



Whole of Seabed Programme

Nature Technical Note

December 2024

Photo credit: Keith Hiscock

**THE CROWN
ESTATE**





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Available via [The Crown Estate's website](#).

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SECTION 1: Introduction

1. Introduction to the Whole of Seabed Programme

The Whole of Seabed Programme (referred to throughout as 'the Programme') is an ongoing, iterative process of data collection, spatial modelling and stakeholder engagement. The aim of the Programme is to generate a holistic understanding of the seabed at present and how the UK might utilise its marine resources out to 2050. The Programme aims to provide a more detailed spatial understanding of marine resources than has ever been available in the UK before, forming a comprehensive evidence base that can be used to support organisations that have a role or wider interest in the marine space. The Whole of Seabed evidence base will also be used by The Crown Estate to underpin the Marine Delivery Routemap, which will coordinate action needed to deliver net zero, nature recovery and a thriving marine economy.

Our analysis covers English, Welsh and Northern Irish waters for a wide range of maritime sectors (**Box 1**). Critically, the Programme considers *Nature* alongside traditional infrastructure and development-based sectors, seeking to spatially represent the most important areas for coastal and marine biodiversity both inside and outside the Marine Protected Area (MPA) network. With this, the Programme enables us to recognise the inherent value of nature and important natural assets, as well as understanding the potential impact of infrastructure and development-based sectors on nature.

Within the Programme, the current and future potential of offshore and coastal sectors, as well as the marine environment, are represented by spatial layers referred to as Potential Areas of Opportunity (PAOs).

For traditional, infrastructure and development-based sectors, each PAO represents a specific sector's resources based on our current knowledge of technical factors, other marine users, development cost and environmental considerations. Each PAO gives consideration to existing (already built) infrastructure, lease agreements and areas of importance for activities outside the remit of The Crown Estate (i.e. shipping, fishing, defence, oil and gas). Sector specific PAOs do not make allowances for the PAOs of other sectors, and as such no inherent prioritisation bias is included. Each PAO represents an area with significant optionality for future development, including more physical space than any given sector could need based on current demand forecasts; therefore, it is expected that the PAOs of different sectors overlap.

For *Nature* within the Programme, the PAO aims to represent a range of the most important areas for coastal and marine biodiversity. The PAO has not been refined in the same way as infrastructure and development-based sectors, which consider technical factors, other marine users, cost and environmental constraints to reduce the spatial extent of the PAO.

Instead, the Nature PAO combines datasets to spatially represent our current understanding of the most important areas for habitats and mobile species, both inside and outside the MPA network. Critically, this approach has been shaped by collaboration with key experts in the nature space, including the Statutory Nature Conservation Bodies (SNCBs), environmental Non-Governmental Organisations (eNGOs) and government departments.



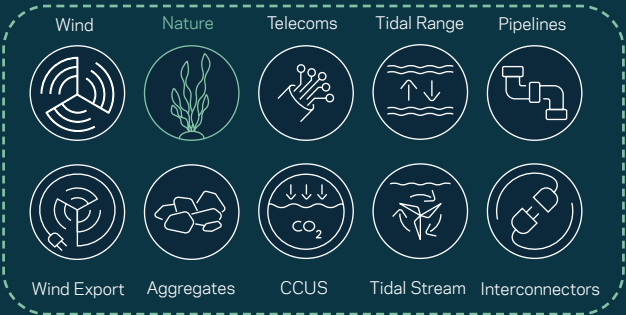
Underwater Photographer of the Year 2022: Rick Ayrton

Box 1: Whole of Seabed Programme Sectors

To Date:

Over the past 18 months we have transformed the Whole of Seabed Programme from an ambition to revolutionise the world of marine evidence, to a highly sophisticated set of analytical tools and processes that are changing how The Crown Estate understand the future of our marine environment. To date we have developed PAOs for Nature and 9 maritime sectors, including: Wind, Telecoms, Tidal Range, Pipelines, Wind Export, Aggregates, Carbon Capture and Storage, Tidal Stream, Interconnectors.

Nature is embedded across the Whole of Seabed Programme, to identify opportunities for positive progress and influencing our approach to infrastructure deployment



Next Steps

Going forwards we will continue to work iteratively to improve and update this evidence base and the capability that underpins it.

The next year will see us evolve the processes around how we use this evidence base, developing a clear cycle of data integration, modelling and stakeholder engagement. Working with Governments, industries and wider stakeholders will be crucial to this work and engagement will be guided by the elements of the analysis that we are focused on improving within a given year.

We have now begun an iterative process of integrating new data and evidence to our analysis, so that the Programme's outputs continually improve into the future. We will necessarily target priority evidence gaps and improvements through each iteration, and will equally remain open to discussion on where to focus our future updates to the Whole of Seabed evidence base. In general, the Programme will explore demand and create PAOs for other offshore sectors we have not yet analysed, as well as improve our work on sectors included in the initial analysis. We will continue to improve our evidence base for Nature, recognising there are critical gaps that can only be addressed by working in partnership with others. We plan to provide an annual update on the Programme, summarising developments to the capability and evidence base over the past year.



Photo credit: Keith Hiscock

Once PAOs have been developed, the Programme can be used to model different future-facing spatial scenarios to understand the various possible interactions across our marine environment, the challenges they may present, and the potential actions that can be taken to resolve challenges through long-term collaborative planning. The outputs of the Programme will provide clearer understanding of the areas required by different sectors in the coastal and offshore environment. By exploring different future-facing scenarios, the Programme will help us to better understand the marine environment's role in achieving net zero, nature recovery and supporting thriving marine ecosystems, economies and communities out to 2050.

The remainder of this report provides an overview of the datasets used to create this first iteration of the Nature PAO (**Section 2**) and explains how nature has been considered in the development of PAOs for infrastructure and development-based sectors (**Section 3**).

For a more detailed overview of the Whole of Seabed methodology please refer to the summary materials provided in **Appendix 1** and **2**, or click the report link below.

General updates on the Programme can be found on The Crown Estate's Marine [webpage](#). Further detail will be provided as we progress the development of PAOs for each sector and begin to produce scenario outputs.



Visit our website at:

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SECTION 2: The Nature Potential Area of Opportunity (PAO)

2a. Overview

Beyond the inherent value of our natural world, our climate, communities and economy depend on healthy and resilient ecosystems. Society is already feeling the impacts of climate change and nature loss, with the UK being considered one of the most nature-depleted countries in the world (State of Nature Partnership, 2023). In order to meet national and international biodiversity commitments we must ensure that we balance the needs of nature alongside other national needs, such as our transition to net zero.

The aim of the Nature PAO is to spatially represent the most important areas for coastal and marine biodiversity, including both habitats and mobile species. The Nature PAO looks both inside and outside Marine Protected Areas (MPAs) and considers locations that are important now or have the potential to be important in the future (e.g., due to the potential for restoration or habitat creation). The Nature PAO does not consider how other sectors may interact with nature, but nature is considered in how we shape all other sector PAOs to help avoid and minimise potential impacts (see [Section 3](#)).

We recognise the challenge in spatially representing UK marine biodiversity and opportunities for nature recovery; however, we believe that collating the best available evidence into one analytical process will enable the UK to better consider the needs of nature alongside the ambitions of infrastructure and development-based maritime sectors.

We believe this is the key to delivering on our vision to create the most sustainable and attractive marine economy and environment in the world.

In developing the Nature PAO we have worked with expert nature stakeholders to identify key datasets to include, but recognise that (as with all PAOs) further iterations will be needed to ensure we are drawing on the best available evidence.

