Future environmental scenarios for offshore wind expansion:

Methodology recommendations

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Further information

This report can be downloaded from the Natural England Access to Evidence Catalogue: http://publications.naturalengland.org.uk/. For information on Natural England publications contact the Natural England Enquiry Service on 0300 060 3900 or email enquiries@naturalengland.org.uk.

Executive summary

The Department for Business, Energy & Industrial Strategy, The Crown Estate and Crown Estate Scotland commissioned a study to scope out illustrative scenarios for future offshore wind expansion in UK waters and understand the trade-offs associated with them (ARUP, 2022). This report identified 190 scenarios through an analysis of costs and spatial constraints.

The publication of ARUP (2022) presents an opportunity to evaluate the environmental impacts associated with the scenarios identified. The results of such an exercise would be highly informative for the sector as they should help to identify barriers to development and facilitate early consideration of mitigation or any compensation requirements associated with illustrative future deployment scenarios.

The purpose of the current report is to outline a range of methods that have potential to be applied to evaluate the environmental risks associated with scenarios identified by ARUP (2022).

Through a process of review and conceptualisation, this report has identified four methods as applicable for the evaluation of environmental risk associated with the multiple scenario outputs of ARUP (2022). These methods are evaluated against a framework and recommendations on their suitability are made.

Contents

1. Introduction

Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

The expansion of offshore wind is a key element of the UK's Net Zero and Energy Security strategies. By 2030, Government has committed to produce 50 GW of energy from offshore wind, and by 2050 the total could rise to at least 100 GW. Meeting this target will require a significant acceleration in development.

Against this backdrop, The Department for Business, Energy & Industrial Strategy ("BEIS"), The Crown Estate and Crown Estate Scotland commissioned a study to scope out illustrative scenarios for future offshore wind expansion in UK waters and understand the trade-offs associated with them (ARUP (2022). This identified 190 scenarios through an analysis of costs and spatial constraints. The study was part of the Offshore Wind Evidence and Change Programme led by The Crown Estate, together with its Programme partners, BEIS and the Department for Environment, Food and Rural Affairs.

The publication of ARUP (2022) presents an opportunity to evaluate the environmental impacts associated with the scenarios identified. The results of such an exercise would be highly informative for the sector as they should help to identify barriers to development and facilitate early consideration of mitigation or any compensation requirements associated with illustrative future deployment scenarios.

The purpose of the current report is to outline a range of methods that have potential to be applied to evaluate the environmental risks associated with scenarios identified by ARUP (2022). The report has been commissioned by Natural England and prepared by NIRAS Group UK ("NIRAS").

2. Model outputs from ARUP (2022) introduction

Scenarios and clusters

ARUP (2022) presents 190 scenarios presented on a 2 km^2 hexagonal grid. Each scenario is divided into a cluster of grid cells representing an array.

For the purposes of the report it is assumed that any evaluation of environmental risk will be carried out at the scenario level and that the scenarios are made up of multiple cluster areas. It is assumed the entirety of the illustrative scenario represents potential areas for development.

Infrastructure

The scenarios presented in ARUP (2022) do not include export cable routes. However, for the purposes of this report, it is assumed that it will be possible to define export cable routes once the scenarios are known, either at a broad scale (‘regions’ e.g. by identifying the maximum range of potential connection options to the National Electricity Transmission System) or at a finer scale (‘corridors’ e.g. as a result of the outcome of the Offshore Transmission Network Review). Within each scenario, clusters represent either fixed foundation (monopile or jacket) or floating.

3. Methods

Scope

The assessment of environmental impacts is limited to impacts from array and export cable routes on designated sites within or spanning English boundaries, onshore and offshore out to 200nm. Designated sites, in this case, refers to:

- Special Areas of Conservation ("SAC")
- Special Protection Areas ("SPA")
- Ramsar sites
- Marine Conservation Zones ("MCZs").

The terminology used to describe the overall negative effect of any environmental impacts differs between the designations (e.g. adverse effect on site integrity, significant effect etc). For the purposes of this report, the term 'environmental risk' has been adopted for consistent use among all designations.

