existing restoration strategies for Walney Extension.*

Habitat delivery					
Habitat	**Habitat importance**	**Impact status**	**Area (Ha)**	**Delivery difficulty**	**Biodiversity value (BU)**
Artificial reef	Important	Likely Pristine	42.635	Moderately difficult (0.67)	511.62
Horse Mussel Beds	very important	Likely Pristine	140	Moderately difficult (0.67)	1688.4
Blue Mussel Beds on Sediment	very important	Likely Pristine	140	Moderately difficult (0.67)	831.6

Table 18: *Comparison of biodiversity values for estimated impacted biodiversity values and intervention biodiversity values (using habitats with existing restoration strategies) for Walney Extension.*

Habitat type	Impacted biodiversity value	Intervention biodiversity value	Change in habitat value (BU)	Total change in habitat value (BU)	Net gain achieved?
Subtidal sands and gravels	2981.112	0	-2981.112	+14.98	Yes (+0.50%)
Mud habitats in deep water	25.812	0	-25.812		
Estuarine Rocky habitats	9.72	0	-9.72		
Artificial reef	0	511.62	+511.62		
Horse Mussel Beds	0	1688.4	+1688.4		
Blue Mussel Beds on Sediment	0	831.6	+831.6		

Trial 2.4. Demonstration of intervention required to meet net gain using existing restoration strategies (strategic significance included)

Purpose: To demonstrate the area of habitat creation required (using habitats with known restoration strategies) to confer a net gain onto the Walney Extension development under conditions where strategic significance is considered and included.

N.B. This trial makes use of the limited number of restorable habitats found within the MNG metric and is not representative of a viable restoration strategy.

Test: Calculate the area of horse mussel and blue mussel beds required to achieve a MNG if strategic significance were accounted for. The biodiversity gain conferred by incidental reef creation was excluded from the calculation due to it not being definable as a strategically significant habitat.

Metric results: The biodiversity value of the impacted habitat from Walney Extension, when accounting for strategic significance, totalled 3493.99BU. In order to achieve net gain, 165 hectares of “likely pristine” Horse Mussel beds totalling 2586.87 BU and 165 hectares of “likely pristine” Blue Mussel beds totalling 1274.13 BU were added to the trial as planned restoration. These interventions totalled 3861.00BU, resulting in a gain of 367.01BU and a 10.50% net gain of biodiversity. Though a smaller area was included in “interventions” for this trial compared to Trial 2.1.2, it is worth noting that the additional 12.625 hectares (and 42.635Ha total) generated by artificial reef has been done so incidentally and therefore does not require the same level of intervention as active restoration.

Table 19: *Biodiversity values for impacted habitats from Walney Extension, including strategic significance as a factor.*

Habitat impacts				
Habitat	**Habitat importance**	**Impact status**	**Area (Ha)**	**Biodiversity value including strategic significance (BU)**
Subtidal sands and gravels	Very important	Likely moderately impacted	248.426	3451.1982
Mud habitats in deep water	Very important	Likely moderately impacted	2.151	30.4524
Estuarine Rocky habitats	Very important	Likely moderately impacted	0.81	12.348

Table 20: *Biodiversity values for hypothetical planned habitat restoration/intervention using habitats with existing restoration strategies, including strategic significance as a factor, for Walney Extension.*

Habitat delivery					
Habitat	**Habitat importance**	**Impact status**	**Area (Ha)**	**Delivery difficulty**	**Biodiversity value including strategic significance (BU)**
Horse Mussel Beds	very important	Likely Pristine	165	Evidence that is possible (0.67)	2586.87
Blue Mussel Beds on Sediment	very important	Likely Pristine	165	Moderately difficult (0.33)	1274.13

Table 21: *Comparison of estimated impacted biodiversity values and intervention biodiversity values (using habitats with existing restoration strategies), including strategic significance as a factor, for Walney Extension.*

Habitat type	**Impacted biodiversity value**	**Intervention biodiversity value**	**Change in habitat value (BU)**	**Total change in habitat value (BU)**	**Net gain achieved?**
Subtidal sands and gravels	3451.1982	0	-3451.1982	+367.01	Yes (+10.50%)
Mud habitats in deep water	30.4524	0	-30.4524		
Estuarine Rocky habitats	12.348	0	-12.348		

Horse Mussel Beds	0	2586.87	+2586.87		
Blue Mussel Beds on Sediment	0	1274.13	+1274.13		

Trial 2.5. Consideration of pressure reduction as an intervention for net gain

Purpose: To demonstrate the efficacy of physical pressure reduction on an area of seabed (e.g. substratum abrasion) in terms of biodiversity, as calculated by the test metric. These trials were conducted using Version A of the test metric (excludes strategic significance as a factor).

Trial 2.5.1. Impacted area by Walney Extension area

Test: Trial the biodiversity gained by pressure reduction on the total area impacted by cable installation on Walney Extension (119.7Ha; 7m around 177km of cable), designating recovered area as “moderately impacted” to account for its presence prior to intervention.

Metric result: 119.7Ha of protected sand and gravel habitat being restored to a “moderately impacted” level results in a biodiversity unit gain of 962.39 units. When compared to the total habitat value loss of 3016.64 units, this trial resulted in a net loss of 2054.25 units, equating to a 68.1% loss in biodiversity value.

Trial 2.5.2. Maximum area (200-meter buffer zone taken from Danish legislation)

Purpose: Repeating the previous trial but applying a buffer zone around inter-array cables based on existing Danish legislation, as calculated by the test metric, to understand the impact in biodiversity terms. Legislation from the Danish Maritime Authority (DMA) requires a 200-meter exclusion zone to be created around all subtidal cables and pipelines. This exclusion zone prevents substratum abrasion activities which could damage the infrastructure present. This exclusion zone can, in theory, reduce pressure from substratum abrasion on habitats.

Test: Trial the biodiversity gained by pressure reduction on the total maximum area calculated when implementing a 200m buffer zone around Walney Extension’s inter-array cable length (171km), designating recovered area as “moderately impacted” to account for its presence prior to intervention.

Metric result: This trial resulted in 3420Ha of subtidal sand and gravel habitat being protected from pressures, which equated to 27,496.8BU. When compared to the total habitat value loss of 3016.64 units, this trial resulted in a net gain of 24,480.16 units, equating to a 811.50% gain in biodiversity value.

Trial 2.5.3. Minimum area required to achieve net gain

Purpose: Demonstrate the minimum area of habitat undergoing pressure reduction required to achieve net gain on Walney Extension.

Trial: Calculate, using the metric multipliers for habitat delivery, the minimum area of habitat required to generate a biodiversity value in excess of 3016.62 (the biodiversity value of impacted habitat for Walney Extension).

Metric result: A 0.03% net gain in biodiversity is achieved when 376.2Ha of subtidal sand and gravel habitat is protected from pressures, generating 3024.65BU – this was calculated using the same criteria as pressure reduction interventions in Trials 2.5.1 and 2.5.2. This equates to a 22m buffer zone around the entirety of Walney Extension's inter-array cable network.

Trial 2.6. Comparison between consented impacts (Biodiversity Units) and actual impacts (Biodiversity Units) of Walney Extension

Purpose: To calculate the difference in biodiversity unit loss generated by the maximum consented impacts for Walney Extension, in comparison to the actual impacts of Walney Extension.

Test: The estimated biodiversity value of each impacted habitat for the consented area of Walney Extension has been calculated and then compared to the actual constructed area of Walney Extension, using version B of the test metric which attributes strategic significance to areas located within MPAs.

Metric result: The total biodiversity value (BU) of the consented parameters for Walney Extension was calculated to be 10,296.89BU, in comparison to 3,473.41 for the actual constructed parameters, which equates to a difference of 6,823.48BU.