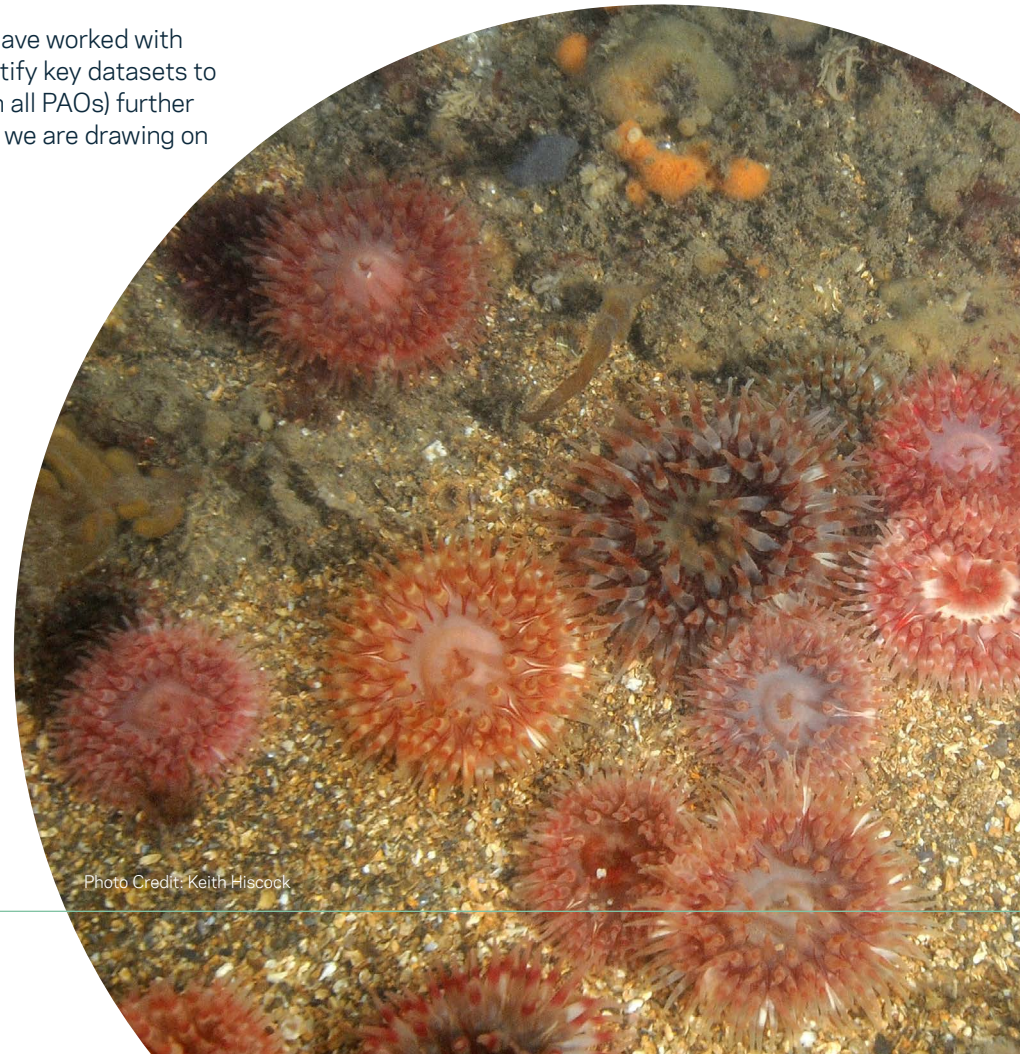


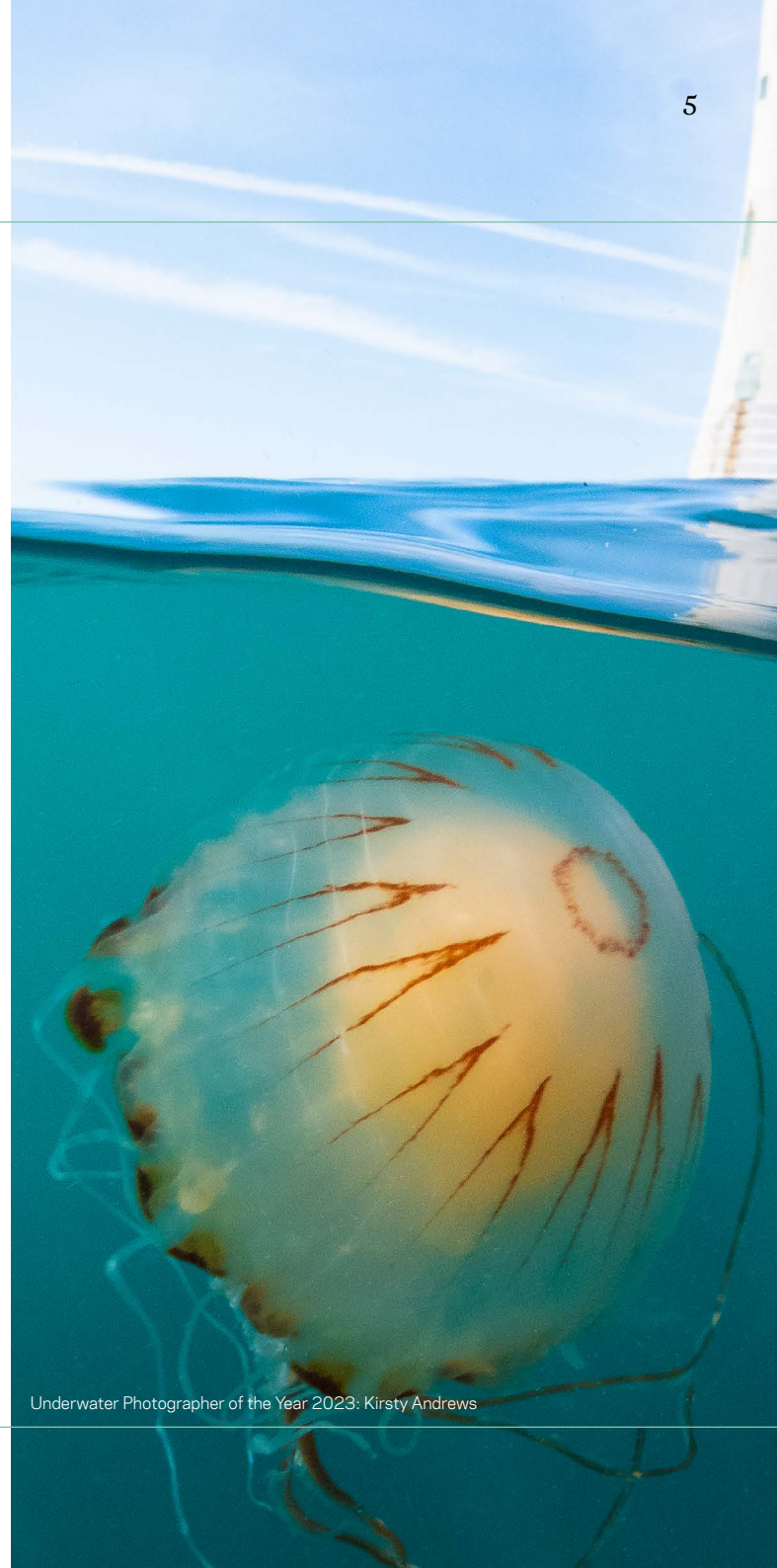
Photo Credit: Keith Hiscock

The MPA network forms the backbone of the Nature PAO, and we have built from this to draw in data to improve our understanding around wider habitats and species across our seabed and foreshore. We have tried to find ways to represent both areas where nature is already thriving and those locations where we have the opportunity to drive improvement and enable recovery. In seeking to draw out areas of high-importance for biodiversity that extend beyond protected areas, we have drawn on a range of data sources and methodologies to develop a holistic picture around England, Wales and Northern Ireland. We have also started to test approaches for representing opportunities around pressure reduction; in particular, the potential to remove redundant infrastructure. In some cases, we have been able to draw in datasets that already exist and integrate them directly into our modelling without additional processing. In other situations, additional processing has been necessary to build data layers that can interface with our GIS systems. The remainder of Section 2 provides detail on these datasets.

We recognise that evidence gaps and data paucity is a genuine challenge for nature, especially in offshore areas. In our work to date we have explored the use of potential proxy information to help with this, and continue to work with relevant experts to focus research efforts and funding to help address knowledge gaps.

At the time of writing there are multiple research programmes underway addressing some of the current evidence challenges, and we look forward to integrating the outputs of this work into the Whole of Seabed Programme as it becomes available. The same is true for updates to information about the condition of protected features within the MPA network, and our understanding of the drivers of condition in different locations.

The Programme is an ongoing, iterative process of data collection, spatial analysis and stakeholder engagement, and as we develop this evidence base, we will continue to work collaboratively with SNCBs, eNGOs, academics and other relevant parties to update and refine the Nature PAO in the coming months and years.



Underwater Photographer of the Year 2023: Kirsty Andrews

2b. Creating the Spatial Outputs

This section provides an overview of the datasets used to create this first iteration of the Nature PAO. As shown in [Figure 1](#), the datasets have been grouped into the following five subcategories:

Marine Protected Area (MPA) Network:

The boundaries of all MPAs are included within the Nature PAO, including: Special Areas of Conservation (SACs), Special Protection Areas (SPAs), Ramsar sites, Marine Conservation Zones (MCZs), Highly Protected Marine Areas (HPMAs) and coastal or marine elements of Sites of Special Scientific Interest (SSSIs) and Areas of Special Scientific Interest (ASSIs). Where possible, condition data for designated features have also been included to highlight areas where features are: Recovered/Recovering (including features in favourable condition), Degraded/Degrading (including features in unfavourable condition) or Condition Status Unknown (including features that have not been assessed).

Habitat Potential:

The known location of past, present and planned restoration or habitat creation projects have been included in the Nature PAO, alongside broader habitat suitability maps that show the potential to restore specific habitats within different areas.

Valuable Benthic Habitats:

Natural England's working definition of marine irreplaceable habitats has been spatially represented within the Nature PAO, across England, Wales and Northern Ireland. This is an exploratory step in representing valuable benthic habitats beyond the MPA network, with a number of known limitations ([Section 2d, page 21](#)). We will continue to work with stakeholders to refine and improve this subcategory of data.

Mobile Species:

Species-specific datasets have been used to capture areas important for mobile species, namely seabirds and marine mammals. This subcategory also includes datasets that indicate areas of high pelagic biodiversity to act as a proxy for some known gaps in mobile species datasets.

Decommissioning:

The location of abandoned cables were included in this first iteration of the Nature PAO. This is an initial step in considering opportunities around decommissioning within the Programme and will continue to be refined in later phases of work.