Identification of applicable methods

A review of relevant offshore wind strategic environmental assessments has been carried out to identify a range of potential methods that could be directly applied to evaluate the environmental risk associated with each scenario. The Strategic Environmental Assessments considered within this review are presented in Table 1.

Table 1. Strategic Environmental Assessments Reviewed.

Strategic Environmental Assessment	Description
OESEA	SEA for UK offshore waters and territorial waters of England and Wales
OESEA2	SEA for UK offshore waters and territorial waters of England and Wales
OESEA3	SEA for UK offshore waters and territorial waters of England and Wales
Sectoral Marine Plan	Plan to identify sustainable plan options for the future development of commercial-scale offshore wind energy in Scotland, including deep water wind

Strategic Environmental Assessment	Description
	technologies, and covers both Scottish inshore and offshore waters
Extensions Plan Level HRA	The Crown Estate's Plan Level HRA for the Round 3 Extensions Plan. English and Welsh waters.
Round 4 Plan Level HRA	The Crown Estate's Plan Level HRA for the Round 4. English and Welsh waters.
Round 4 MCZ Assessment	An MCZ Assessment carried out by The Crown Estate in English and Welsh waters.

The review found that the above strategic environmental assessments relied on a screening step to identify specific features and pressures (associated with offshore wind) to take forward for assessment. The second step of the assessment is often undertaken at a high level, where precise and definitive assessment is generally deferred to the project level. However, some of the more recent plan-level assessments for Round 4 contained sufficient detail to develop meaningful conclusions on environmental risk. These methods have therefore been reviewed and modified to suit the objectives of this project, and are presented in Results.

In order to evaluate suitability, each method has been assessed against a framework. The criteria used within this framework have been identified as being those most important to the delivery of Natural England's objectives for this project: repeatability, cost and ability to inform mitigation and compensation requirements (Table 2).

Table 2. Framework for the evaluation of method suitability

Criteria	Description
Repeatability	Ability of the method be applied consistently among scenarios.
Cost Upfront	Approximate initial set-up costs, including assessment of the first scenario. This is predominantly a function of time, though there may be costs associated with soft-ware and data collection/access. Each cost is an estimate. The true cost can only be determined once the final scope is defined.

Criteria	Description
Cost per Scenario	Approximate costs associated with repeated assessments for each scenario (a function of time). As above, this is predominantly a function of time. Each cost is an estimate. The true cost can only be determined once the final scope is defined.
Efficacy	Ability to inform mitigation and compensation requirements

4. Results

Overview of methods identified

Through a process of review and conceptualisation, four methods have been identified as applicable approaches for the evaluation of environmental risk associated with multiple scenarios.

1. Full Assessment - environmental risk is determined by full screening (stage 1), then by undertaking an assessment of impacts for each feature/pressure relationship (stage 2) in a manner similar in character to project-level HRAs or MCZ assessments.
2. High Level Screening & assessment of indicative key target features– application of basic screening criteria in GIS to establish connectivity with key features only, followed by further assessment. to .
3. Risk Based Approach- determines environmental risk by combining scores assigned to represent both the feature’s and the designated site’s vulnerability to offshore wind development. The envisaged product is a web-based tool that would score any area of sea as high, medium or low risk.
4. Single Issue Models - determines environmental risk by focussing on a select group of feature/pressures relationships to calculate an apportioned impact for any given area. The envisaged product is a web-based tool, which could be used to compliment methods 2 or 3.

Method 1: full assessment

Description

Under Method 1, environmental risk is determined by undertaking a full assessment of impacts for key feature/pressure relationships, similar in character to aspects of project-level HRAs or MCZ assessments. Screening (stage 1) is recommended as a precursor to this approach as it would focus the assessment (stage 2) to only those sites and features within range for the selected pressures. An example of this style of assessment at the plan level is the Round 4 Plan Level HRA.

Stage 1

Screening allows systematic criteria to be applied to identify which features and pressures to assess in the next stage of the assessment. Screening is undertaken on features with use of specific spatial criteria that takes account of the pressures associated with offshore windfarms and the likelihood of an interaction occurring. Screening could be under-taken manually, or more preferably within web-based tools such as the forthcoming HRA Screening Tool created for The Crown Estate and the NatureScot Foraging Range screening tool, both due to become publicly available this year.