Table 22: *Consented impacts biodiversity values for Walney Extension.*

Habitat impacts - Consented				
Habitat	**Habitat importance**	**Impact status**	**Area (Ha)**	**Biodiversity value including strategic significance (BU)**
Subtidal sands and gravels	Very important	Likely moderately impacted	733.467	10,137.74
Mud habitats in deep water	Very important	Likely moderately impacted	7.997	113.22
Estuarine Rocky habitats	Very important	Likely moderately impacted	3.013	45.93

Table 23*: Actual impacts biodiversity values for Walney Extension.*

Habitat impacts - Constructed				
Habitat	**Habitat importance**	**Impact status**	**Area (Ha)**	**Biodiversity value including strategic significance (BU)**
Subtidal sands and gravels	Very important	Likely moderately impacted	248.426	3451.19
Mud habitats in deep water	Very important	Likely moderately impacted	2.151	12.50
Estuarine Rocky habitats	Very important	Likely moderately impacted	0.81	9.72

Table 24: *Comparison of consented and actual impacts biodiversity values for Walney Extension.*

Habitat	Consented: biodiversity value (BU)	Constructed: biodiversity value (BU)
Subtidal sands and gravels	10,137.74	3451.19
Mud habitats in deep water	113.22	12.50
Estuarine Rocky habitats	45.93	9.72
Total	**10,296.89**	**3,473.41**

3.3 Scenario 3: Walney Extension area, Scroby Sands location: Complex considerations for MNG

Trial 3.1 Impact v. intervention

Trial 3.1.1. Impact v. intervention: restoring the same area of habitat like-for-like

Purpose: To demonstrate the difference in biodiversity value if habitat interventions attempted to recreate the same habitat lost as a result of developmental impacts.

Test: Input the areas of each habitat located within the Walney Extension area in the hypothetical North Sea location and calculate the biodiversity value associated with each habitat. Compare these values to the values calculated by attempting to restore like-for-like habitat.

Metric results: The total biodiversity value of habitats present in Scenario 3 was 2439.36BU. Comparatively, due to the delivery difficulty multiplier, restoring the same area of like-for-like habitats resulted in an overall biodiversity value of 1473.13BU, which equates to a -966.23BU difference between restored and impacted values and a net loss of -39.61% in biodiversity value.

Table 25: *Biodiversity values for impacted habitats from Scenario 3.*

Impacted habitat				
Habitat	**Habitat importance**	**Impact status**	**Area (Ha)**	**Biodiversity value (BU)**
Subtidal Sands and Gravels	Very important	Likely moderately impacted	171.061	2052.732
Mud Habitats in Deep Water	Very important	Likely moderately impacted	8.646	103.752
Sabellaria spinulosa Reefs	Very important	Likely moderately impacted	23.573	282.876

Table 26: *Biodiversity values for hypothetical planned habitat restoration/intervention using like-for-like habitats for Scenario 3.*

Habitat delivery					
Habitat	**Habitat importance**	**Impact status**	**Area (Ha)**	**Delivery difficulty**	**Biodiversity value (BU)**
Subtidal Sands and Gravels	Very important	Likely moderately impacted	171.061	Evidence that is possible (0.67)	1375.33044
Mud Habitats in Deep Water	Very important	Likely moderately impacted	8.646	Evidence that is possible (0.67)	69.51384
Sabellaria spinulosa Reefs	Very important	Likely moderately impacted	23.573	Very difficult (0.1)	28.2876

Table 27: *Comparison of estimated impacted biodiversity values and intervention biodiversity values of like-for-like habitats for Scenario 3.*

Habitat type	**Impacted biodiversity value**	**Intervention biodiversity value**	**Total change in habitat value (BU)**	**Net gain achieved?**
Subtidal Sands and Gravels	2052.732	1375.33044	-966.23	No (-39.61%)
Mud Habitats in Deep Water	103.752	69.51384		
Sabellaria spinulosa Reefs	282.876	28.2876		

Trial 3.1.2. Impact vs. intervention: the requirement to achieve net gain

Purpose: Use the current test metric to demonstrate the area of each like-for-like habitat that would require restoring in order to achieve net gain.

Test: Calculate area values for Scenario 3 habitat restoration that confers a net gain in biodiversity value.

Metric result: Restored habitat values required to achieve net gain were calculated as 260Ha for subtidal sands and gravels, 40Ha for Mud habitats in deep water and 50 Ha of *Sabellaria spinulosa* reef, which resulted in a net gain of 1.34%.

Trial 3.2. Impact vs. intervention using currently available restoration methods

Purpose: To demonstrate the difference in biodiversity value of restoration when including strategic significance in Scenario 3's area, all of which falls within an MCZ and is therefore strategically significant.

Test: Biodiversity values for impacted habitats of Scenario 3, both with strategic significance excluded and included, were calculated. The area of Horse mussel and Blue mussel bed generation required to achieve a 10% gain when strategic significance was excluded from the calculation, alongside 38.17Ha of artificial reef that would occur as a result of incidental creation on the scour protection of wind turbines, was calculated. This was 186Ha for each habitat. The same area of restoration was then implemented in an intervention which included strategic significance, to identify the difference in biodiversity value and net biodiversity gain outcome.

Metric result: The creation of 186Ha of blue mussel bed and 186Ha of horse mussel beds, alongside 38.17Ha of artificial reef creation, conferred a 10.28% net gain in biodiversity compared to the calculated habitat impacts of Scenario 3 when strategic significance was not included. Comparatively, a run-through of the same scenario but with the inclusion of strategic significance as a factor resulted in a net gain of 5.94%.

Trial 3.3. Species impacts

Purpose: To test how the metric would incorporate a development's impact on species into biodiversity value calculations.

Test: Using existing empirical data of species counts, calculate the biodiversity value of the three species present in Scenario 3: *Phoca vitulina*, *Halichoerus grypus* and *Sterna scandvicensis*. The *P. vitulina* population present was assumed to be likely very impacted, as the population has been suffering declines since 2016 (Thompson and Russel, 2021). The *H. grypus* population was described as "likely moderately impacted" as the population has been increasing since 2016 (Thompson and Russel, 2021). It was broadly estimated that the number of sandwich terns using the offshore wind area is 2,138. This was based on a population estimate of 4,275 terns in the Norfolk area combined with the European Seabirds At Sea (ESAS) density data map (Figure 11) where density is split into an 8-point scale; the estimated density of sandwich terns in Walney Extension was 50%. The sandwich tern population was classified as "likely moderately impacted" in the metric, owing to the sandwich tern's relatively stable but slowly declining population in the UK and the recent increased occurrence of avian flu, as well as their designation as Least Concern on the International Union on the Conservation of Nature (IUCN) Red List and Amber on the Birds Of Conservation Concern (BOCC) register.

Metric result:

The biodiversity value of the current *P. vitulina* population in the vicinity of Scenario 3 was valued at 188 BU. The *H. grypus* population was valued at 12,856 BU and the sandwich tern population was valued at 17,104 BU.