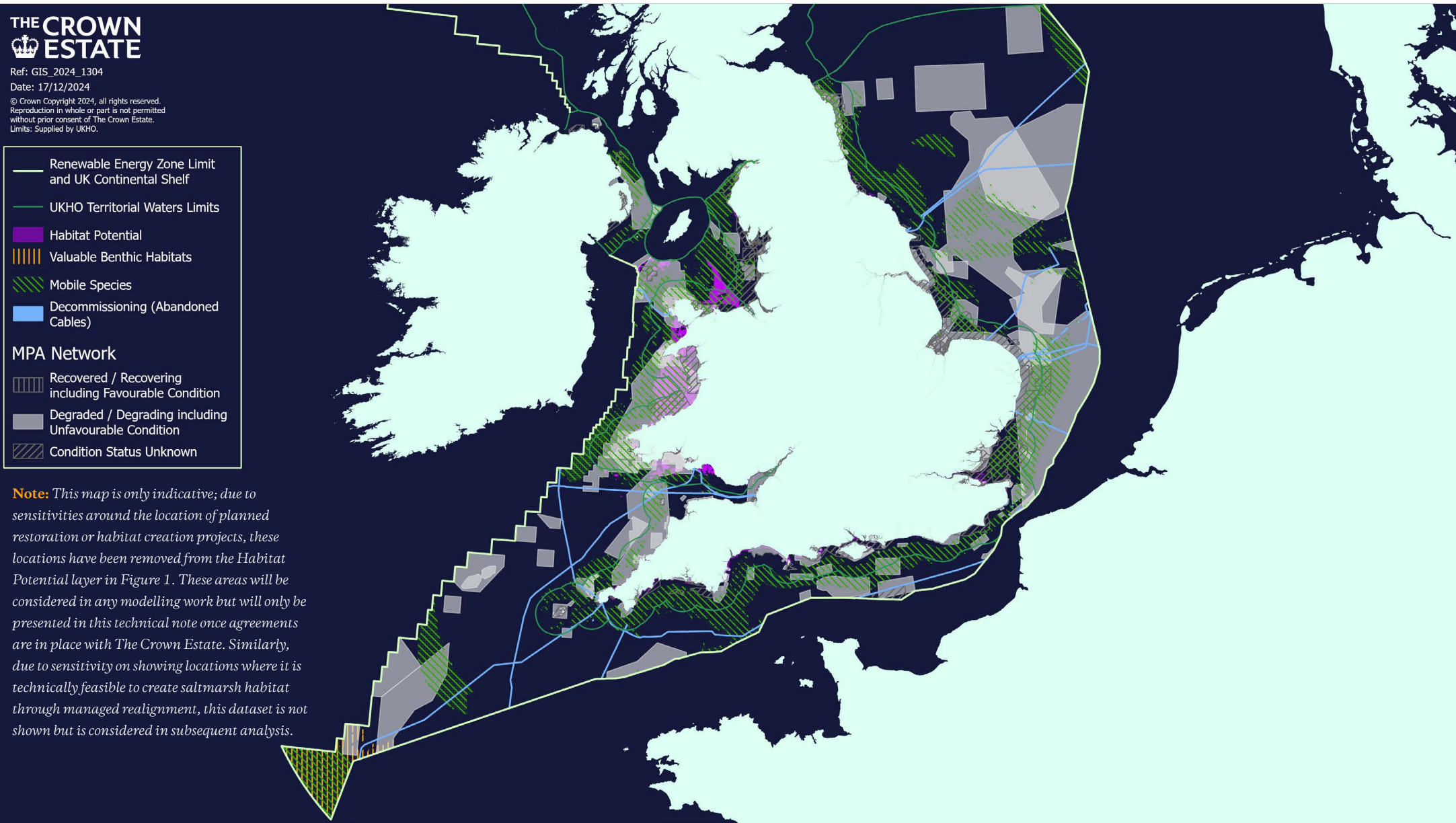


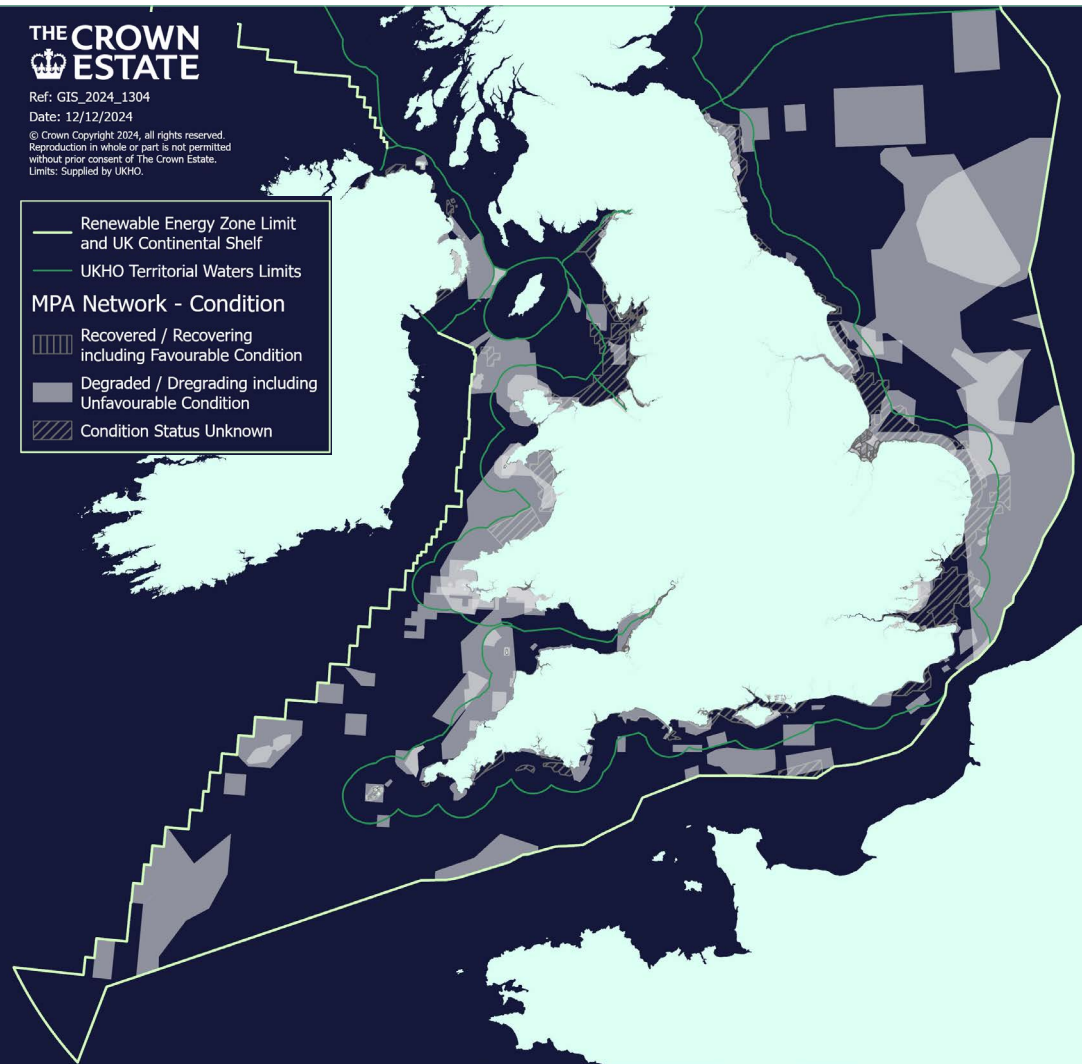
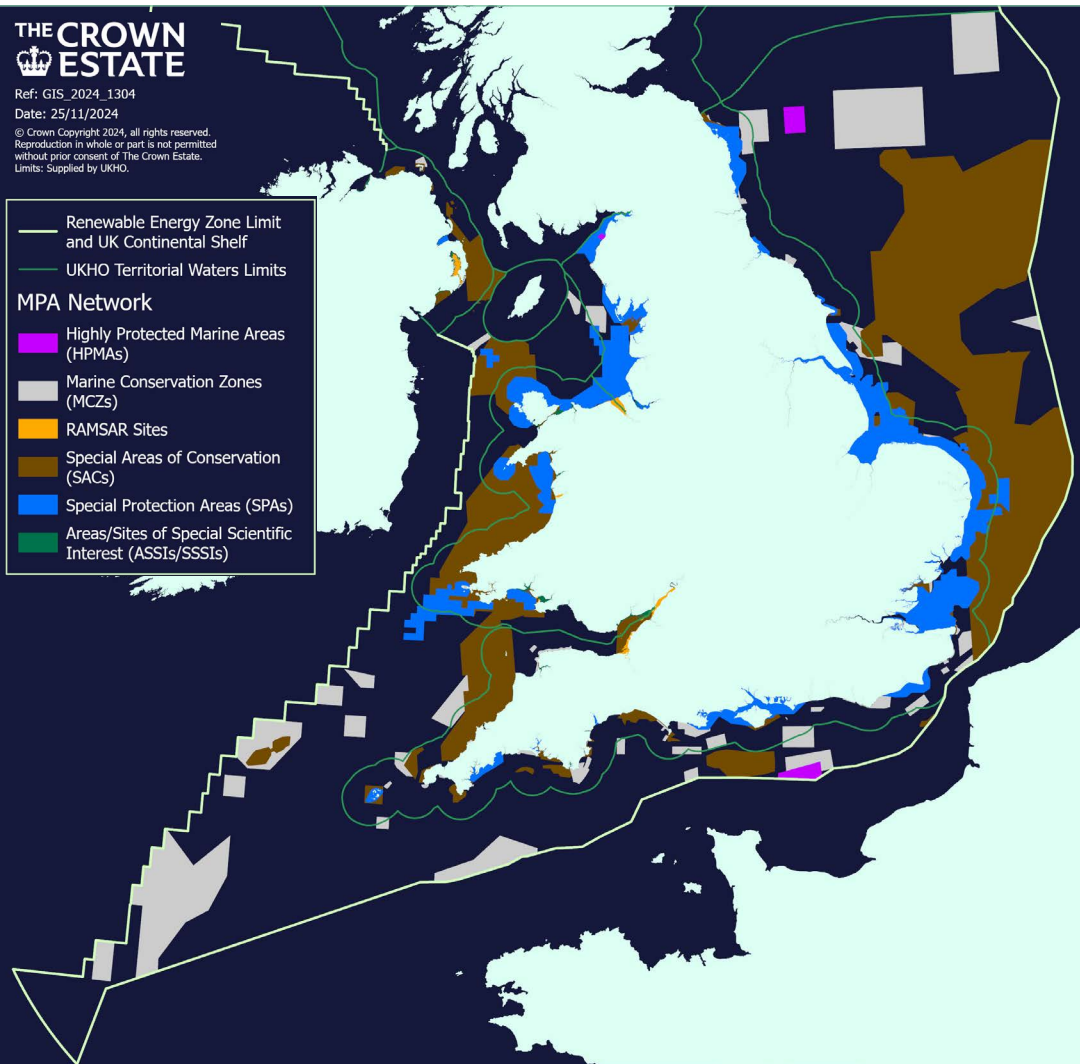
Figure 1: The Nature Potential Area of Opportunity (PAO).

2c. Datasets

Here we provide maps and tables of the datasets used to define each of the five subcategories within the Nature PAO. If the dataset required GIS processing before including in the Nature PAO, an overview of the steps is given in [Section 2d](#).



Photo Credit: Keith Hiscock



Note: Condition data was obtained from The Wildlife Trusts' MPA Recovery Check Assessment and combined with publicly available information on the condition of Ramsar sites, Sites of Special Scientific Interest (SSSIs) and Areas of Special Scientific Interest (ASSIs). All datasets included in the MPA Network subcategory are listed in Table 1. We are aware of additional work that is ongoing across SNCB's to update feature condition assessments and we will include this data as it becomes available.

Figure 2: MPA Network

Figure 3: MPA Network Condition Status

Table 1: Datasets contributing to the Marine Protected Area (MPA) Network subcategory

Dataset	Description	GIS Processing Notes
Marine Protected Area (MPA) site boundaries	The spatial boundaries of UK MPAs are available from the relevant SNCBs. For inshore waters this includes: Natural England, Natural Resources Wales, and the Department of Agriculture, Environment and Rural Affairs (DAERA) in Northern Ireland. For UK offshore waters this is available via the Joint Nature Conservation Committee (JNCC). An overview of where to download this data is available via JNCC's website .	No additional GIS processing was undertaken.
Marine Protected Area (MPA) Recovery Check Assessment	<p>The Wildlife Trusts have collated publicly available data on the condition of protected areas, and worked to summarise this information as an MPA Recovery Check Assessment layer.</p> <p>The data layers and accompanying methodology report are available via The Wildlife Trusts' Marine Platform (The Wildlife Trusts, 2023).</p>	<p>We use The Wildlife Trusts' data and the 100% rule to group the MPA network into three categories:</p> <ul style="list-style-type: none"> Recovered/Recovering (includes features in favourable condition) Degraded/Degrading (includes features in unfavourable condition) Condition Status Unknown (includes features that have not been assessed). <p>The 100% Rule: All features must be favourable, recovered or recovering for the MPA to be classed as "Recovered/Recovering". If one or more features are considered to be degraded or degrading, then the MPA goes into the "Degraded/Degrading" category. If one or more features do not have a corresponding condition assessment, then the MPA goes into the "Condition Status Unknown" category. For a more detailed methodology, please refer to The Wildlife Trusts' report.</p> <p>For the Nature PAO, we combined The Wildlife Trusts' data with publicly available data on Ramsars, SSSIs and ASSSIs, as explained below.</p>
Ramsar Sites	<p>Ramsar Sites are wetlands of international importance that have been designated under the criteria of the Ramsar Convention on Wetlands (JNCC, 2019).</p> <p>NIRAS (in relation to work through The Crown Estate's Offshore Wind Evidence and Change Programme) were commissioned to collate publicly available information on the condition of features within Ramsar sites, alongside other designations.</p> <p>This dataset is not publicly available, for more information please contact The Crown Estate.</p>	Across England, Wales and Northern Ireland, one or more features were found to be without condition information at each Ramsar site. Therefore, Ramsar sites were added to the "Condition Status Unknown" category.

Table 1 continued: Datasets contributing to the Marine Protected Area (MPA) Network subcategory

Dataset	Description	GIS Processing Notes
Sites of Special Scientific Interest (SSSIs) - England Sites of Special Scientific Interest (SSSIs) - Wales Areas of Special Scientific Interest (ASSIs) - Northern Ireland	<p>Sites of Special Scientific Interest (SSSIs) and Areas of Special Scientific Interest (ASSIs) provide statutory protection for areas that are considered to be of special interest due to the species, habitats and/or geological features present (DAERA, 2024; Natural England, 2024). Where they are designated to protect coastal or marine features they legally form part of the MPA network in accordance with the Marine and Coastal Access Act 2009 and The Marine Act (Northern Ireland) 2013.</p> <p>The spatial dataset containing condition data for SSSIs in English waters is available via Natural England's Open Data Geoportal (Natural England, 2024).</p> <p>The spatial dataset containing condition data for SSSIs in Welsh waters is available via DataMapWales (Natural Resources Wales, 2024).</p>	<p>SSSIs in England and Wales were categorized according to the 100% rule (see above).</p> <p>No available data was found on the condition status of ASSIs. Therefore, ASSIs were added to the "Condition Status Unknown" category.</p>