Pressures

In undertaking previous plan-level assessments, NIRAS has developed the following list of pressures that can be expected to occur during the construction and operation of the array and export cable routes of fixed and floating offshore windfarms. These have been developed in view of the pressures Natural England and JNCC use within Advice on Operations documents but represent a simplified version of those pressure (note: some pressures are only applicable to the array):

- P1 - Habitat loss / gain
- P2 - Direct physical damage
- P3 - Indirect physical damage/habitat change
- P4 - Collision (marine mammals and fish)
- P5 - Collision (birds)
- P6 – Collison (bats)
- P7 - Physical Presence (visual disturbance and barrier effects)
- P8 - Underwater noise (including, disturbance, injury and death)
- P9 - Above water noise
- P10 - Toxic contamination
- P11 - Electromagnetic Fields (EMF)
- P12 - Light
- P13 - Temperature
- P14 - Suspended sediments
- P15 - Invasive non-native species
- P16 - Entanglement (only applicable to floating offshore windfarms)

Interaction

Features are screened in if an overlap is found to exist between the range of a pressure and a feature’s distribution. Therefore, for sessile species only the range of the pressure needs to be considered; but for mobile species, the ranging behaviour of the species and the range of the pressure must be considered together.

Example: Breeding Birds in the Breeding Season

To improve the efficiency of the screening process, features can be grouped into ‘receptor groups’, to which consistent spatial criteria can be applied. This is demonstrated in Table 3, which contains the spatial criteria used for the pressures applicable to the receptor group ‘Breeding Birds in the Breeding Season’ (i.e. breeding seabird features). The table makes a distinction between pressures that occur in a fixed location (e.g. collision with wind turbine) and pressures that can occur at range (e.g. suspended sediment). For the latter category, a 15 km buffer is applied to account for this movement.

Table 3. Method 1. Example Screening Criteria.

Pressures used for Screening	Spatial Criteria used for Screening
P1 Habitat loss / gain A loss of habitat for prey species as a result of infrastructure during the operational phase	Foraging range of each species as described in Woodward *et al*. (2019).
P2 Direct physical damage Damage to habitat utilised by prey species as a result of activities associated with construction	Foraging range of each species as described in Woodward *et al.* (2019).
P3 Indirect physical damage Damage to habitat utilised by prey species as a result of activities associated with construction	15km+ Foraging range of each species as described in Wood-ward *et al*. (2019).
P5 Collision (birds) Direct collision risk to birds from operational array	Foraging range of each species as described in Woodward *et al*. (2019).
P7 Physical Presence (visual disturbance and barrier effects) Physical presence of vessels and infrastructure during construction and operation phases, leading to displacement of birds	15km+ Foraging range of each species as described in Wood-ward *et al*. (2019).
P8 Underwater Noise Noise generated during construction and operation adversely affecting prey species or leading to displacement of birds	15km+ Foraging range of each species as described in Wood-ward *et al*. (2019).

Pressures used for Screening	Spatial Criteria used for Screening
P9 Above water noise Noise generated during construction and operation leading to displacement of birds	15km+ Foraging range of each species as described in Wood-ward *et al*. (2019).
P10 Toxic contamination Toxic contamination during construction or operation adversely affecting prey species or birds	15km+ Foraging range of each species as described in Wood-ward *et al*. (2019).
P12 Light The behaviour of birds could be affected by light pollution during the construction and operation phases	15km+ Foraging range of each species as described in Wood-ward *et al*. (2019).
P14 Suspended sediments Addition of suspended sediments adversely affecting prey species during the construction phase	15km+ Foraging range of each species as described in Wood-ward *et al*. (2019).
P16 Entanglement Entanglement of birds during the operational phase (applies to the mooring lines associated with floating offshore wind-farms only)	15km+ Foraging range of each species as described in Wood-ward *et al*. (2019).

Refinement of screening outputs

Screening scenarios that cover a wide geographical area will result in a substantial number of feature/pressure relationships being taken forward for a full assessment. However, there may be opportunities for refinement by selecting only the key feature/pressures (identified through expert judgment) to screen. For example, we know from previous planning decisions that the key risks from offshore wind development are likely to be:

- Impacts associated with collision (P5) and physical presence of infrastructure (P7) on seabird features
- permanent loss (P1) or damage (P2) to key habitat features, and

- impacts of underwater noise on marine mammal features.