Table 28: *Calculated biodiversity values for each of the mobile species with the potential to be impacted by Scenario 3.*

Species	**Species importance**	**Impact status**	**Population pre-impact**	**Value (BU)**
P. vitulina population	Important	Likely very impacted	47	188
H. grypus population	Important	Likely moderately impacted	1607	12856
Sandwich tern population	Important	Likely moderately impacted	2138	17104

3.4 Summary of Results

Table 29: *Scenario 1 summary of results*

Trial number	Aim	Test	Outcome
1.1	Demonstrate effect of habitat importance multiplier	Compare two identically valued habitats with different habitat importance values	Habitat with higher importance calculated to have higher biodiversity value (BU)
1.2	Demonstrate effect of habitat condition multiplier	Compare two identically valued habitats with different habitat importance values	Habitat with higher condition calculated to have higher biodiversity value (BU)
1.3	Demonstrate effect of habitat delivery difficulty multiplier	Compare two identically valued habitats with different habitat delivery difficulty values	Habitat with higher delivery difficulty calculated to have lower biodiversity value (BU)
1.4	Demonstrate effect of habitat condition multiplier	Compare two identically valued habitats with different habitat importance values	Habitat with higher strategic significance calculated to have higher biodiversity value (BU)
1.5	Demonstrate the effect on net gain of impacting strategically significant habitats and restoring non-strategically significant habitats	Compare strategically significant impact values with non-strategically significant interventions of identical habitats	BU value of impacts higher than interventions; net gain not achieved
1.6	Demonstrate the effect on net gain of impacting non-strategically significant habitats and restoring non-strategically significant habitats	Compare non-strategically significant impact values with strategically significant interventions of identical habitats	BU value of interventions higher than impacts: net gain achieved

Table 30: *Scenario 2 summary of results*

Trial number	Aim	Test	Outcome
2.1.1	Calculate biodiversity loss as a result of Walney Extension construction impacts (strategic significance multiplier excluded)	Calculate total biodiversity value (BU) of each habitat area impacted by Walney Extension when not considering strategic significance	Total biodiversity loss = 3016.64 BU
2.1.2	Calculate biodiversity loss as a result of Walney Extension construction impacts (strategic significance multiplier included)	Calculate total biodiversity value (BU) of each habitat area impacted by Walney Extension when considering strategic significance	Total biodiversity loss = 3494.00 BU
2.2	Demonstrate biodiversity value gained through incidental reef creation on Walney Extension turbine scour protection. Determine whether net gain is achieved as a result.	Calculate biodiversity value of artificial reef created by Walney Extension and compare to the biodiversity value of impacted habitats	Total biodiversity units generated by artificial reef = 665.11 BU Net gain not achieved (-80.96% change in BU)
2.3	Demonstrate the area of habitat creation required, using habitats with known restoration strategies, to confer a net gain onto the Walney Extension development (strategic significance excluded)	Calculate the area of horse mussel and blue mussel beds required (including biodiversity gain conferred by incidental reef creation) to achieve a net gain compared to biodiversity loss from impacted habitats (strategic significance excluded)	140 hectares of “likely pristine” Horse Mussel beds (1688.4BU) and 140 hectares of “likely pristine” Blue Mussel beds (831.6BU) required to achieve a net gain (0.5% change in BU)
2.4	Demonstrate the area of habitat creation required, using habitats with known restoration strategies, to confer a net gain onto the Walney Extension development (strategic significance included)	Calculate the area of horse mussel and blue mussel beds required (including biodiversity gain conferred by incidental reef creation) to achieve a net gain compared to biodiversity loss from impacted habitats (strategic significance included)	165 hectares of “likely pristine” Horse Mussel beds(2586.87 BU) and 165 hectares of “likely pristine” Blue Mussel beds (1274.13 BU) required to achieve a bet gain (10.50% change in BU)
2.5.1	Consider biodiversity gain (BU) achieved through pressure reduction methods; Walney Extension cable installation area	Calculate biodiversity value of improving condition of sand and gravel habitat impacted by Walney Extension cable installation (7m	Condition improvement = gain of 962.39 BU Net gain not achieved (-68.1% change in BU)

		around interarray cables) from “very impacted” to “moderately impacted”	
2.5.2	Consider biodiversity gain (BU) achieved through pressure reduction methods; Area based on Danish cable protection legislation	Calculate biodiversity value of improving condition of sand and gravel habitat area contained within an exclusion zone (200m around interarray cables) from “very impacted” to “moderately impacted”	Condition improvement = gain of 27,496.88 BU Net gain achieved (811.50%% change in BU)
2.5.1	Demonstrate minimum area of habitat required to undergo pressure reduction to achieve net gain	Calculate minimum area of sand and gravel habitat requiring improvement from “very impacted” to “moderately impacted” to exceed 3016.62 BU (impacted habitat value for Walney Extension)	376.2 Ha of habitat undergoing improved condition required to achieve net gain (0.03% change in BU) Equivalent to 22m around interarray cables
2.6	Compare biodiversity value consented and actual impacts of Walney Extension	Calculate BU of habitats impacted by Walney Extension and compare to maximum potential impacts which could have occurred as a result of impacts consented for for Walney Extension	Actual constructed impacted habitat value = 3,473.41 BU Maximum consented impacted habitat value = 10,296.89 BU

Table 31: *Scenario 3 summary of results*

Trial number	Aim	Test	Outcome
3.1.1	Demonstrate difference in biodiversity value (BU) of recreating habitats lost as a result of developmental impacts and calculate whether net gain achieved	Compare BU values of each habitat impacted by Scenario 3 to the same area of each habitat as a restoration intervention	Total impacted habitat value = 2439.36 BU Total restored habitat value = 1473.13 BU Net gain not achieved (-39.61% change in BU)
3.1.2	Demonstrate the area of habitat creation required, using habitats impacted by Scenario 3's construction, to achieve net gain	Calculate restored area values (BU) of habitats within Scenario 3 required to achieve a net gain	Restored habitat values required: 260Ha subtidal sands and gravels) 40Ha (mud habitats in deep water) 50 Ha (*Sabellaria spinulosa* reef) Net gain achieved (1.34% change in BU)
3.2	Demonstrate the difference in biodiversity value of restoration, using habitats with existing restoration strategies, when including strategic significance for impacted habitats	Calculate values for impacted habitats (strategic significance included) and calculate area of horse mussel and blue mussel habitat restoration required alongside incidental reef creation to achieve 10% gain in BU	Restored habitat values required: 186Ha (blue mussel bed) 186 Ha (horse mussel bed) 38.17 Ha (incidental artificial reef) Net gain achieved (10.28% change in BU)
3.3	Test how a metric incorporates developmental impacts on mobile species populations found within Scenario 3	Used empirical data of species counts to calculate biodiversity value (BU) of *Phoca vitulina*, *Halichoerus grypus* and *Sterna scandvicensis*	*Phoca vitulina* population value = 188 BU *Halichoerus grypus* population value = 12,856 BU *Sterna scandvicensis* population value = 17,104 BU

4. Discussion

4.1 Scenario 1

The purpose of the trials within Scenario 1 was to demonstrate the function of the test MNG metric by altering different parameters and observing the impact on a habitat's biodiversity value compared to a control. At present, the test metric considers the importance, condition and area of a habitat in calculations for impacted habitat and habitat delivery. It also considers delivery difficulty as an additional factor for habitat delivery. Version B of the metric considers strategic significance, which for the purposes of this study was equated to any area that was present within an MPA.

4.1.1 Habitat importance:

The comparison in Trial 1 tested the difference in outcome when a difference to habitat importance was applied. In a comparison between 125Ha of concrete (designated as "less important" by the MNG metric) and 125Ha of Maerl beds (designated as "very important" by the MNG metric), the Maerl bed habitat returned a significantly higher score in biodiversity terms. This is what should be expected from a metric attempting to describe the relative biodiversity of different habitats. At present, the metric allows habitats to be classified as one of three different levels of importance (very important, important or less important), each with a value assigned. This simplistic scale could allow two habitats to be allocated the same value despite, in reality, having relatively large differences in their importance for biodiversity (such as horse mussel beds compared to subtidal sands and gravels). This may generate erroneous comparative values where biodiversity is presumed by the metric to be more similar between two habitats than it is in reality. It is suggested that habitat importance values designated by the metric are divided into a finer scale, with values relating directly to a more detailed measured value of "importance" across habitats.