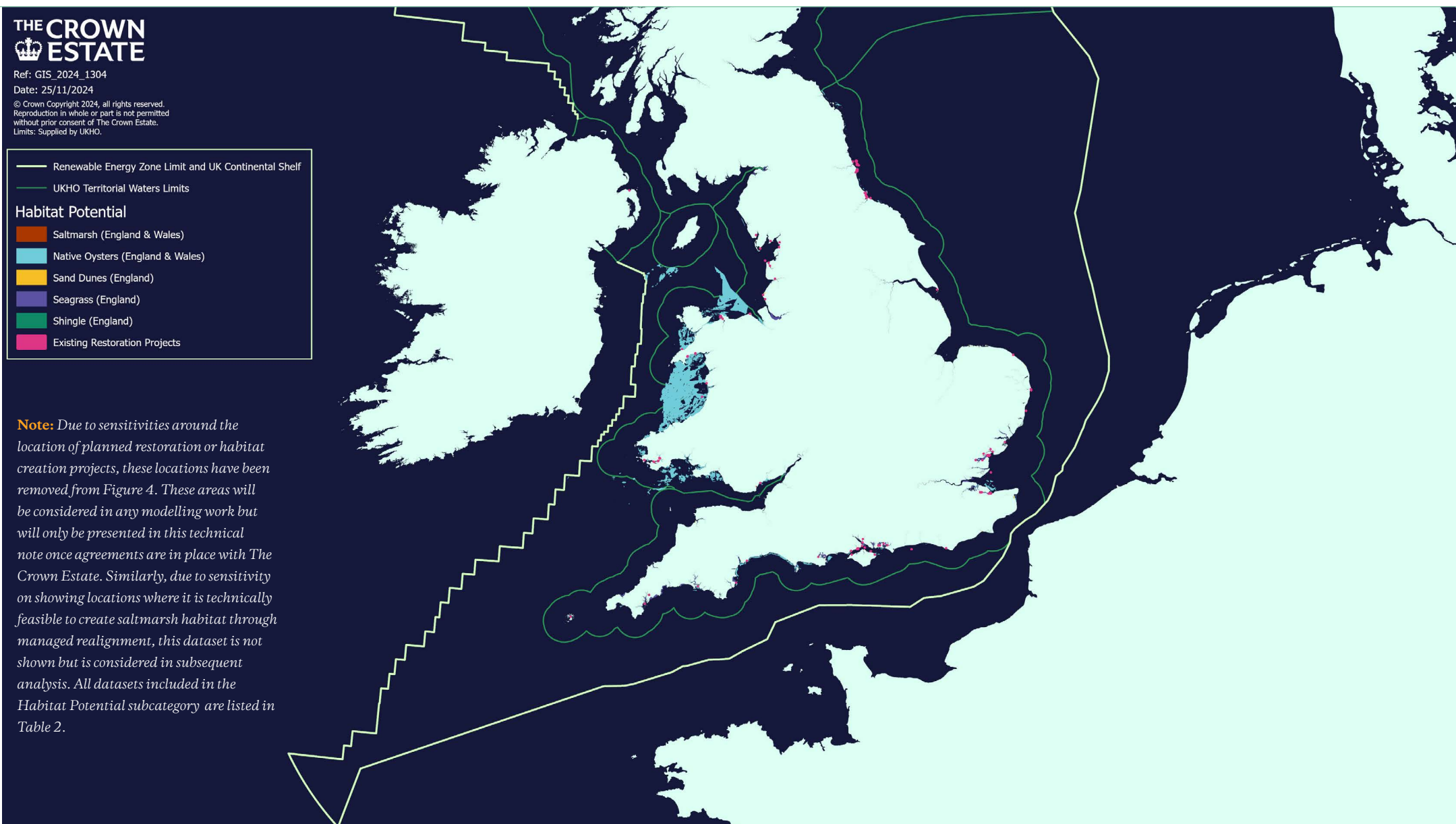


Figure 4: Habitat Potential

Table 2: Datasets contributing to the Habitat Potential subcategory

Dataset	Description	GIS Processing Notes
Restoration Projects	<p>A dataset generated by The Crown Estate to map the location of known habitat restoration projects in England, Wales and Northern Ireland.</p> <p>This dataset combines information collated by ABPmer on behalf of The Crown Estate as well as restoration projects already known to The Crown Estate and logged within our GIS system.</p> <p>This dataset is not publicly available, for more information please contact The Crown Estate.</p>	<p>Restoration projects that hold an agreement with The Crown Estate, or have registered an interest in an area for a future project, are represented as polygons.</p> <p>Projects identified by ABPmer are represented as point data, with a 25m buffer representing the project area.</p>
Sand Dune Restoration potential - England	<p>A dataset provided by Natural England to map sand dune restoration potential in England.</p> <p>This dataset is not yet publicly available, for more information please contact Natural England.</p>	<p>Restoration potential datasets have not undergone additional GIS processing, the layers have been included within the Nature PAO in their entirety.</p> <p>Please note that the datasets provide a national, high-level indication of where the habitats/species could potentially be restored or created. The datasets should be considered as an initial aid to identifying sites for future projects.</p>
Shingle restoration potential - England	<p>A dataset provided by Natural England to map shingle restoration potential in England.</p> <p>This dataset is not yet publicly available, for more information please contact Natural England.</p>	
Native oyster restoration potential - England	<p>A dataset provided by the Environment Agency to map native oyster restoration potential in England.</p> <p>This dataset considers sediment type and current energy to identify areas of restoration potential, with additional input from local area teams within Natural England, the Marine Management Organisation and Environment Agency. This spatial dataset is available via data.gov (Environment Agency, 2024).</p>	
Native oyster restoration potential - Wales	<p>A dataset provided by Natural Resources Wales to map native oyster restoration potential in Wales.</p> <p>This dataset considers sediment type, depth and current speed to identify areas of restoration potential. See Armstrong et al. (2021) for more information.</p>	

Table 2 continued: Datasets contributing to the Habitat Potential subcategory

Dataset	Description	GIS Processing Notes
Seagrass restoration potential - England	<p>A dataset provided by the Environment Agency to map seagrass restoration potential in England.</p> <p>This dataset considers wave and current energy, elevation and salinity to identify areas of restoration potential, with additional input from local area teams within Natural England, the Marine Management Organisation and Environment Agency. This spatial dataset is available via The Rivers Trust (2024).</p>	<p>Restoration potential datasets have not undergone additional GIS processing, the layers have been included within the Nature PAO in their entirety.</p>
Saltmarsh creation potential - England	<p>A dataset commissioned by The Crown Estate to map saltmarsh creation potential in England, produced by ABPmer.</p> <p>This dataset builds on previous work that used national flood maps to provide a high-level view on saltmarsh creation potential. This work considers additional factors (e.g., presence of infrastructure, historic landfills locations, nature of existing flood defenses) to refine the areas of saltmarsh creation potential and to provide a more realistic view on sites that are technically feasible to deliver.</p> <p>This dataset is not publicly available, for more information please contact The Crown Estate.</p>	<p>Please note that the datasets provide a national, high-level indication of where the habitats/species could potentially be restored or created. The datasets should be considered as an initial aid to identifying sites for future projects.</p>
Saltmarsh creation potential - Wales	<p>A dataset commissioned by The Crown Estate to map saltmarsh creation potential in Wales, produced by ABPmer.</p> <p>A baseline saltmarsh creation potential layer was created for Wales using national flood maps. Additional factors (e.g., presence of infrastructure, historic landfill locations, nature of existing flood defences) were used to refine the areas within the baseline layer, providing a more realistic view on sites that are technically feasible to deliver. This follows the approach used to identify potential sites in England (see above).</p> <p>This dataset is not publicly available, for more information please contact The Crown Estate.</p>	



Figure 5: Valuable Benthic Habitats

Table 3: Datasets contributing to the Valuable Benthic Habitats subcategory

Dataset	Description	GIS Processing Notes
Irreplaceable Habitats	<p>To help inform casework and new policy areas such as marine net gain, Natural England have been working to increase their understanding of habitats that could be considered irreplaceable within the marine environment. Natural England commissioned the Marine Biological Association of the UK (MBA) to help define coastal and marine irreplaceable habitats, and to assess irreplaceability at a range of EUNIS habitat levels.</p> <p>Project outputs include a technical report (Tillin et al., 2022) and an Excel spreadsheet that captures how each habitat (EUNIS Level 2 to 6) scores against the irreplaceability criteria, with an accompanying overall irreplaceability score. The report and Excel spreadsheet can be downloaded from Natural England's website.</p>	<p>We have applied this methodology across England, Wales and Northern Ireland. It is recognised that the methodology is still in development and may not have direct transferability beyond English waters.</p> <p>Please note that this is an initial step in representing valuable benthic habitats beyond the MPA network. We will continue to work with stakeholders to refine and improve this subcategory of data.</p> <p>For further details see See Section 2d, page 21.</p>