Stage 2

Stage 2 would differ depending on the feature/pressure under investigation. A specific example is the assessment of the harbour porpoise feature of the Southern North Sea SAC to establish the disturbance effect of underwater noise. The assessment would follow standard industry guidance (JNCC, 2020), but in order to apply this approach at the scenario level, worst case parameters must be identified. The key parameter requirements for this approach would be piling frequency, number of piling events and piling location. On a highly precautionary basis, it can be assumed that all pile driving will be located at the closest position within each scenario to the Southern North Sea SAC and that one piling event will take place each day. Using a 26 km Effective Deterrent Radius, the worst case % area of the SAC affected can be calculated on a daily and seasonal basis. Other plans and projects likely to be contributing underwater noise in the same area at the same time, could also be assessed in the same manner. The outputs can be compared against the thresholds provided in JNCC (2020), which will provide an understanding of in-combination risk. In this way, way informed decisions can be made on the likelihood of mitigation and compensation requirements.

Evaluation

Method 1 requires high levels of assessor input to repeat stages 1 and 2 for multiple scenarios. The cost is dependent on the number of feature/pressure relationships screened in, but assuming a refined list of key feature/pressure relationships are screened for using an automated web-based tool, then the cost to apply this method to the first scenario would be approximately £30,000. Following this, subsequent scenario repetitions are likely to be cheaper as the assessment tools would already be set-up (e.g. in spreadsheets), but still relatively time consuming (nominally around £10,000 per scenario but it would be expected that significant economies of scale could be achieved if analysis of more than 4-5 scenarios was required'). A key attribute of this method is that it provides a very detailed assessment of environmental risk for key feature/pressure relationships, which can be used to quantify the potential mitigation or compensation requirements attached to each scenario. A summary of this evaluation is provided in Table 4.

Table 4. Method 1 Evaluation Summary.

Criteria	Assessment
Repeatability	Method 1 requires high levels of assessor input to repeat for multiple scenarios.
Cost Upfront	Approximately £30,000

Criteria	Assessment
Cost per Scenario	Nominally around £10,000 per scenario but it would be expected that significant economies of scale could be achieved if analysis of more than 4-5 scenarios was required.
Efficacy	A key attribute of Method 1 is that it provides a very detailed assessment of environmental risk for key feature/pressure relationships, which can be used to quantify the potential mitigation or compensation requirements attached to each scenario

Method 2: targeted screening (& follow up assessment) of key features

Description

Method 2 is a 'quick connectivity check' that considers the location of each scenario against the locations of designated sites (JNCC's designated site data layer) for a handful of key features. These features would be those that typically have the potential to be the most effected (the most sensitive). This differs the normal approach to plan level assessment, which generally sees all features being screened for. Key bird features might include Kittiwake and red-throated diver, and sandbanks and reef for habitats. This method applies basic screening criteria in GIS to establish connectivity with key features to infer the level of risk associated with each scenario. Suggested screening criteria for receptor groups containing key features are provided in Table 5. It does not quantify the impact of specific pressures; nor does it consider the in-combination impact of other plans and projects. In order to do that, this method should be combined with methods 1 or 4. This method is the most basic of the methods assessed within this report, but it is a variation of an approach that is frequently applied to identify environmental risk for offshore windfarm investors at an early stages of development (e.g. for due diligence exercises).

Table 5. Method 2: Suggested Screening Criteria for key receptor groups.

Receptor Group	Screening Criteria
Seabirds (breeding and overwintering features) e.g. kittiwake or red-throated diver	Foraging range of each species as described in Woodward *et al*. (2019) for breeding features. For overwintering features, the SPA plus a suitable buffer (usually 15km) could be used.