4.1.2 Habitat condition:

Habitat condition is currently designated in a similar way to habitat importance, with condition divided broadly into three categories; "likely pristine", "likely moderately impacted" and "likely very impacted". Trial 1.2 demonstrated that a reduction in habitat condition on the same area of habitat resulted in a lower biodiversity score which, similarly to habitat importance, is the desired outcome for a biodiversity measuring metric, aligning with research relating biodiversity declines to loss or degradation of habitats (e.g. Green et al., 2021; Unsworth et al., 2021). Once again, the current values attributable to habitat condition within the metric are defined on a scale with very few gradations, and the current descriptions of pristine, moderately impacted and very impacted are not defined, preventing the description of habitat condition in a representative way. Data exists for more detailed descriptions of habitat conditions for UK waters, to finer scales and assessing numerous impacts such as contaminants, impulsive noise and physical damage to benthic habitats (OSPAR, 2017). For example, aggregated surface abrasion data, collated for the OSPAR regions II and III, covering the UK seas region, was used to assess physical impacts on marine benthic habitats. These assessments calculated the extent of physical damage to an area by considering the habitat type present, its resilience/resistance to physical damage and the distribution and intensity of physical pressures on the seabed (OSPAR, 2017). The assessment outputs divided the level of disturbance into a 9-point scale, which was then applied to the habitats present. New assessments and indicators of habitat condition are currently in development by JNCC. These may provide highly useful datasets, to inform a more finely detailed scale to describe habitat condition and the reference to then designate each habitat area inputted into the metric.

4.1.3 Delivery difficulty:

The comparison between "very difficult" habitat delivery of subtidal chalk and "easy intervention" habitat delivery of artificial reef returned a considerably lower biodiversity value for the same area of impacted subtidal chalk. The difficulty multiplier adds an uncertainty factor to habitat delivery and assumes that the more difficult a habitat has been evidenced to restore or create, the lower the likelihood that the restoration would be successful. This is represented within the metric as a reduction in biodiversity value of the final delivered habitat, as a negative multiplier is applied. A key purpose of adding a difficulty multiplier would be to discourage initial removal or degradation of a habitat which is difficult or impossible to restore. However, there are currently no trading rules within the metric linking impacted habitats to habitat interventions, which would prevent selection of easier-to-restore habitats as interventions to replace harder-to-restore habitats that were impacted through development.

At present, delivery difficulty, without a "time to restoration" multiplier/category, is the only way of measuring the probability of restoration success and is therefore difficult to make site-specific as the same value is attributed to a habitat regardless of its location or the time of which restoration is undertaken relative to the development. Therefore, in situations where developers may have completed habitat restoration, or are in the process of restoring a habitat that they wish to include as an intervention for a project, which therefore reduces the uncertainty of successful restoration, there is no current avenue for altering the likelihood of success for this restoration.

4.1.4 Strategic significance:

The impact of the strategic significance multiplier was demonstrated in Trial 1.4, comparing 125Ha of strategically significant sublittoral sand habitat to non-strategically significant sublittoral sand habitat. The biodiversity value of the strategically significant sublittoral sand habitat was calculated as greater than that of the non-strategically significant sublittoral sand; this is the preferred outcome of the scenario as it demonstrates, in numerical terms, the difference in importance to biodiversity that an area has when it is of some strategic significance, such as its presence within an MPA, which is the example utilised in this report. Including this as a factor within the metric disincentivises development impacts on strategically significant habitats, which have been designated to have particular importance to biodiversity. However, the inclusion of strategic significance as a factor for habitat interventions also provides the possibility to increase the biodiversity value of interventions such as habitat creation, restoration or enhancement if they are carried out in an area of high importance to biodiversity such as an MPA. This provides the opportunity to neutralise the additive effect of strategic significance on habitat impacts by conducting restoration in an adjacent area that would also have this multiplier included. Additionally, in a scenario where strategic interventions are considered, if multiple developments contribute to the restoration or enhancement of one larger area, the benefits of including strategic significance may play a role in encouraging the selection of sites with strategic significance to biodiversity as the location of restoration efforts and avoiding such areas for development. This would enable interventions of a relatively smaller area to achieve a net gain. This was demonstrated by the comparison between Trials 1.5 and 1.6 where net gain was achieved through the restoration of the same area of habitat in a strategically significant area, in comparison to the area impacted not being located in a strategically significant area.

4.2 Scenario 2

The trials that were run for Scenario 2 attempted to quantify the biodiversity value impacted by the construction of Walney Extension, as well as explore the potential avenues for interventions and the challenges that may arise with different approaches.

4.2.1 Habitat classification scale

Building on the examples of Scenario 1, Trial 2.1 demonstrated the biodiversity value that would have been calculated for Walney Extension using the test metric. Results showed that each of the three habitat types present within Walney Extension were calculated by the test metric to have exactly the same biodiversity value per hectare (12BU/Ha), despite the unlikelihood of all three habitats supporting the same level of biodiversity per hectare. Habitat condition and importance were both defined on scales with only three options (and therefore three multipliers) to choose from. This prevented quantifying the biodiversity of these habitats to a precise enough degree to show the variation in biodiversity that would exist between them. The condition assessment of “moderately impacted” was chosen due to the knowledge of fishing and trawling activities which occurred prior to the development of Walney Extension wind farm (Cumbria Wildlife Trust, 2019); however, it is likely that the impact of physical disturbance and other anthropogenic activities varied widely across the Walney Extension area. Additionally, “Subtidal sand and gravel” as a habitat classification contains a wide range of more specific habitats which vary considerably in terms of their biodiversity (e.g. upper estuarine mobile sands have poor species diversity, in comparison to circalittoral gravels, sands and shell gravel habitats are characterised by high diversity) (UK Biodiversity Action Plan, 1994; Priority Habitat Descriptions. BRIG (ed. Ant Maddock) 2008). As previously discussed, the implementation of finer scales within the metric to describe both the habitats present and their condition would be beneficial to describe more accurately the biodiversity present within a designated area. Data on the finer-scale classification of habitats affected by a development could be sourced from developer surveys conducted as part of the ES.

4.2.2 Habitat restoration: like-for-like, currently available methods and pressure reduction

At present, there are no proven means of conducting active restoration methods for any of the habitats impacted by the construction of Walney Extension. At present, pressure reduction is the only viable means of enhancement for sand and mud habitats and protection from anthropogenic pressures is the only means of recovery considered in Habitat Action Plans. However, the calculator used in this report does not currently account for a change in habitat condition; at present, entire removal or creation is the only option.

To account for this, the pressure reduction scenario exhibited in Trial 2.5 “created” habitat to a moderately impacted condition in lieu of improving the area’s condition from very impacted to pristine, as this represented an identical change in the value of the condition multiplier. As an alternative to attempting to restore habitats with no current active restoration strategy, the creation of blue mussel and horse mussel beds alongside incidental artificial reef creation were also considered in Trials 2.4 and 2.5.

At present, there is a lack of information, understanding and methodology at our disposal to actively restore the majority of marine habitats which can impact the development of MNG policy. The BNG metric includes trading rules which prevent the creation or enhancement of a different habitat to the habitat/s impacted by development; at present, no such rules exist for the MNG test metric, and decisions surrounding whether to implement similar rules for MNG policy have not yet been made. However, given the lack of current ability to restore many marine habitats, it is currently impractical and unfeasible to impose this as a requirement, as it would likely limit the habitats that can be impacted to such a point where the majority of developments would be impossible as they would be unable to deliver like-for-like net gain.

Trials 2.4 and 2.5 investigate the potential to achieve net gain using habitats where restoration methods are currently available. Though this was proven to deliver a net gain in biodiversity, this strategy replaced three important habitats with three completely different habitats. This generates the question of whether, in the marine environment where it is mostly not viable to restore like-for-like habitats, restoring different habitats to improve biodiversity is delivering a biodiversity gain that contributes to the overall health of the seabed. The creation of artificial reef that would occur alongside the construction of Walney Extension was also included in Trials 2.4 and 2.5; incidental reef creation, such as that generated by scour protection on wind turbines (demonstrated in Trial 2.5.1, 2.5.2 and 2.5.3) may confer a biodiversity gain to the site with little active effort. However, the gain in biodiversity may not be appropriate for the site; the introduction of a hard substrate to a soft sediment environment may structurally and functionally change the ecosystem by providing colonisation opportunities for species that may not have inhabited the area prior to development (Degraer, S. et al., 2020). The creation of artificial habitats that are targeted to specific species may enable artificial reef to be more representative of the species endemic to the habitat (e.g. options detailed in Hermans, Bos and Prusina, 2020). However, the development of artificial reef conferring benefits to particular species requires further research. A possible avenue for the inability to restore most habitats like-for-like would be to categorise habitats by the type of biodiversity that they support and allow for substitution of habitats within these categories. What would require determining is how marine habitats would be categorised, and to what degree of specificity.