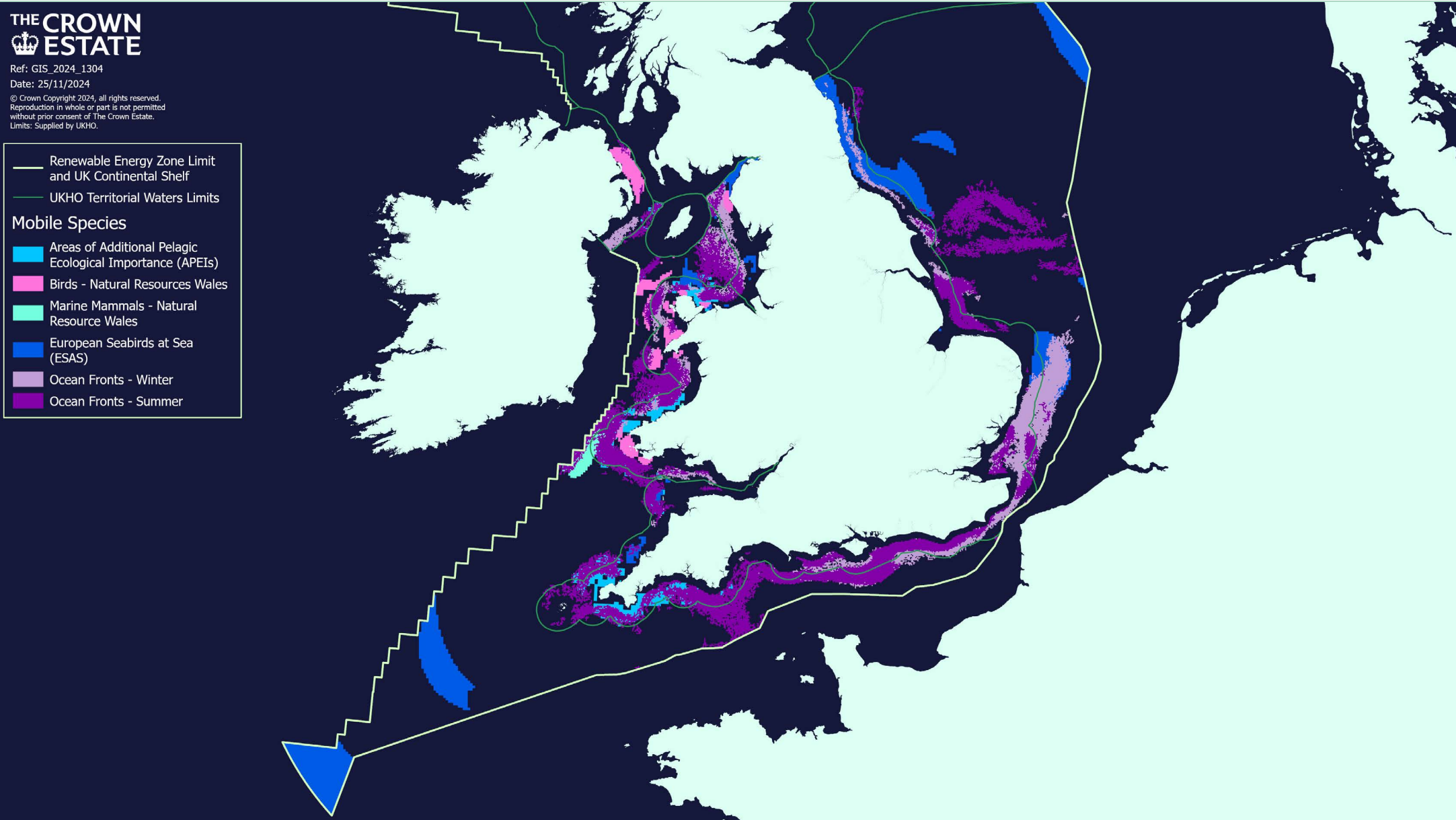


Figure 6: Mobile Species

Table 4 : Datasets contributing to the Mobile Species subcategory

Dataset	Description	GIS Processing Notes
Natural Resources Wales (NRW) Mobile Species Data	<p>This dataset represents the population density for a wide range of marine mammal and seabird species, both within and outside the MPA network.</p> <p>The dataset includes information relating to the following species:</p> <p>Marine Mammals: Bottlenose dolphin, common dolphin, harbour porpoise, minke whale, Risso's dolphin.</p> <p>Seabirds: Atlantic puffin, black legged kittiwake, common guillemot, european shag, european storm petrel, great black backed gull, great skua, herring gull, lesser black backed gull, manx shearwater, northern fulmar, northern gannet, razorbill.</p> <p>This spatial dataset is available via DataMapWales (Natural Resources Wales, 2023).</p>	<p>Data for seabirds and marine mammals were processed separately.</p> <p>For each taxa group, the species datasets were combined and the maximum density value obtained. The top 10% of population density areas were included in the Nature PAO to represent the 'hotspot' areas for birds and marine mammals.</p> <p>For further details see Section 2d, page 23.</p>
European Seabirds at Sea (ESAS) data	<p>This dataset is a collation of offshore monitoring data for a wide range of seabird species recorded during JNCC's European Seabirds at Sea (ESAS) boat surveys and WWT Consulting's aerial surveys. Survey data covers the summer months (April to September inclusive) between 1979 and 2011.</p> <p>This spatial dataset is available via the International Council for the Exploration of the Sea (ICES) data portal (ESAS, 2022). For a detailed methodology please refer to Bradbury <i>et al.</i> (2014)</p>	<p>For each species, the top 10% of population density areas were included in the Nature PAO.</p> <p>For further details see Section 2d, page 23.</p>
Areas of Additional Pelagic Ecological Importance (APEI)	<p>This dataset originates from work aiming to identify megafauna hotspots within English and Welsh waters, collating data from Whale and Dolphin Conservation, Marine Conservation Society, Shark Trust, RSPB and JNCC.</p> <p>The data layer provides information on important areas for whales, dolphins, porpoises and basking sharks. Areas are classified as high, medium and low importance for each species or taxa group. For more information, please refer to Batey and Edwards (2014). Data supplied by The Wildlife Trusts.</p>	<p>Areas identified as high importance within the APEI data layer were included in the Nature PAO.</p>
Ocean Fronts	<p>This layer is derived from satellite data and the aggregation of monthly front maps to identify strong, persistent and frequently occurring oceanic fronts within a given season, according to sea surface temperature.</p> <p>Frequent fronts are indicated by the percentage time in which strong fronts occurred in a pixel within a given season. For a detailed methodology please refer to Miller and Christodoulou (2014). Data supplied by Plymouth Marine Lab.</p>	<p>The top 5% of values from both summer (June to August) and winter (December to February) were extracted from the wider data set and included into the Nature PAO.</p> <p>For further details see Section 2d, page 25.</p>



Figure 7: Decommissioning

Table 5: Datasets contributing to the Decommissioning subcategory

Some infrastructure currently deployed on the seabed will soon be coming to the end of its operational life. As an example of such infrastructure, the location of unused cables were included in this first iteration of the Nature PAO to help us test how opportunities around decommissioning can be represented within the Programme. We will continue to refine this work and recognise the potential to consider decommissioning within other infrastructure-based sectors.

Dataset	Description	GIS Processing Notes
Unused cables	<p>A dataset created by The Crown Estate to represent inactive cables where we have a high-degree of certainty on their location.</p> <p>This dataset is not publicly available but for more information please contact The Crown Estate.</p>	<p>No additional GIS processing was undertaken.</p>

2d. GIS Processing Notes, Getting from Data Inputs to the PAO.

In some cases, the best available data needed an element of processing to make sure it could be integrated into the geospatial tools being used in the Programme. This section describes how some of the more complex datasets were processed before being included in the Nature PAO, presented with a corresponding figure for each of the datasets. For a full list of the datasets included in the Nature PAO please refer to [Section 2c](#).

Irreplaceable Habitats

Habitats can be considered valuable for a multitude of reasons, whether this is represented by legal protections (e.g., designated features within the MPA network), the known importance of that habitat to a particular ecosystem service or the life cycle of a particular species, or because the habitat supports a wide variety of species and may be considered a biodiversity hotspot. As an initial step in representing valuable benthic habitats beyond the MPA network, we have applied Natural England's working definition of marine irreplaceable habitats to the Nature PAO.

Data sources:

- Tillin *et al.*, 2022
- JNCC, 2022

Data overview:

Through a combination of literature review, expert elicitation and systematic assessment, Natural England have developed a working definition of an irreplaceable habitat within the marine environment; namely, habitats that cannot be successfully restored or created based on one or more of the following factors: they are very difficult to restore or very slow to recover, they may be nationally rare (based on extent, range or distribution) and/or have an unusual or rare environmental context (Tillin *et al.*, 2022). Natural England have scored habitats according

to these criteria, with the summed value providing an irreplaceability score that is linked to EUNIS habitat codes. Whilst a high score against any one individual criteria may pose a challenge for the habitat to recover or to be restored following disturbance, habitats that score above 40 are considered to have scored highly against the assessed criteria and therefore considered to either be highly vulnerable, rare or both. For a detailed methodology, please refer to Tillin *et al.* (2022)

GIS processing:

We matched EUNIS Level 3 codes in English, Welsh and Northern Irish waters (JNCC, 2022) to Natural England's overall irreplaceability score (Tillin *et al.*, 2022). EUNIS Level 3 habitats with a score greater than 40 were included in the Nature PAO.

Known caveats and limitations:

We have taken a simple approach to spatially representing Natural England's working definition of irreplaceable habitats. We recognise that Natural England's definition of irreplaceable habitats may change in the future, that this definition may not reflect the views of other SNCBs and, by only mapping EUNIS Level 3 habitat codes, we lose a degree of detail compared to the irreplaceability scores for EUNIS Level 4, 5 and 6 biotopes. This was an initial attempt at representing valuable benthic habitats outside of the MPA network, and we will continue to work with stakeholders to refine and improve on this subcategory of data.



Figure 8: Identified Irreplaceable Habitats



Mobile Species - Excluding Ocean Fronts

Recognising the importance of areas both inside and outside the MPA network for different species, we have worked with stakeholders to identify and incorporate the best available mobile species data within the Programme. A number of live projects (including research funded by The Crown Estate's Offshore Wind Evidence and Change Programme) will improve upon this evidence base, and we will continue to work with project leads and stakeholders to incorporate outputs into the Programme where appropriate.

Data sources:

The mobile species data incorporated within the Programme to date, includes:

- European Seabirds At Sea (ESAS), 2022
- Natural Resources Wales, 2023
- Bradbury *et al.*, 2014

GIS processing:

Each of the mobile species datasets were processed in order to extract the areas with the highest – top 10% – population densities. The processing steps were as follows:

- Population density values were categorised into value bands and a max-upper density value was assigned to each species, containing the top 10% of population density.

- These areas were then merged to give the spatial extent containing the top 10% most densely populated areas per species.
- The process was repeated for each species and the areas merged, providing a spatial output that captures the highest (top 10%) population areas for all of the species considered in the analysis.

Please note that, in addition to the datasets listed above, we also include areas of Additional Pelagic Ecological Importance (APEIs). APEIs have been identified using marine mammal and basking shark data and are categorised as high, medium and low importance to each species or taxa group (Batey and Edwards, 2014). For the Nature PAO we only include areas identified as high importance (see [Table 4, page 18](#) for more information).

Known caveats and limitations:

The spatial coverage of mobile species datasets are dependent on the survey effort underpinning them. Although these represent the best available datasets, gaps are still known to exist for different species. To partially address this limitation, we have included data on oceanic fronts to identify likely areas of high pelagic biodiversity that are not yet captured in the datasets above (see section below). A further limitation is the fact we have not yet considered the impact of climate change on datasets within the Nature PAO, including the potential impact on species distributions; this is a known limitation and an area for future development.

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— Renewable Energy Zone Limit
and UK Continental Shelf
— UKHO Territorial Waters Limits

Mobile Species

Areas of Additional Pelagic
Ecological Importance (APEIs)
Birds - Natural Resources Wales
Marine Mammals - Natural
Resource Wales
European Seabirds at Sea
(ESAS)

Data sources:

*The mobile species data
incorporated to date within the
Programme includes:*

- *European Seabirds at Sea
(ESAS), 2022*
- *Natural Resources Wales,
2023*
- *Bradbury et al., 2014*

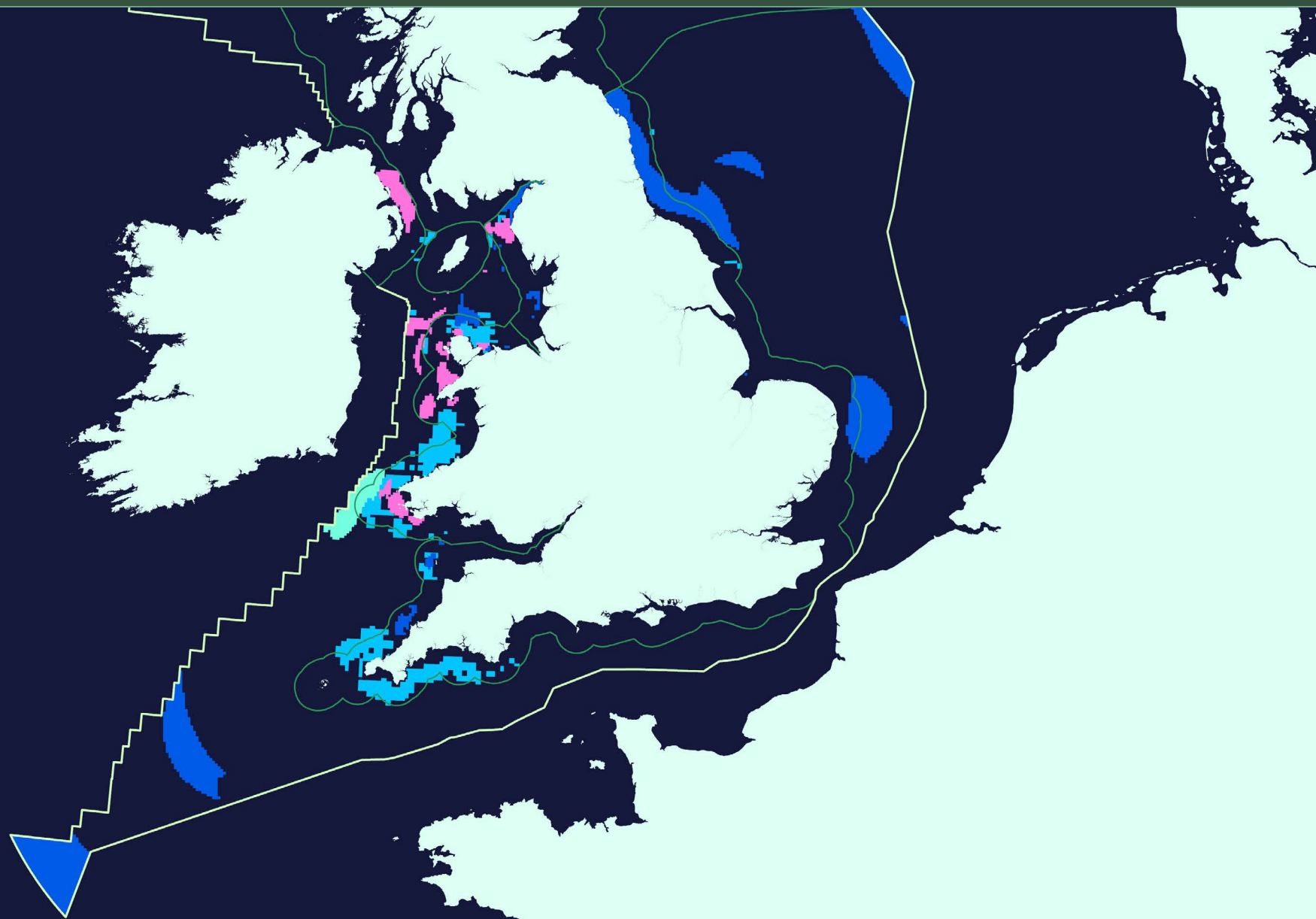


Figure 9: Mobile Species Data (Excluding Ocean Fronts)

Ocean Fronts

Oceanic fronts are dynamic structures where two water masses of different temperature, density or another property meet. Fronts can concentrate nutrients and plankton, leading to areas of greater biological productivity that attract other fauna (Miller and Christodoulou, 2014). The location of persistent oceanic fronts can provide a useful proxy for pelagic biodiversity, which has already fed into UK decision-making processes by helping to inform the designation of Marine Conservation Zones (Miller and Christodoulou, 2014).