Receptor Group	Screening Criteria
Marine Mammals e.g. harbour porpoise	26 km is frequently used to assess disturbance on cetacean species in the UK, and it is derived from a literature review used to inform SNCB guidance (JNCC *et al*., 2020)
Benthic Habitats e.g. sandbanks	15 km based on average tidal ellipse

Evaluation

Method 2 is highly repeatable due to its simplicity. Given the small number of species/habitats considered, the cost up front would be approximately £5,000 and subsequent iterations would be in the region of £1,000. Method 2 is a useful 'quick check' option that will give an indication of any potential areas for further investigation but as this method only establishes connectivity, any inferences made for each scenario will not be accurate enough to form the basis of final decisions on mitigation and compensation requirements (unless combined with a manual or automated method (such as Methods 1 and 4)). A summary of this evaluation is provided in Table 6.

Table 6. Method 2 Evaluation Summary.

Criteria	Assessment
Repeatability	Method 2 is highly repeatable due to its simplicity
Cost Upfront	Approximately £5,000- to source and generate the distribution layers for a limited number of features.
Cost per Scenario	Approximately £1,000
Efficacy	A useful 'quick check' option that will give an indication of any mitigation or compensation requirements; but as this method only establishes connectivity, any inferences made for each scenario will not be accurate enough to form the basis of final decisions on such requirements. As such, Method 2 should be combined with a detailed assessment method (e.g. Methods 1 or 4 (below).

Method 3: risk-based approach

Description

Method 3 would evaluate the scenarios by identifying high risk areas within or in close proximity by combining scores (high, medium and low) assigned to represent both the feature's and the designated site's vulnerability to offshore wind development. A feature's vulnerability is established in view of its distribution and its sensitivity to specific pressures. Designated site vulnerability is established in view of the in-combination risk and the condition of the site. Once combined using a matrix, the overall score will give an indication of the nature and extent of mitigation and compensation requirements as areas with a high overall score will be more likely to require mitigation or compensation then areas with a low score. The envisaged product is a layer for each feature on hexagonal grid that matches the outputs of ARUP (2022). These could be used manually to overlay with each scenario and run spatial analysis to determine which areas are overlapped/in the vicinity of the scenario, or created as a web-based tool, so any scenario could be overlayed to get an instant indication of the environmental risks (without the need for a GIS analyst or desk-based software). This tool would require minimal maintenance; only periodic updates to incorporate any changes to the datasets underpinning the scoring system. The tool would need to be hosted, so there would be a small hosting cost after the project ends.

An example scoring system is described in more detail below.

Feature vulnerability

This score is derived by combining scores for two sub-criteria: A score representing a feature's distribution and a score representing a feature's sensitivity to specific pressures.

A score representing a feature's distribution can be derived by combining scores representing a feature's proximity to designated sites with scores representing the feature's density in a matrix. Both scores will depend on scores for density depends on the biology of receptor group. Additionally, the score for feature density will depend on the availability of density data. Modelled densities provide indicative UK distributions and are available for seabirds (Waggitt *et al*. 2020 and Kober *et al.* 2010) and marine mammals (Waggitt *et al.* 2020 and Carter *et al*. 2020). A combination of these datasets would be required in order to achieve adequate species/spatial coverall, with preference given to datasets created with more advanced/improved modelling techniques (e.g. Waggit *et al*. 2020). Scoring thresholds for density can either be determined from the literature or using tools in GIS (e.g. a Natural Jenks Breaks Classification). Where density data is unavailable (e.g. fish), a matrix will not be required, as feature proximity on its own can be used to establish a score for a feature's distribution. As habitat features are generally located within the boundaries of a designated site, to score a habitat feature's distribution it is preferable to use a measure of percentage cover to determine high medium and low categories.

Information to score a feature's sensitivity to specific pressures can mostly be derived from the scientific literature and conservation advice published by NE. In some cases, where feature specific information is unavailable, species and habitats with similar characteristic can be used as a proxy. Individual pressures associated with that feature are scored a single overall score, which is based on the highest scoring pressure.

Designated site vulnerability

This score is derived by combining scores for two sub-criteria: A score representing a designated site's condition and a score representing a spatial in-combination threat. The condition of designated sites can be obtained and scored from information documents published by JNCC and Natural England. For example, a high score would be awarded to those sites in unfavourable condition. To score the in-combination threat, existing data layers can be used to identify activities that exert the same pressures being evaluated. For, example, for collision risk all planned or built windfarms would be relevant; whereas for habitat loss relevant activities would extent to other structures like oil and gas platforms, cables and pipelines. For each data layer, clusters would be identified to in order to assign feature/pressure-specific scores for an area.