Another potential workaround for the lack of active restoration strategies is the inclusion of pressure reduction as a net gain measure. The increase in habitat condition as a result of physical pressure reduction trialled in the test metric was shown to confer some gain in biodiversity. However, when the area subjected to pressure reduction was restricted to the 7m boundary area impacted by cable routes, the gain in biodiversity was not enough to confer a net gain on the site (See Trial 2.5.1). Conversely, when allowing for pressure reduction by preventing physical substratum abrasion in the 200m zone around cables (as practiced in Danish legislation to protect surface-laid cables and pipes (Danish Maritime Authority, 1992)), net gain was achieved under the same conditions by approximately 800% (see Trial 2.5.2). Though the metric is using approximate values by which to conduct calculations, there is merit in the comparison between different scenarios and it is still a demonstration that pressure reduction is a viable method by which to increase biodiversity through enhancement of a habitat's condition. With the total protected area required to achieve net gain within the scenarios being 376.2Ha, this is a relatively small area compared to that demonstrated by using the same buffer requirements as Danish legislation. As the only viable option for enhancing habitats such as sand and gravel, this would enable developers to deliver on-site biodiversity gains of the same habitats as impacted by the development. However, there are uncertainties surrounding whether pressure reduction can be considered an intervention under current legislation, particularly in areas such as MPAs where measures to monitor, assess and manage protected features are already in place, with the view to achieve conservation objectives that often (if not always) include improvement in habitat condition. Additionally, if an exclusion zone is created primarily to prevent physical impacts on marine infrastructure, there is a question around whether the habitat recovery that occurs incidentally as a result of this should contribute towards net gain. It should be noted that if considering pressure reduction as a net gain strategy (or indeed as a part of any strategy), the focus should be to reduce pressure by removing it from the seabed completely, rather than relocating from one area (the focal area/development area) to another.

The pressures faced by marine environments from human activities such as contaminants, Invasive Non-Native Species (INNS), radioactive substances, dredging activities, underwater noise, marine litter and eutrophication may provide additional avenues by which to improve a habitat's condition through pressure reduction. Innovative approaches to tackle these pressures could provide a way for developers to reduce pressures on a habitat those provided by an MPA. For example, Ørsted's contribution towards the "Fishing for Litter" programme (van der Kooij, 2014) has resulted in a reduction of marine litter, reducing the impact of this pressure on the marine environment.

If pressure reduction is to be considered as a net gain strategy, long-term monitoring data would be necessary to understand the effects of such reductions on habitat condition over time, particularly as the majority of marine habitats are slow growing and effects of interventions may only be apparent over longer timescales (Duarte et al., 2020; JNCC, 1994). Additionally, adjustments to the metric would need to be made to account for changes in habitat condition.

The only way to incorporate habitat enhancement or degradation within the metric at present is to include that habitat in both the location value and delivery sections of the metric. The calculation accounts for the change in condition by comparing the BU of an area of habitat of one condition (e.g. "likely pristine") and the same area of the same habitat of a different condition (e.g. "likely moderately impacted") (as seen in Trial 1.2, Table 4). Though this works from a calculation perspective, it may cause confusion where developers cannot visualise the difference in biodiversity value that would occur due to a change in habitat condition as this individual difference is not displayed anywhere. In order to demonstrate pressure reduction or enhancement in a more user-friendly way, the metric should include sections for pre- and post-impact habitat condition and pre-and post-intervention habitat condition. Changes in BU as a result of impacts and interventions would be kept separate, which would make the individual BU value associated with changing a habitat's condition easier to visualise.

A scenario which was not considered in any of these trials was the effect of indirect impacts on an area's biodiversity. For example, sediment plumes generated by offshore developments may cause smothering of light-sensitive habitats (e.g. Maerl beds – see Perry & Tyler-Walters 2018) which would reduce their condition, despite not being directly impacted on. These indirect effects are a point to consider when developing MNG policy.

4.2.3 Constructed vs. consented impacts

As calculated in Trial 2.6, the biodiversity value loss attributed to the impacts of Walney Extension's actual construction was 33.73% of the biodiversity value loss that would have been attributed to the maximum consented impacts. Other than the area affected, all parameters of the metric remained similar between consented and constructed (and therefore changes made to the metric will be applied to both scenarios in equal measure), it is therefore likely that this is a realistic proportion of biodiversity value between consented and constructed.

MNG policy is likely to be implemented within the consenting process of an offshore development, meaning that prior to gaining consent, developers must demonstrate their ability to deliver MNG for the development. Under the current consenting process, developers would be required to research, secure and demonstrate their ability to deliver restoration strategies that would deliver in excess of the predicted biodiversity loss resulting from consented impacts, which is demonstrated in Trial 2.6 to be considerably higher than the biodiversity loss caused by the eventual actual impacts.

It is highly likely that there will be a difference between the amount of intervention required within the consented boundaries of future projects and the intervention required to meet net gain requirements against the actual total impact conferred by a project's construction. This poses a question around at what stage of the consenting or construction process MNG requirements should be imposed, and which values should be considered in MNG calculations. As such, there are several potential avenues that could be considered as an approach to delivering MNG for a development:

1. "Buy-back": Developers are required to demonstrate strategies to achieve MNG for the entire consented area of a development, with the potential to "buy-back" BU which account for the biodiversity loss of habitat which is then not impacted in the construction process.
2. Likely constructed:consented ratio prediction: Using available data on the percentage of the consented area that is actually constructed, it may be possible to

generate values for the "most likely" proportion of the consented area that becomes part of construction. This reduces the initial predictions of biodiversity loss to a potentially more "realistic" value, but runs the risk of underestimating the impact of a development should it fall outside the calculated bounds of the most likely scenario. In this situation, remedial measures would need to be implemented to account for the additional loss in biodiversity and the consequent effect on MNG calculations.

3. Reassess MNG calculations post-consent but pre-construction: Re-evaluation and resubmittal of MNG calculations and planned interventions after consent has been granted but prior to construction, where post-consent strategies are adjusted to the predicted impacts of construction.

Each of these possible avenues is purely a hypothetical suggestion at this stage, and would require considerable investigation and consultation between different seabed stakeholders and users in order to agree on the most viable option which best ensures successful developments and marine recovery.

4.3 Scenario 3

Scenario 3 used the area of Walney Extension and applied it to an area which contained more complex conditions than that of Walney Extension's real location. Additionally, the entirety of Scenario 3 was placed within an MPA, to understand the effect of all impacted habitats within the development being strategically significant. As with Scenario 2, there are no successful restoration strategies available for any habitats found within Scenario 3. Preliminary feasibility studies for *S. spinulosa* restoration have been conducted; however, more work is required to understand the conditions that affect growth capacity and therefore reef growth (Franzitta et al. 2022). Additionally, the delivery difficulty of restoring *S. spinulosa,* a known slow-growing species, resulted in a large reduction in the biodiversity value of delivered *S. spinulosa* reef compared to impacted reef. As a result, delivering the same area of each impacted habitat in Trial 3.1.1. resulted in a considerable net loss of biodiversity.