Due to known data gaps for mobile species (see Known Caveats and Limitations on [page 23](#)), ocean fronts data was included in the Nature PAO in order to identify likely areas of high pelagic biodiversity that are not yet captured in our other datasets. The Crown Estate has engaged with industry experts in oceanic fronts to validate the methodology and approach taken.

Data source:

Data supplied by Plymouth Marine Laboratory.

Data overview:

This layer is derived from satellite data and the aggregation of monthly front maps to identify strong, persistent and frequently occurring oceanic fronts within a given season, according to sea surface temperature. Frequent fronts are indicated by the percentage time in which strong fronts occurred

in a pixel within a given season. For a detailed methodology please refer to Miller and Christodoulou (2014).

GIS processing:

Various thresholds were tested to explore areas with the most consistent oceanic fronts, measured as a seasonal frequent front metric with a 1km resolution. For the Nature PAO, the top 5% of values from both summer (June to August) and winter (December to February) were extracted, vectorized into polygons and dissolved. The area of each polygon was calculated and any polygon <10km² was removed. The remaining polygons for summer and winter were added to the Nature PAO.

Known caveats and limitations:

We have not yet considered the impact of climate change on datasets within the Nature PAO, including the potential impact of increasing ocean temperatures on the location of oceanic fronts.

Another key limitation of this data is that it is not directly measuring mobile species, and further evidence is needed on the relationship between different taxa and oceanic fronts, in order to improve our understanding of how this data can be used as a proxy for pelagic biodiversity. The Crown Estate is supporting a live research project in this area and we will continue to work with project leads to incorporate outputs into the Programme where appropriate.

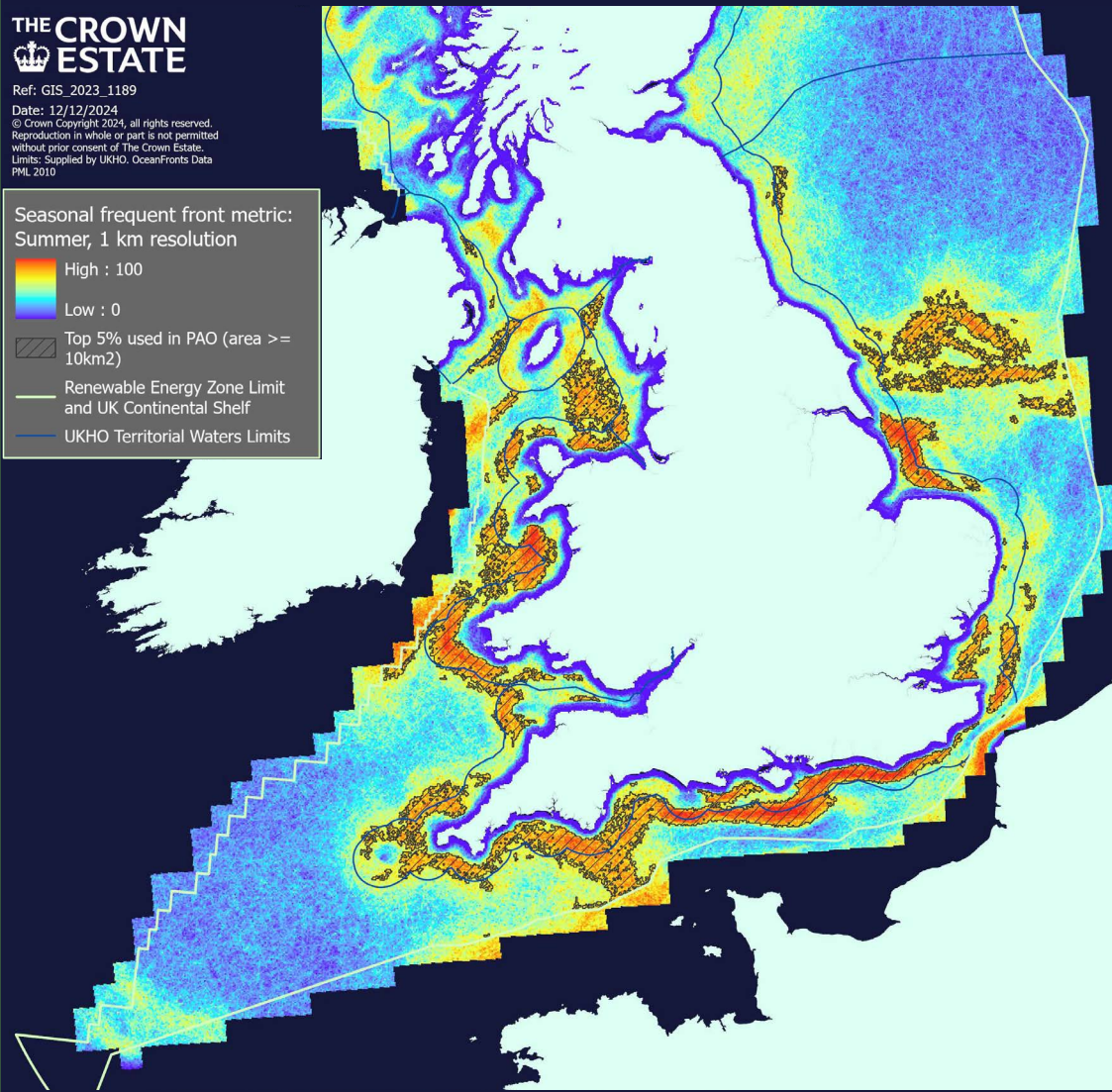


Figure 10: Overview of the Ocean Fronts Dataset - Summer

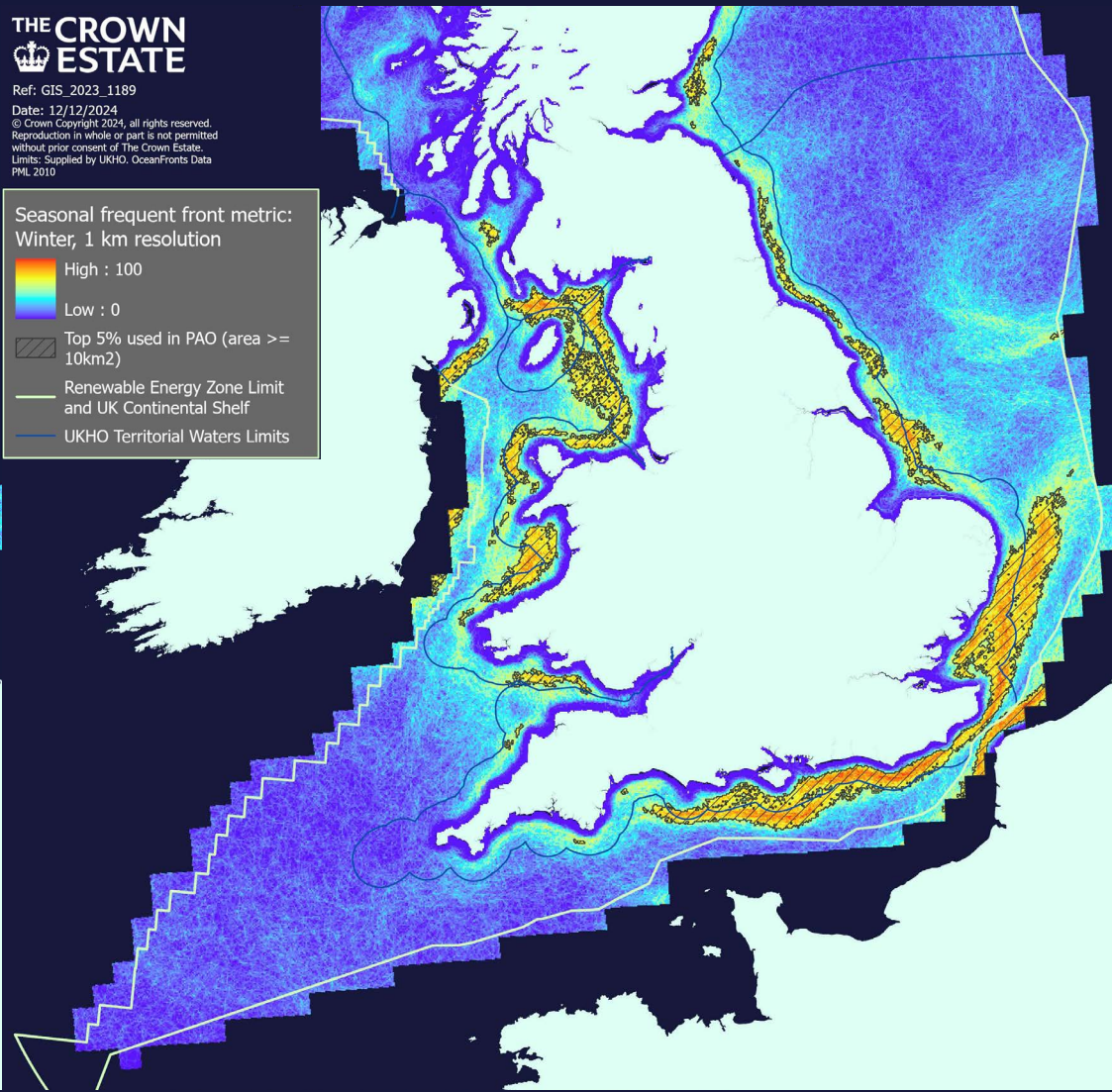


Figure 11: Overview of the Ocean Fronts Dataset - Winter

SECTION 3: Integration of Nature Evidence in Other Sectors

Our approach to Nature and representing its social, economic and environmental value is core to the Whole of Seabed Programme. Within the Programme, the opportunities for Nature are represented alongside traditional infrastructure and development-based sectors; whilst the Nature PAO spatially represents our current view of the most important areas for coastal and marine biodiversity, nature-related data is also used in refining and informing the design approach to the other PAOs.

Our modelling allows us to include, compare and analyse features that may be less compatible or create complexity for development activity and delivery. Although the approach is mirrored for each PAO, the content driving the modelling is bespoke to each infrastructure and development-based sector, allowing us to reflect any unique considerations on a sector-by-sector basis.

Example constraints model:

For traditional infrastructure and development-based sectors within the Programme, the modelling includes spatial datasets that allow us to consider economic, environmental and social constraints for that sector. Within each of these three branches, the spatial datasets have been weighted in terms of the risk posed to the sector, helping to refine the PAO to more realistic areas of potential opportunity whilst keeping a high degree of optionality for future development. An example of this are MPAs, which are included in the constraints modelling and have the effect of pushing infrastructure and development-based sectors away from these locations. All MPAs are included within the model, except for Highly Protected Marine Areas (HPMAs) which are excluded from each of the infrastructure and development-based sector PAOs.

The spatial datasets used within the constraints models are weighted using Analytical Hierarchical Processing (AHP) within The Crown Estate's Resource Identification and Optimization (RIO) tool, as explained in **Box 2**.