Evaluation

The initial set up of the scoring system and risk layers takes time, but once incorporated into a web-based tool, this method is highly repeatable for each scenario. The cost of this set-up is likely to be in the region of £60,000 (£30,000 to develop the layers and £30,000 to develop the web-based tool). As the tool would be publicly available on a user-friendly interface, there would be no cost to each scenario iteration (provided no further interpretation is needed). This method falls short of a full assessment, as specific impacts are not quantified. Nevertheless Method 3 provides a consistent and systematic way to identify high risk areas for a high number of feature/pressure relationships against the proximity to multiple scenarios. The overall score will give an indication of the nature and extent of mitigation and compensation requirements as areas with a high overall score will be more likely to require mitigation or compensation then areas with a low score. A summary of this evaluation is provided in Table 7.

Table 7. Method 3 Evaluation Summary.

Criteria	Assessment
Repeatability	This method is highly repeatable for each scenario, once the initial set-up is completed.
Cost Upfront	Approximately £60,000
Cost per Scenario	NA as final output is envisaged to be a publicly available web-based tool

Criteria	Assessment
Efficacy	This method falls short of a full assessment, as specific impacts are not quantified. Nevertheless Method 3 provides a consistent and systematic way to identify high risk areas for a high number of feature/pressure relationships. Once mapped, the scores can be used to judge the potential mitigation or compensation requirements attached to each scenario.

Method 4: single issue models

Description

Method 4 determines environmental risk by focussing on the assessment aspect of a select group of feature/pressures relationships to calculate an apportioned impact for any given area. It could either be semi-automated or fully automated in a web-based tool.

Method 4 could be used as an add-on to methods 2 and 3 if a more detailed approach is required in order to quantify mitigation or compensation requirements. For example, this method could be deployed if an evaluation undertaken with Method 3 were to identify any high risk areas that require further investigation. Depending on the method used, future development options could include building capability to hand draw or import polygons to allow use at the project level (but for the context of this work it would need to be designed to work with the hexagonal grided scenario clusters). Possible options include models to determine the extent of the impact associated with:

- Marine Mammals Noise Disturbance
- Habitat Loss
- Collison risk or displacement for birds (illustrated in the below example)

Total breeding and non-breeding collision and displacement impact mapped per hexagonal grid cell

This approach relies on UK wide density data for seabirds. Modelled density surfaces provided by Marine Ecosystems Research Program (MERP; Waggit *et al*., 2020) or Joint Nature Conservation Committee (JNCC; Kober *et al*., 2010) provide annual density data in UK waters using 10 km^2 and 6 km^2 grid sizes respectively. The MERP dataset is preferred but only includes 12 species, for remaining species the JNCC dataset would be used. To capture fundamental differences in at-sea distribution these density data would be split into breeding and non-breeding seasons. JNCC data are provided already split into seasons (see Kober *et al*., 2010 for method), but MERP data are provided by month, which can be assigned to either breeding or non-breeding seasons using the seasonal definitions presented in Furness (2015). Monthly densities are required by the Band (2012) collision risk model, which conform with the format from MERP; however, seasonal JNCC density values would need to be attributed to their constituent months to approximate monthly density (accepting a degree of uncertainty). Displacement analyses are calculated per season, which conforms with the format of both density datasets.

In addition to the above density data, additional information would be required to parameterise collision risk models and displacement analyses. For collision risk, species-specific model parameters such as flight height and avoidance rates will follow current guidance, and turbine parameters will follow a generic windfarm setup (number turbines per km^2, turbine size etc). Collision risk modelling could be run in R using specifically designed code (SNH 2018a). For displacement analyses species specific displacement and mortality rates will follow current guidance. Collision risk models and displacement analyses could be run on each individual hexagonal grid cell of seasonal density data, outputting the predicted total number of birds killed by collision or displacement per hexagonal grid cell in the breeding season or the non-breeding season. These can then be mapped over UK waters providing a spatial estimate of collision and displacement risk per species in each season.