As demonstrated in Trial 1.3, incorporating a "delivery difficulty" multiplier ensures that, unless there is no risk of unsuccessful habitat delivery (difficulty multiplier of 1), delivering the same amount of habitat as that which was lost will always result in a net loss of biodiversity, due to the uncertainty of restoration success. It is therefore worthwhile for all stakeholders to work towards reducing the difficulty of habitat restoration. This raises an important question surrounding the inclusion of research efforts or trial studies as contributions towards MNG, especially within strategic interventions. Including funding and support for research into marine habitat restoration strategies may not only directly benefit the marine environment but also provide developers with more effective restoration strategies to implement in future marine net gain interventions. Currently, the metric itself and/or a policy that relies purely on a metric such as the one used in this report cannot account for this type of intervention (read: an intervention that does not confer a direct measurable gain on a habitat area within the marine environment). However, research into more effective restoration strategies may result in an increased likelihood of restoration success, reducing the negative effect of the "delivery difficulty" multiplier of the metric and therefore increasing the per hectare BU value of a habitat. Whether it is appropriate for offshore developers to have the responsibility of funding or supporting the development of restoration strategies is to be debated. However, the fact remains that this responsibility must fall to someone, if strategies are to be developed which will effectively restore habitats at risk of loss to offshore development within the ever-shortening timeframe of governmental renewable energy and biodiversity targets.

For this report, habitats within MPAs were classified as having high strategic significance. This resulted in less net gain being achieved by interventions of like-for-like habitat restoration in Trial 3.2 than those achieved when strategic significance was not included as a factor in the metric calculation. This was due to incidental artificial reef creation being included as an intervention. Artificial reef creation cannot currently be considered as strategically significant because it does not create suitable habitat. This scenario demonstrated the capacity for an offshore wind farm to be present in an area that is located entirely within an MPA and aimed to pose the question of how to achieve net gain in a situation where all impacted habitats possessed high strategic significance.

4.3.1 Species

The use of a test metric to measure the impact of Scenario 3's development on mobile species present in the area – *H. grypus, P. vitulina* and *S. sandvicensis* – was measured. Though empirical species counts were used to estimate species presence with the development, it is highly likely that the actual level of interaction with a development of this scale by each species was inaccurately represented by the values used within the test metric, as it was beyond the scope of this report to calculate this.

In addition to changes in population size, there are numerous other ways a species can be impacted by an offshore wind farm that require consideration. At present, the metric requires a species pre-development population size and calculates a biodiversity value based on this. The metric assumes total population loss when in reality, the effects of a wind farm on species range from outright mortality to fitness loss and behavioural changes and therefore are not accurately represented by complete loss of an individual population (Skeate, Perrow and Gilroy, 2012) (Garthe and Hüppop, 2004). Additionally, the survivability, growth rate, vulnerability to change and chance of total collapse are all affected by population size and therefore the magnitude of different degrees of loss to a population is not linear; this is also not currently represented in the metric as the biodiversity value of each individual is assumed to be the same, regardless of the total population size.

Similarly to habitats, species are subject to numerous pressures; however, these pressures may undergo more temporal variability. This needs to be considered when measuring the impact of a development on a species population. For example, seabird populations have suffered declines after a particularly severe rate of avian flu in 2022, which will have knock-on effects if combined with developmental impacts. In short, the impact of an offshore development on a species population will vary based on the health of the population prior to development, which is likely to vary based on other external factors and over time which is not currently considered by the metric.

Another consideration is that, despite research on developmental impacts on marine mammals and birds being far from comprehensive, existing research has shown variation in vulnerability of different species to offshore wind developments, based on their characteristics (Garthe and Hüppop, 2004). Seabird species which exhibit differences in, for example, flight altitude, percentage of time flying and flexibility in habitat use may be affected by offshore developments in varying intensities. These factors, amongst others that would be useful to include when determining a species' vulnerability to offshore developments, would increase the accuracy of biodiversity loss as a result of offshore development.

It is understood that the inclusion and incorporation of all of these factors into a metric similar to that of the BNG metric would likely result in a tool that sacrificed simplicity and ease of access for accuracy of impact. Consequently, this report is not recommending the incorporation of all of these factors into a metric. There is scope to consider using models to calculate a mobile species sensitivity to offshore development. Early models have been developed for a range of seabirds (Garthe and Hüppop, 2004) and *H. grypus* (Skeate, Perrow and Gilroy, 2012). Such models use empirical data and expert opinions to calculate a species' sensitivity to offshore developments. These models could be developed and adapted to fit the requirements of MNG, generating sensitivity values that could be input in place of the existing criteria for species within the test metric and used to calculate the biodiversity value lost due to development or gained following restoration interventions. As this area of research is very much in its infancy, the specifics of these models remain to be determined; however, it is the opinion of the authors that calculations or models outside of the metric are required to generate an accurate "value" to represent the impact of a development on any mobile species. In order to further the development of these models, or generate new ones fit for the purpose of MNG, considerable data collection is required; both through the collation of existing historical data on marine mammal and seabird characteristics, distribution and behaviour, as well as new data representing short and long-term impacts of existing developments on species of interest. It is advised that the collation of existing data and commissioning of new research is actioned to contribute to the development of these models. Where modelling the impacts is deemed unnecessary or inappropriate, collating this data is necessary to better understand the impacts of developments on species and will help generate more accurate, species-specific values for a metric or biodiversity calculation.

4.4 Limitations

4.4.1 Direct/indirect data availability

A limitation encountered during this project was the lack of precise impact data. The realistic impact data was taken from West of Walney's CSIP and CMS documents which provide information on the expected development footprint. This was compared to the original RE to show the difference in development impact that would be put through the metric if MNG was required at the ES stage. As no monitoring of direct impacts are required currently, the true difference between the RE and actual cannot be stated. This provides an issue with the MNG metric if MNG requirements were to be calculated at the pre-consent stage. A developer would be required to produce a higher number of habitat/species units using RE figures than if they used the refined development footprint envelope. Further discussion around this issue would be required between developers, eNGOs and government bodies to develop an appropriate solution that would benefit developers without risking achieving net gain.

This report and iteration of the metric only considered direct development impacts (foundations, scour protection etc.) but does not consider the indirect impacts on habitats within the development area. Indirect impacts include increased suspended sediment concentrations, increased smothering, re-mobilisation of contaminants and reductions in water quality, these have the potential to reduce habitat condition. Although the habitats within this report display resilience to smothering (Hill, Tyler-Walters and Garrard, 2020; Jackson and Hiscock, 2008) other sensitive habitats could be impacted resulting in a decline to their condition.

4.4.2 Report Limitations

The Marine Futures Internship (MFI) involves four partner organisations, North West Wildlife Trusts, TCE, Ørsted and Natural England. Each partner organisation has sensitivities that cannot be shared publicly or with the other organisations. Producing the report and using data from different partners had to ensure commercially sensitive information was managed correctly. The internship focuses on progress towards collaboration between industries in the marine environment; this report highlights the further need for collaboration to ensure data can be used to understand how offshore developments in the marine environment can negatively or positively affect its biodiversity.

The MFI commenced one day before the MNG consultation was released by Defra. The "Consultation on the Principle of Marine Net Gain" ran from the 7th June 2022 until the 13th September 2022 and highlighted multiple ways in which MNG policy could be implemented. The initial introduction to the project proved difficult due to the policy being in its early stages, no clear pathway for MNG and a lack of research around MNG. Part of this consultation included the use of a metric to determine development impact and restoration efforts similar to that of the BNG metric 3.1. The responses to this consultation will shape how MNG policy will be implemented. The metric analysed in this report was based upon and simplified from the metric developed for BNG; if a metric is used in MNG, this metric will be developed further and will differ. It is likely that other methods of improving marine biodiversity will be used before the metric is fit for purpose. Strategic restoration targets may be chosen due to the larger benefits they can impose on the marine environment. However, it is crucial that the impact which a development places onto the marine environment is calculated accurately; this is where a metric would be required. As mentioned throughout, this report does not intend to shape MNG policy but instead intends to provide insight into how a metric may be used to measure MNG and the benefits and drawbacks of this approach.