Figure 12 illustrates the environmental branch within an example constraints model and contains the following data:

- Environmental designations, namely: Special Areas of Conservation (SACs), Special Protection Areas (SPAs), Ramsar sites, Sites of Special Scientific Interest (SSSIs), Areas of Special Scientific Interest (ASSIs), Marine Conservation Zones (MCZs) and Marine Nature Reserves (MNRs).
- Environmental Features; this example constraints model contains spatial data on the spawning and nursery ground locations for fish species of conservation importance. The dataset is available from Ellis *et al.* (2012).
- Disposal Sites, recognising that both closed as well as open disposal sites may pose a contamination risk if disturbed. The dataset is available from Cefas (2022).
- MPA Risk Layers, a bespoke dataset that has been developed to represent the risk of a sector to the designated features within an MPA. This data layer is explained in more detail below.

Box 2: Resource Identification and Optimisation (RIO) Tool

One of the key tools used to weight and analyse datasets is our world-leading spatial planning system RIO – the Resource Identification and Optimisation tool. RIO is a unique, custom-built digital platform that can be used to build spatial models that respond to data inputs, structuring and prioritising environmental, social and economic interests, and fairly representing the weighting of datasets.

In this initial phase of the Programme, RIO has been used to develop the PAOs for all infrastructure and development-based sectors, taking into account both hard constraints (i.e., exclusions) and soft constraints (i.e., restrictions) to the sector's development. To incorporate soft constraints within the sector's PAO, RIO uses a Analytic Hierarchy Process (AHP) to structure the data inputs and how they inform the final spatial output. Using AHP allows different combinations of data to be weighted in different ways and provides a robust, traceable and repeatable methodology for structuring and developing spatial models.

For a worked example showing how The Crown Estate has used AHP in offshore wind spatial modelling, please refer to The Crown Estate's Celtic Sea Floating Offshore Wind Leasing Round 5: Site Selection Methodology (The Crown Estate, 2023).



Figure 12 Environmental Constraints Doughnut Chart. This figure shows the different environmental constraint considerations within an example RIO model. The size of the segments within the doughnut are proportional to the weighting of the dataset; these weightings can vary by sector, or according to the spatial scenario that we are testing within the Programme.

Note: This is an illustrative example of the environmental constraints used to generate a sector PAO and is not representative of all constraints models across different sectors. Constraints models are designed specifically for each sector, in order to reflect the fact that constraints may impact each sector differently. Highly Protected Marine Areas (HMPAs) are not included within the constraints model as they are reflected in the exclusion models for each sector.

MPA Risk Layers:

Spatial planning traditionally draws on the boundaries of designated sites as the main dataset for environmental considerations; however, more detail is needed to better consider the risk of an activity to any given designated features within a site. For example, relying on the boundaries of designated sites alone does not allow us to consider mobile species that are at risk outside of site boundaries, the fact that some features may be more sensitive to a particular activity compared to other features, nor the fact that features in poor condition are at greater risk to additional pressures due to in-combination effects. These differences are important to consider when planning for future development.

To address this knowledge gap, The Crown Estate commissioned NIRAS (an environmental consultancy) to develop a spatial dataset that captures the risks different sectors pose to MPA features. The first phase was funded through the Offshore Wind Evidence and Change Programme and was focussed on offshore windfarm development (fixed and floating turbines, and export cables). Adopting the same methodology, a second phase of the project is underway and focusses on carbon capture and storage (CCS), co-located hydrogen, telecoms cables and marine aggregates. The methodology and outputs have been developed with input from SNCBs, eNGOs as well as the Department for Environment, Food and Rural Affairs (Defra) and the Department for Energy Security and Net Zero (DESNZ). We are currently exploring options for a third phase of work that would

incorporate additional sectors, and we will update this technical note in due course.

Through this work NIRAS have developed risk maps for features within Special Areas of Conservation (SACs), Special Protection Areas (SPAs), Ramsar sites and Marine Conservation Zones (MCZs). The risk maps are an indication of the spatial extent and degree of relative risk a sector may pose to these features, taking into consideration the availability of mitigation options and feature distribution, extending beyond the spatial footprint of the designated sites where appropriate (e.g., extending beyond site boundaries for seabirds based on their foraging range).

NIRAS assigned an overall risk score to each feature and sector, with 1 being the lowest risk and 7 being the highest risk. Levels 4 to 7 were taken into consideration for analysis within RIO as these capture the highest levels of relative risk and areas where mitigation is likely to be challenging. The lower risk levels 1 to 4 are not included in the constraints model, as this would have the effect of increasing constraint across the whole model rather than allowing us to prioritise the highest risk areas (i.e. if all levels were included large areas would be indicated as constrained when in practice any effects could easily be avoided or mitigated). For each of the sectors a summary layer was produced, taking the highest risk score across all features within a 1km² hexagonal grid square.

This summary layer was fed into the constraints model and was used to generate the sector PAOs; therefore, areas ranked as level 7 within the MPA Risk layer are weighted the highest and represent the areas of most constraint for the sector.

Please note that the use of the MPA Risk Layers within the Programme (and any resulting spatial outputs) do not look to prejudice outcomes of any plan or project level Habitats Regulations Assessment (HRA) or MCZ assessment, or replace the need for a detailed assessment during the HRA stage.

SECTION 4: Next Steps

We recognise that nature-related data and evidence will continue to be developed, and our understanding of the distribution, condition and sensitivity of marine biodiversity to individual sectors will continue to improve. However, the urgency of addressing the climate and biodiversity crisis, whilst continuing to deliver economic opportunities for the nation, means we cannot only wait for future insights. We must use the data and evidence available now to inform our decision-making and ensure that we have the systems in place to bring the latest, best available evidence, into the process ahead of key decision points.

The Whole of Seabed Programme is an ongoing, iterative process of data collection, spatial modelling and stakeholder engagement. There will be a continuous need to review the nature-related data being used within the Programme, and to update, replace or add to the data currently being used. The data inputs need to be carefully considered as simply adding an ever-increasing number of datasets into the analysis will dilute the value of the spatial outputs and insights gained. With this, we are committed to working collaboratively with stakeholders to identify the best available evidence to use within the Programme, to identify and address key knowledge gaps that become apparent, and to review new data as it becomes available, building on the work described in this technical note and ensuring the Programme keeps apace with new evidence and understanding.

The work to date has focused on developing the operational capability within The Crown Estate, and to integrate a number of key datasets in order to generate initial spatial outputs and to more easily communicate the ambitions of the Programme.

We are in the process of developing the Whole of Seabed analysis into a mature evidence base that will embed a cyclical process of data integration, modelling and engagement. This will support our ambition to agilely provide the latest version of the Whole of Seabed evidence base to support The Crown Estate's leasing decisions as well as Government policy development and delivery. In the coming months, we will continue to focus on getting feedback on the work so far, while progressing plans to make improvements to our analysis and to integrate new data that has already been identified through our engagement.

We also want to share how our Whole of Seabed evidence base will inform our strategic approach across a range of sectors, including nature, in our Marine Delivery Routemap (MDR). The Routemap is a collaborative initiative to develop a long-term strategy for the marine space, underpinned by our Whole of Seabed evidence base.

In September 2024 we published a report on the Routemap as well as the first of a series of sectoral reports outlining our thoughts for the future of offshore wind. This Routemap series of publications will continue to expand, with future thinking to be shared on our approach to nature, carbon capture and storage, and marine aggregates. Updates on our Marine Delivery Routemap and copies of all available publications can be found on The Crown Estate's [website](#).



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Glossary

Key Resource Area (KRA)	An area where it is understood to be technically feasible to develop a given sector based on geological and metocean factors.
Levelised Cost of Energy (LCOE)	A measure of the average cost of energy generation over the generator's lifetime, based on assessing the total cost of building and operating the energy generation asset.
Marine Delivery Routemap	The Marine Delivery Routemap is a collaborative initiative to develop a long-term strategy for the marine space. It will help coordinate action across agencies and sectors to deliver on net zero and nature recovery policy; build a thriving marine economy; and support onshore communities.
Marine Protected Area (MPA)	MPAs are areas of the ocean established to protect habitats, species and processes essential for healthy, functioning marine ecosystems.
Nature Potential Area of Opportunity	A Potential Area of Opportunity designed to provide a way of considering nature in its own right alongside other sectors. In summary, this consists of mapping opportunities for nature recovery, protection and enhancement, giving us a way of representing the diversity of demands from nature. To date it does not consider the cost of any of these activities in order to define the spatial output.
Potential Area of Opportunity (PAO)	A Potential Area of Opportunity for an individual sector, identified through consideration of cost and existing marine users and interests. A PAO does not take into consideration areas of potential opportunity for other sectors or co-location of future activities, but are used as inputs to spatial scenarios which model all future activities to provide a deconflicted view of development out to 2050.
Resource Identification and Optimisation tool (RIO)	An in-house digital tool developed by The Crown Estate to analyse spatial data in a structured and prioritised way.
Sector	For the purposes of our analysis this consists of a range of activities which The Crown Estate plays a role in leasing or managing. It is therefore used to represent activities from the protection of nature, to tidal energy generation, to the laying of telecommunications cables.
Whole of Seabed Approach	How The Crown Estate wants to inform its leasing and management activities going forwards with a holistic understanding of the seabed at present and far into the future.
Whole of Seabed Programme	An ongoing, iterative process of data collection, spatial modelling and stakeholder engagement to generate and improve the spatial evidence and data at the heart of this approach.

Appendices

Appendix 1: Whole of Seabed Programme Summary **34**

Appendix 2: Whole of Seabed Programme Methodology Overview **37**



Photo Credit: Keith Hiscock

Appendix 1:

Whole of Seabed Programme Methodology Summary

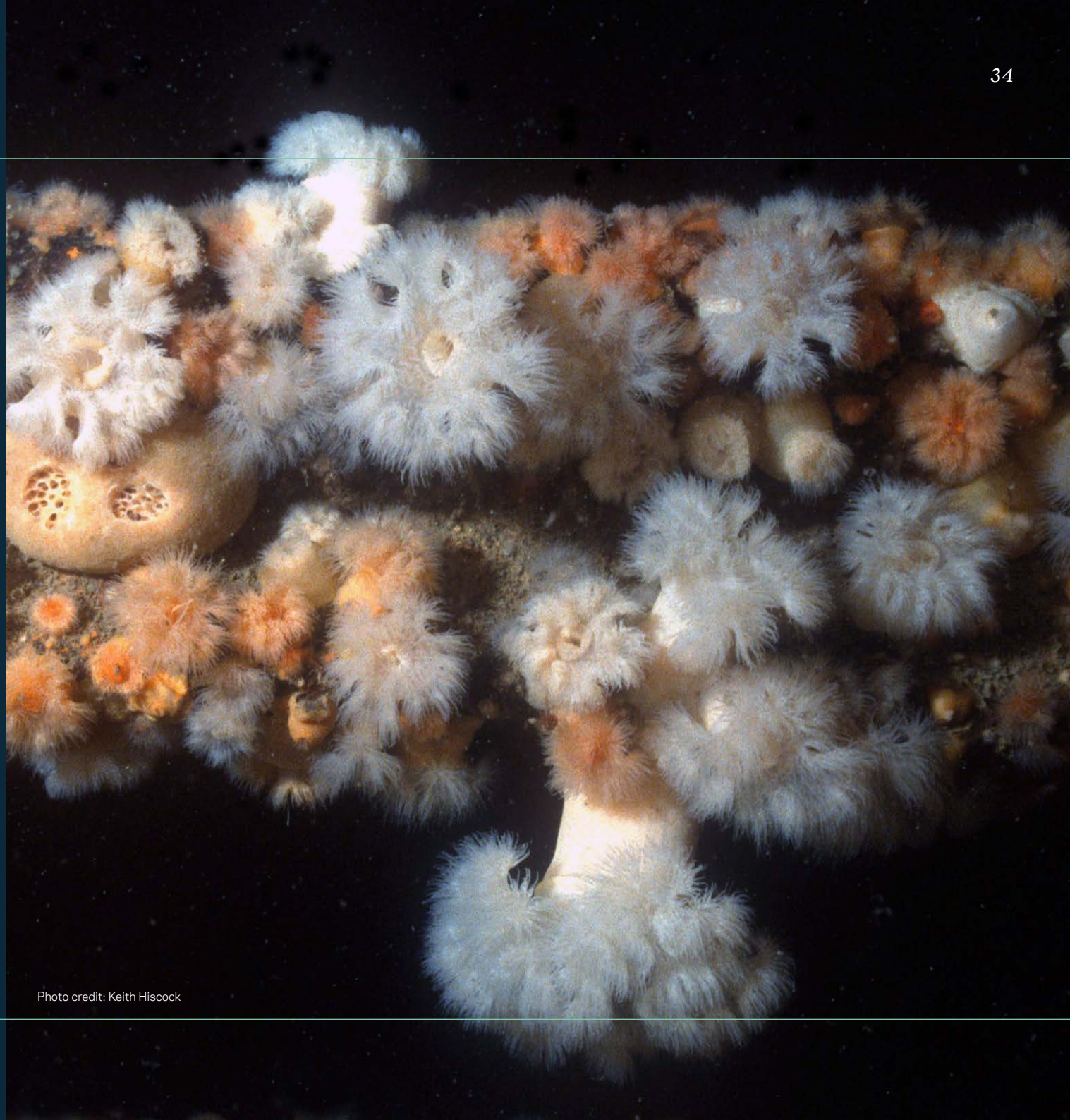


Photo credit: Keith Hiscock

Summary

The Whole of Seabed Programme is an ongoing, iterative process of data collection, spatial analysis and stakeholder engagement. **It aims to provide a highly sophisticated understanding of how the UK might utilise its marine resources to 2050**, including a more detailed spatial understanding of marine resources than has ever been available in the UK before. The Programme is exploring different future-facing spatial scenarios about how the seabed might be used, to better understand the marine environment's role in achieving net zero, as well as supporting thriving marine ecosystems and economies to 2050.

Our analysis maps potential areas of opportunity across English, Welsh and Northern Irish waters for a wide range of sectors, for example, carbon capture and storage, marine aggregates, offshore wind, other marine energies, and telecommunication cables. Critically, the analysis considers the protection and restoration of nature as an activity and fundamental goal in its own right, rather than solely considering the potential future impact of other sectors on nature. **The Programme represents a unique ambition to consider the diverse objectives of different sectors to 2050 and how they might interact.** The scenarios we model allow us to understand the various possible interactions across our marine environment, the challenges they might pose, as well as potential enabling actions to resolve them through long-term collaborative planning.

The outputs of the Programme constitute high quality spatial evidence informed by hundreds of spatial datasets, providing a clearer understanding of the areas required to support offshore and coastal sectors, as well as the marine environment. We will look to communicate this understanding by engaging both on the spatial outputs but crucially the statistics, caveats and issues they highlight for further discussion.

The Whole of Seabed Programme is not an action plan or a static set of outputs.

Who? The Whole of Seabed Programme draws upon sectoral and analytical expertise from across The Crown Estate. We are now engaging with a wide range of external stakeholders across all sectors, activities and industries, to ensure that we can consider appropriate social, environmental and economic factors. This will help to ensure that we have tested our analytical approaches through engagement or partnered working and that we are using the best available spatial data and evidence to represent all relevant factors within our modelling.

There will be an ongoing process of validating our data and assessing how we can update and improve it on a rolling basis. We are working closely with both UK and devolved governments to ensure our approach takes account of policy and that our outputs are made available to them as a source of evidence.

Why? As managers of the seabed, we have a responsibility to manage it in the most sustainable and efficient way, to help meet our net zero and biodiversity targets whilst considering social, environmental and economic value. In doing so, we ensure that our management of the seabed supports The Crown Estate's guiding purpose of creating shared and lasting prosperity for the nation, as well as enabling Government policy and supporting UK industry.

To make the most informed decisions about how we manage the seabed, we must use the best available data and evidence. Over the last 20 years of seabed management in the UK, we have significantly advanced our spatial modelling tools and capabilities, learning valuable lessons through spatial design and analysis for the range of activities we manage.

The Whole of Seabed Programme was created both to consolidate this learning from processes such as our **Round 5 Offshore Wind Leasing**, including the engagement on the analysis used to inform it, as well as to fill a critical gap in the world of UK marine data and evidence – how to create a holistic view of our marine environment over the long-term, grounded in data. Working alongside our full range of stakeholders, we are continuing to advance our spatial data and evidence capabilities through our Whole of Seabed Programme, to ensure future sustainable use and protection of the seabed are considered in the highest possible detail, depth and clarity.

Summary

When? The Whole of Seabed Programme is a multi-year initiative of analytical capability development and evidence creation, enabling The Crown Estate in collaboration with marine stakeholders to evolve its approach to seabed management through creating cutting-edge data and evidence. Once these capabilities and holistic evidence are fully embedded into our ways of working, the Programme itself will come to a close, enabling us to take a Whole of Seabed Approach to our seabed management. As the capability will develop iteratively, we will review the Programme's progress on a yearly basis until that time. In line with this, we will equally provide an annual update on the Programme and analysis we have undertaken.

The Programme's first year of development has seen it progress from an ambition to an operational analytical capability, which has produced initial outputs. These include developing a refreshed spatial understanding of the seabed resources for 10 sectors based on our new methodologies (for further refinement), creating a holistic view of the resources and needs for nature and its recovery as well as building a technical capability to run multi-sector scenarios.

As more data becomes available, and as we engage with stakeholders in more depth, we will assess and evaluate how further spatial analysis and scenarios need to be run to ensure we capture the best available data and evidence.

Due to the ongoing and iterative nature of the Programme, the outputs will continue to change over time. We will engage with stakeholders throughout this process, to share our latest insights and understanding and to integrate stakeholder feedback into our approach.

How will it be used? The Whole of Seabed evidence base and analysis capability will be offered to inform external programmes we engage in such as UK Government's Marine Spatial Prioritisation Programme and National Grid ESO's Strategic Spatial Energy Plan. Whole of Seabed evidence alongside partner information will also inform a long-term delivery strategy out to 2050 for the marine space. It will underpin the Marine Delivery Routemap, a collaborative initiative convened by the The Crown Estate to coordinate action across agencies and sectors to deliver on Net Zero and Nature Recovery. Aligned to this, it will also inform the The Crown Estate's own seabed management and leasing activity for sectors that it manages.

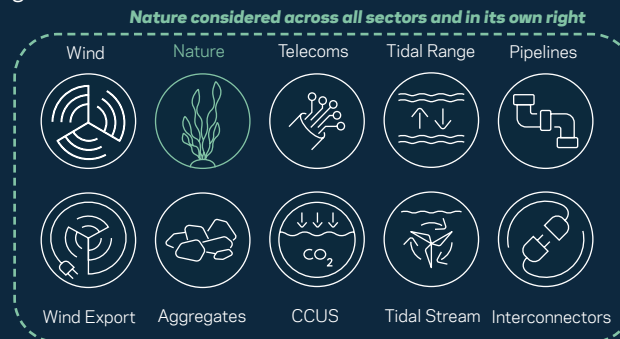


Photo credit: Keith Hiscock


Appendix 2:

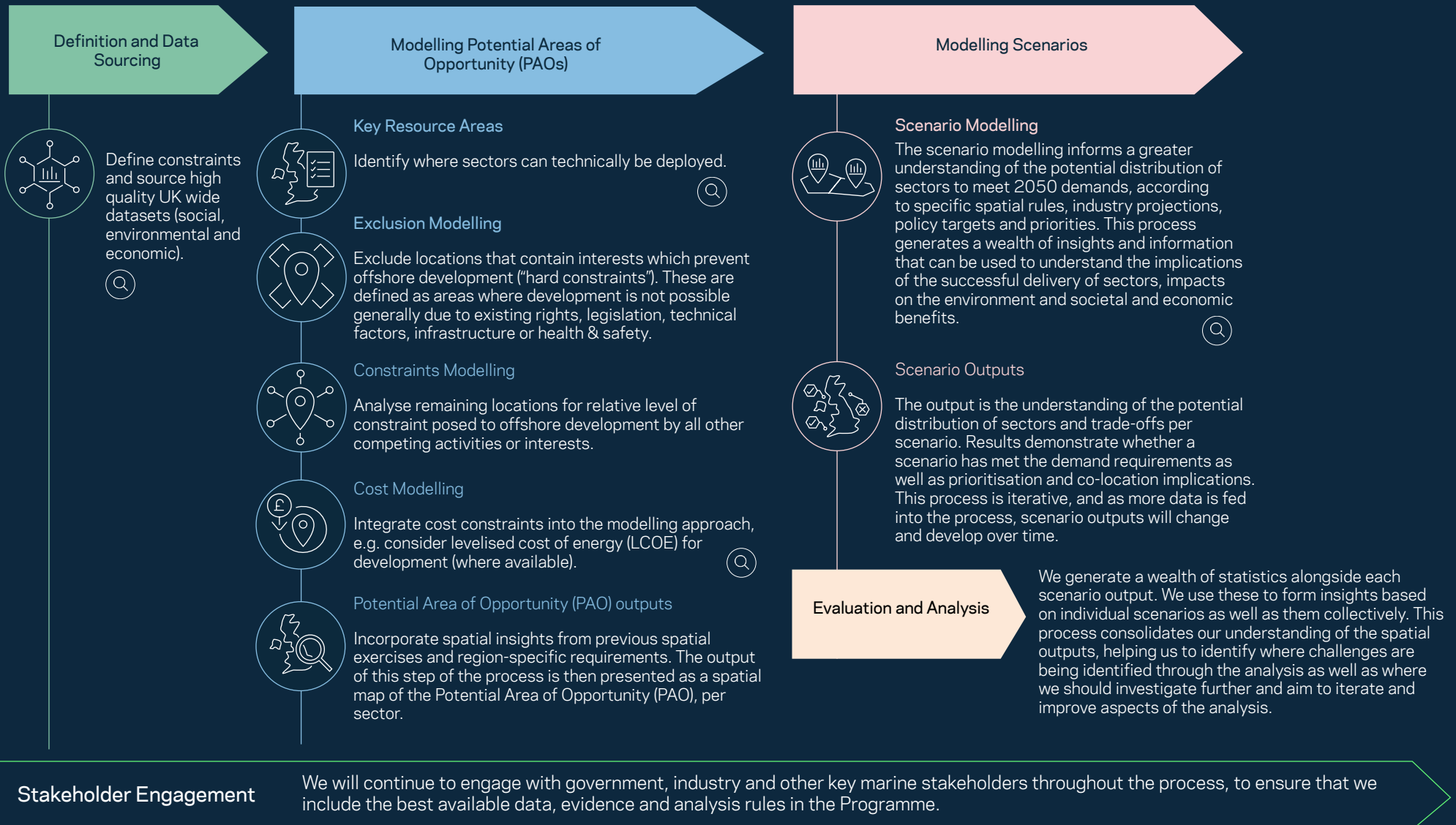
Whole of Seabed Programme Methodology Overview



Photo credit: Keith Hiscock

Whole of Seabed Methodology Overview

 This symbol illustrates the quality assurance process (QA), conducted to ensure outputs are reliable and that only high quality datasets have been used in the modelling process.





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