Total collision and displacement impact per hexagonal grid cell apportioned to designated sites

The above calculated collision or displacement impacts could be apportioned to populations from designated sites to provide number of birds from designated site impacted per hexagonal grid cell per year. Apportioning methods are dependent on season: In the breeding season the method developed by SNH (2018b) captures the importance of near-colony activity in a simple and consistent way, whereas in the non-breeding seasons the BDMPS method developed by Furness (2015) captures dispersal of seabirds across broad sea regions.

The SNH (2018a) method requires information on species foraging ranges (e.g. Woodward *et al.* (2019), or site-specific tracking if available), and UK seabird colony locations and population sizes (e.g. JNCC Seabird Monitoring Program data). Using these data and geographic constraints (access to sea and distance to colony), the SNH (2018b) apportioning method calculates the number of adult birds originating from each designated site for any given location. In our case this location would be each breeding density hexagonal grid cell, and using the number of adult birds originating from each designated site, the proportional weight for each designated site would be attributed to each grid cell. This designated site weighting would be applied to the corresponding total breeding collision or displacement impact value to divide the total number of birds impacted by collision or displacement per grid cell in the breeding season into components for each designated site.

The BDMPS approach uses proportions of UK designated site populations which are distributed evenly across broad sea areas (BDMPS units). The BDMPS units could be mapped to overlap the non-breeding density data, and UK designated site population proportions could come from Appendix A of Furness (2015). The non-breeding season can be considered as a whole, but if population contributions to BDMPS units in Furness (2015) differ within this period (e.g. in Autumn, Winter and Spring), the maximum value can be taken on a precautionary basis. Similarly to the SNH (2018b) apportioning method above, distributing Furness (2015) proportions of UK designated site populations across BDMPS units can provide the number of adult birds originating from each designated site for any given location (each non-breeding density hexagonal grid cell), providing the proportional weight for each designated site for each grid cell. This designated site weighting can be applied to the corresponding total non-breeding collision or displacement impact value to divide the total number of birds impacted by collision or displacement per grid cell in the non-breeding season into components for each designated site.

Scenario cluster total and establishing in-combination risk

With the above in place it will be possible to overlay scenarios and clusters (or even draw a polygon around multiple clusters) and calculate total impacts for each area from the underlying hexagonal grid cells. Code can be written to automatically add this total to existing in-combination impact totals, which will give the user an up-to-date understanding of in-combination risk.

Evaluation

This example provided above is highly repeatable for each scenario, once the initial set-up is completed. The cost for each tool is likely to be equivalent to the costs associated with Method 3, but there would be no costs associated with scenario re-runs as it is envisaged that the tool would be made public. This tool could be used to quantify the impact of key pressures within defined sea areas, which in turn could be used to specify detailed mitigation or compensation requirements. A summary of this evaluation is provided in Table 8.

Table 8. Method 4 Evaluation Summary.

Criteria	Assessment
Repeatability	This example provided above is highly repeatable for each scenario once the initial set-up is completed.
Cost Upfront	£60,000
Cost per Scenario	NA
Efficacy	This tool would be used to quantify the impact of key pressures within defined sea areas, which in turn could be used to specify detailed mitigation or compensation requirements

5. Summary and recommendations

Through a process of review and conceptualisation, NIRAS have identified four methods as applicable for the evaluation of environmental risk associated with the multiple scenario outputs of ARUP (2022):

1. Full Assessment - environmental risk is determined by screening (stage 1), then undertaking an assessment of impacts for each feature/pressure relationship (stage 2), similar in character to project-level HRAs or MCZ assessments
2. High Level Screening (and follow up assessment) of indicative key target features– application of basic screening criteria in GIS to establish connectivity with key features to infer the level of risk associated with each scenario
3. Risk Based Approach- determines environmental risk by combining scores assigned to represent both the feature's and the designated site's vulnerability to offshore wind development. The envisaged product is a web-based tool that would score any area of sea as high, medium or low risk.
4. Single Issue Models - determines environmental risk by focussing on a select group of feature/pressures relationships to calculate an apportioned impact for any given area. The envisaged product is a web-based tool, which could be used to compliment methods 2 or 3.