This report encountered limits within GIS software and scenario analysis. One example of this was calculating the exact 200-meter exclusion zone area of the Walney Extension inter-array cables due to complications with the cable shapefile. As the shapefile included other Ørsted cables, the total buffer area would not accurately represent the Walney Extension inter-array cables. Instead, the calculation assumed the inter-array cable was linear and had no overlaps; the figure produced from this calculation was higher than it would have been had it included overlaps. As net gain could be achieved with just a 22-meter buffer zone, the outcome of the trial still provided a valid discussion point. Another limitation encountered was where scenario analysis of habitat impacts could not progress due to a lack of data on the habitats off the Cumbrian coastline (Figure 8). Due to the nature of the MFI, access to restricted habitat layers produced by NE could not be accessed to overcome this limitation. The use of pre-construction benthic data produced by Ørsted for their ES on Walney Extension was eventually cleared and able to be used in the report. However, this was a different data set to what was used in Scenario 3 and therefore was not consistent throughout the report.

4.5 Recommendations

4.5.1 MNG calculation and metric recommendations:

1. Utilise models to generate values that can be input into the metric to represent the impact on species by a development. The impacts calculated in the models will have to be reviewed regularly.
2. It is recommended to use a marine habitat classification scale that is similar to the JNCC Marine Habitat Classification as a baseline for habitats detailed in the metric. The majority of habitats should be identified at a certain level within the classification (level 3 or 4) and habitats of high importance, identified by specialists, should be detailed to the appropriate level.
3. The scales for habitat importance and condition used within the metric should be based on research that relates to pre-existing criteria on habitat like the BNG metric; the scores should be based on specialist research.
4. A “time to restoration” multiplier be added to the metric, as seen in the BNG metric, to account for the difference in the likelihood of delivery that is conferred by completing or beginning restoration before beginning a development, as well as considering the possibility of restoration failure.
5. The metric should allow the user to see the value (BU) of the change in habitat condition both pre- and post-impact and pre- and post-intervention. This would allow the user to more easily visualise the effect of habitat degradation and enhancement interventions. BNG includes the option to retain habitat where the development occurs and enhance that habitat.
6. In order for the metric to benefit both developers and the marine environment, developer and stakeholder insight and active involvement should be included in a metric’s development. Involving stakeholders and developers in the creation of a metric will improve their understanding of how a metric would function in MNG policy and therefore ensure a smoother transition into policy when ready.

4.5.2 Questions and recommendations for partners:

1. Does the flexibility of the metric allow for too much exploitation (any habitat can be delivered to offset the impacts on another) and not focus enough on replacing

habitats that have a similar function for biodiversity to those impacted by a development?
   a. If yes, would a method that requires a habitat within the same classification to be replaced work in the marine environment?
   b. If yes, what minimum degree of classification should be applied for the marine environment?
2. From a developer's point of view, the difference between consented impacts and expected impacts is considerable. The RE allows a developer flexibility within the DCO to deal with changes, delays or challenges. This, however, has the potential to increase the amount of restoration required under certain scenarios to achieve a net gain from a development.
   a. How does MNG fit into a development and when does it need to be implemented?
   b. Is it possible to investigate the difference between consented and expected impacts of recent developments to identify a likely "constructed:consented" ratio to be used for option two as stated in section 4.23?
   c. Should direct impacts be measured and shared with relevant bodies (like NE) to collect a wider dataset on developments footprint compared to consented?
3. Discuss and explore the rights a developer obtains when leasing an area of seabed
   a. Can inspiration from Danish legislation on exclusion zones be taken or does it not work in UK policy?
   b. What other rights does a developer have that can reduce pressure within their leased zone?
4. Begin accumulating data on species impacts from offshore developments in combination with other impacts on a species success to be incorporated into a framework that represents the impact on a particular species population.
   a. Can current bird mortality modelling outputs from ES be used as an impact measure on bird species in a calculator?
   b. Are there models on marine mammals to determine disturbance and mortality rates as a result of offshore developments?
5. Can restoration activities be conducted in MPAs given that active restoration goes against the principle of not disturbing an MPA but does improve the quality of habitats found within it?
   a. Would this be considered strategically significant if it coincides with the objectives of the MPA?
6. Are models the best way to measure impacts on all species that interact with offshore development?
7. Should research contributions towards new restoration strategies be included as contributions towards MNG at this stage?

   a. If not, whose responsibility is it to fund and conduct the research on marine habitat restoration that will allow developers to restore marine habitats for MNG?
   b. Is it within scope of TWT to undertake research into understanding the impacts of offshore developments on important marine species?
8. At the current stage, what is the best method to deliver appropriate gains in biodiversity to the marine environment?
9. Should incidental reef creation be included within MNG due to a lack of restoration options?
   a. If no, are there any measures to develop artificial reef creation that would be appropriate for MNG?
10. Should the threshold for net gain be the same as BNG (10%) or should it have flexibility to align with the increased risk of restoring subtidal habitats (if it is between 8-10% it is still acceptable)?

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6.0 Appendices:

6.1 Appendix A: UK marine habitats

Table 32: *Table displays some of the key marine habitats found in the UK alongside their description, historic loss and potential restoration.*

Habitat name	Habitat description	Habitat loss	Habitat restoration
Seagrass meadows	Seagrass meadows confer numerous benefits both on the environment that they inhabit and the ecosystem services they provide, which include but are not limited to sediment stabilisation, carbon sequestration, organic matter production, direct and indirect food provision for waterfowl, the provision of a nursery habitat for commercially important fish species and a direct habitat for colonising algae and bryophyte species (Green, Chadwick and Jones, 2018; Unsworth et al., 2021). As such, their decline is associated with a significant loss in the biodiversity and health of the ecological community reliant on them.	Notable examples of ecologically significant habitat loss include the decline in seagrass meadow cover in UK coastal waters. Recent analysis, based on current coverage and historical records, estimated a loss of a minimum of 44% coverage over the past 90 years, with losses over longer timespans potentially reaching as high as 92% (Green et al., 2021). This loss is largely attributed to the incidence of a seagrass "wasting disease" and anthropogenic pressures reducing the ability of seagrass beds to recover. For example, substratum abrasion from moorings can remove areas of seabed where seagrass species reproduce via rhizomes, if substratum loss occurs the recoverability rate is considerably low (Tyler-Walters, 2005; Tyler-Walters, 2008). Such estimates are vulnerable to huge uncertainty, owing to the lack of consistency of monitoring and definitions of healthy seagrass meadows between different regions and surveyors and a dearth of comprehensive historical data on seagrass coverage; this issue is shared across the majority of marine habitats, owing mostly to their inaccessibility. Additionally, most habitats have only been recognised as being important for nature relatively recently (JNCC, 1994; OSPAR, 2008), and therefore have only	Several Non-Government Organisations (NGOs), with funding from government, private organisation/businesses and national lottery grants, have undertaken restoration projects in an effort to aid seagrass bed recovery in the UK. The first full-scale seagrass restoration project in the UK concluded in 2021 and experimentally restored two hectares in the Dale estuary in Pembrokeshire, Wales (Seagrass Ocean Rescue, 2022). Lessons learned from this project have since been applied to numerous restoration projects, with nine large-scale restoration projects currently underway in the UK and several more in development. As a hugely important habitat for biodiversity, coastal protection and carbon sequestration, the multiple benefits of restoring seagrass meadows have become very apparent and have the potential to contribute significantly towards governmental targets of improving biodiversity and achieving Net Zero.

		had significant effort towards monitoring them recently as well.	
Maerl beds	Maerl beds are biogenic habitats formed by encrusting coralline red algae, and are found in the open coast or within channels of marine inlets (Connor et al., 2004). In comparison to habitats occupying the same biogeographical niche, maerl beds support a disproportionately high number and variety of species which utilise the bed as a feeding ground (e.g. Atlantic cod) (Hall-Spencer et al., 2003), which burrow into the layer underneath living maerl, or rely on the living algae as a habitat (Hall-Spencer, Kelly and Maggs, 2010). Some species, many rare and relatively poorly understood, appear to be found almost exclusively within the maerl habitat, further highlighting their specific importance to biodiversity. Many of the most extensive maerl beds in Europe are found in the UK, primarily in Scottish waters (Connor et al., 2004; Hall-Spencer, Kelly and Maggs, 2010).	Maerl beds are incredibly sensitive to physical disturbances and pressures. Alongside the obvious impacts of targeted maerl dredging and removal for use in agriculture (In the UK up to 30,000 tonnes p. a. of maerl were harvested commercially in the Fal from 1975 to 1991) (Hall-Spencer, Kelly and Maggs, 2010), towed demersal fishing activity has also negatively impacted beds, their associated biodiversity, and their long-term viability. This is exemplified by scallop dredging in the UK, which has been recorded to reduce the amount of live maerl in areas that previously have not been dredged by up to 70%, with no sign of recovery after 4 years (Hall-Spencer and Moore, 2000). Additionally, sediment plumes, pollution and other activities which obscure the water column impact the photosynthetic capabilities of the coralline algae, as well as impacting the associated community living on the beds (Jones, Hiscock and Connor, 2000).	The three species which maerl beds are most commonly comprised of have extremely low growth rates of as little as 0.1 - 1 millimetre per year (Bosence and Wilson, 2003); as a result, damaged or destroyed maerl beds face little chance of natural recovery. At present, there is no known method of actively restoring maerl beds, with all efforts focused on conservation of the beds that remain (Hall-Spencer, Kelly and Maggs, 2010). In most cases with subtidal habitats, active restoration is proven to be ineffective or not possible and instead the use of pressure reduction can allow a natural habitat to recover using its own natural processes.
Kelp forests	UK kelp forest habitats are dominated by six key species of large brown seaweed that can form an important, complex habitat. Being photosynthetic, kelp requires sunlight to survive and can therefore grow in clear water to a depth of 40 meters (de Bettignies et al., 2021). Kelp forests produce a canopy within the water column allowing epibiotic communities to form; the creation of complex ecosystems is a reason kelp forests are important habitats in both the UK and Europe (de Bettignies et al., 2021). In addition to being ecosystem engineers	At current rates there could be no kelp forests habitats found in the UK by the end of the century if nothing is done to intervene (Hendy, 2020). This is due to being sensitive to increasing sea water temperature, decreasing water quality (turbidity and pollution) and substratum abrasion (e.g., dredging, dragging gear) (de Bettignies et al., 2021; Krumhansl et al., 2016). If degradation of this habitat continues, UK marine life could experience losses of up to 90% (Reeftrust, 2021).	Similar to seagrass restoration, kelp restoration projects are being initiated by NGOs around the UK. A large restoration project in Sussex aims to restore kelp forests that have experienced a 96% loss since 1987 (Rewilding Britain, 2022; Williams et al., 2022). The main restoration method being used is pressure reduction by banning damaging fishing practises, such as bottom-towed fishing gear. This project will monitor the recovery of the kelp forest with sustainable fishing methods (e.g. potting) still being permitted. Even though pressure reduction is the main form of restoration, the project is investigating

	(Krumhansl et al., 2016), kelp forests are understood to be carbon sequesters that can absorb over 600 million tons of carbon a year globally, helping to combat climate change (Krause-Jensen and Duarte, 2016).		the feasibility of active restoration which, like most subtidal habitats, has not been fully understood yet.
Oyster beds	*Ostrea edulis* beds are typically found down to 10 meters depth with the beds being made up of a mix of live and dead oyster shells (Haelters and Kerckhof, 2009). *O. edulis* beds typically form in sheltered estuarine areas on clean, hard substrate that can be colonised. Dead *O. edulis* shells make up a substantial portion of the substratum; the mixture of shells support several communities within the beds (Haelters and Kerckhof, 2009; Perry, Tyler-Walters and Garrard, 2020).	In the 18th-19th century *O. edulis* beds formed at much deeper depths, down to 50 meters in the North Sea, but since then have experienced a decline in abundance due to higher consumer rates (Edwards, 1997; Haelters and Kerckhof, 2009). High rates of consumption increased the demand on fisheries which in turn resulted in overfishing and habitat destruction (Laing, Walker and Areal, 2006). Anthropogenic pressures combined with other negative factors (disease and invasive species) have caused a 95% loss of *O. edulis* since the 1800s (Laing, Walker and Areal, 2006; Perry, Tyler-Walters and Garrard, 2020; Robertson et al., 2021).	Chichester Harbour has seen a decrease of 96% of native *O. edulis* beds due to mounting pressures. The closure of fisheries did not aid *O. edulis* recovery due to the presence of an invasive species, *Crepidula fornicate*, that could outcompete the native *O. edulis* population (Helmer et al., 2019). Pressure removal in this instance did not result in habitat recovery and therefore active intervention of invasive species control would be needed to prevent further decline.

6.2 Appendix B: Benthic sediment survey methods

Table 33: *Methods used by Ørsted to obtain benthic sediment data within the Walney Extension consented area.*

Collection method	Number of sites	General description
Benthic grab sampling	75 grab sites	Three sites failed due to stones preventing the jaws from closing. One grab sample consisted of a 0.1 m^2 sample area that was collected at each station in order to assess macrofaunal content, sediment type, epifauna and infauna. Samples were analysed in multiple laboratories depending on the property being assessed.
Underwater camera survey	40 drop-down camera sites	One location not being used due to poor weather. To ensure data collected was of high-quality surveys were done at neap tides following calm weather to minimise the effects of suspended sediment. While the camera was lowered to the seabed, observations on sediment characteristics and fauna were recorded. Three high quality images of the seabed alongside the video were taken at each site.
Beam trawling	29 trawl sites	Two sites were unable to be surveyed due to fishing gear. A 2m scientific beam trawl with a square mesh cod-end was used to collect data over a distance of 300m into the prevailing current. The catch from the trawl was recorded via photographs and measurements.

6.3 Appendix C: Workshop 4th October 2022

Workshop agenda:

- Run-through of project report sections
- Test metric run-through
- Overview of test scenarios
- Questions from interns
- Questions and feedback from partners

Table 34: *The questions raised to partners alongside their responses and suggestions.*

Questions raised to partners	Answers
What species would be useful test species for the metric?	Partners were happy with species selected but suggested including gannets if possible.
How are species impacts monitored? Does this need to change to work for MNG?	Monitoring requirements are site specific and dependent upon local sensitivities. Benthic and bird monitoring is usually undertaken over a period of c. 10 years, with surveys being carried out in non-consecutive years (i.e. 3-4 surveys spread across a 10 year period). Inspiration from the star metric (from the IUCN red list for birds) could be taken to measure impacts on birds.
What habitats should be included in the metric? How specific should the habitats in the metric be for effectively calculating MNG?	To measure quality of a habitat, it needs to be more specific – to biotope level. Looking generically at subtidal mud/sand can add difficulty in demonstrating gain in biodiversity due to being broadscale habitats. Communities could be a way to define habitats (sea pen and burrowing mega fauna) that are already well defined.
What should count as appropriate restoration – now and in the future? Should pressure reduction, nature-inclusive/restorative design and/or research be included? Which habitats can be restored as a substitute for others? Can any?	Nature inclusive design should be included as a possible restoration method until it is proven non-effective (due to there being so few options to actively restore). NE are running a pilot project called MaRePo that is investigating habitats that can be restored within English waters (looking at OSPAR threatened habitats and historic presence data). The mapping of these restoration sites will be important for MNG. If the metric can measure how much the developer needs to restore to achieve net gain, the developer can then contribute towards projects like MaRePo.
Actual vs Consented impact – at what part of the process should MNG requirements be applied, given that these two values can be very different?	Mention on some sort of way to pay back the developer for surplus of MNG but this question was left out of the workshop and instead asked to each partner individually.