In order to evaluate suitability, each method has been assessed against a framework. The criteria used within this framework have been identified as being those most important to the delivery of Natural England's objectives for assessment: repeatability, cost and ability to inform mitigation and compensation requirements.

In view of this evaluation, it is recommended that the risk-based approach (Method 3) is the most suitable method for the determination of environmental risk associated with multiple scenario outputs. It provides a consistent and systematic way to identify high risk areas for a high number of feature/pressure relationships. Once mapped, the scores can be used to judge the potential mitigation or compensation requirements attached to each scenario.

The envisaged product is layer for each feature on hexagonal grid that matches the outputs from ARUP (2022). It would be created as a web-based tool, so any scenario could be overlayed to get an instant indication of the environmental risks. Method 3 is therefore highly repeatable.

In addition, it is recommended that Method 4 could be used to complement Method 3, in circumstances where a more detailed approach is required in order to quantify mitigation or compensation requirements in high-risk areas (identified by Method 3). A range of model options are possible for option 4 (seabird collision and displacement, marine mammal disturbance, habitat loss). If developed, it is likely that these models would prove useful at the project level, as they would allow for quick and consistent assessments to be undertaken for key feature/pressure relationships within any area of sea.

References

ARUP. 2022. Future Offshore Wind Scenarios: An assessment of deployment drivers. April 2022. Available from: https://www.futureoffshorewindscenarios.co.uk/assets/report/20220421_FOW_Final_Report.pdf

CARTER, M. I. D., BOEHME, L., DUCK, C. D., GRECIAN, W. J., HASTIE, G. D., MCCONNELL, B. J., MILLER, D. L., MORRIS, C. D., MOSS, S. E. W., THOMPSON, D., THOMPSON, P. M. and RUSSELL, D. J. F. 2020. Habitat-based predictions of at-sea distribution for grey and harbour seals in the British Isles. Sea Mammal Research Unit, University of St Andrews, Report to BEIS, OESEA-16-76/OESEA-17-78.

BARNES, M.K.S. 2008. Lampetra fluviatilis European river lamprey. In Tyler-Walters H. and Hiscock K. Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 17-12-2021]. Available from: https://www.marlin.ac.uk/species/detail/49.

FURNESS, R.W. 2015. Non-breeding season populations of seabirds in UK waters: Population sizes for Biologically Defined Minimum Population Scales (BDMPS). Natural England Commissioned Reports, Number 164.

JNCC. 2020. Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (England, Wales & Northern Ireland). JNCC Report No. 654, JNCC, Peterborough, ISSN 0963-8091. Available from: https://data.jncc.gov.uk/data/2e60a9a0-4366-4971-9327-2bc409e09784/JNCC-Report-654-FINAL-WEB.pdf. [Accessed 6 July 2021].

KOBER, K., WEBB, A., WIN, I., LEWIS, M., O'BRIEN, S., WILSON, L.J. and REID, J.B. 2010. An analysis of the numbers and distribution of seabirds within the British Fishery Limit aimed at identifying areas that qualify as possible marine SPAs. JNCC report, 431.

SNH. 2018a. Stochastic collision risk model for seabirds in flight. Available from: https://www.gov.scot/publications/stochastic-collision-risk-model-for-seabirds-in-flight/

SNH. 2018b. Interim Guidance on apportioning impacts from marine renewable developments to breeding seabird populations in SPAs. Available from: https://www.nature.scot/doc/interim-guidance-apportioning-impacts-marine-renewable-developments-breeding-seabird-populations

WAGGITT, J.J., EVANS, P.G., ANDRADE, J., BANKS, A.N., BOISSEAU, O., BOLTON, M., BRADBURY, G., BRERETON, T., CAMPHUYSEN, C.J., DURINCK, J. and FELCE, T. 2020. Distribution maps of cetacean and seabird populations in the North-East Atlantic. Journal of Applied Ecology, 57(2), pp.253-269.

WOODWARD, I., THAXTER, C.B., OWEN, E. and COOK, A.S.C.P. 2019. Desk-based revision of seabird foraging ranges used for HRA screening. [Online]. Available from: http://www.marinedataexchange.co.uk/ (Accessed July 2020).

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