REPORT

Development of Ornithology Regional Compensation Measures

Ornithology compensation measures

Client: NE / E ScotWind developers' group

Reference: PC4885-RHD-XX-XX-RP-X-0001

Status: Final/01

Date: 1 May 2024

HiDef AERIAL SURVEYING LIMITED

Royal HaskoningDHV Enhancing Society Together

Internal use only

HASKONINGDHV UK LTD.

Regus House
Exeter Business Park
1 Emperor Way
Exeter
EX1 3Qs
United Kingdom
Water & Maritime

+44 1392 447999 **T**
info@uk.rhdhv.com **E**
royalhaskoningdhv.com **W**

Document title:	Development of Ornithology Regional Compensation Measures
Subtitle:	Ornithology compensation measures
Reference:	PC4885-RHD-XX-XX-RP-X-0001
Your reference	
Status:	Final/01
Date:	1 May 2024
Project name:	Ornithology Regional Compensation Measures
Project number:	PC4885
Author(s):	Paolo Pizzolla, Glen Tyler, Murray Grant, Will Salmon, Jaz Harker, Ross Bower
Drafted by:	Paolo Pizzolla, Glen Tyler, Murray Grant, Will Salmon, Jaz Harker, Ross Bower
Checked by:	Murray Grant
Date:	1 May 2024
Approved by:	
Date:	

Classification
Internal use only

Table of Contents

Table of Tables

Appendices

1 Introduction

Royal HaskoningDHV and **HiDef Aerial Surveying Limited** with input from **Nima** (together the 'Project Team') have prepared this final report on potential regional compensation measures for predicted impacts on Special Protection Area (SPA) seabird populations on behalf of a developer consortium progressing offshore wind farm (OWF) projects in the Northeast (NE) and East (E) ScotWind regions.

This report follows the preparation of a 'long-list' of potential compensation measures produced by the Project Team, and a follow-up workshop held online with a range of stakeholders on 19 October 2023, as well as a separate workshop with fisheries stakeholders on 15 November 2023. The long-list was developed using the Project Team's collective experience and familiarity with measures already brought forward for existing OWF projects in Scotland and elsewhere in the UK, plus work that has already been undertaken on identifying and reviewing potential measures within UK offshore waters. The workshops sought to engage stakeholders in inputting to, and providing appraisal of, the potential measures identified, and to assist with the development of a refined list which have been considered further in this report.

A draft version of this report was produced, and a second stakeholder workshop held on 17 January 2024 to discuss the refined list and elicit further input. This report therefore incorporates comments provided on the draft and represents the final output from this project.

1.1 Background

The requirement for support in identifying potential regional scale compensation measures derives from the high levels of impacts that are predicted to occur at breeding seabird SPAs on the east coast of Scotland due to the in-combination effects from consented OWFs. As a result of these predicted impacts, it is considered that limited 'headroom'[1] remains for some seabird populations which are qualifying features (or named components of the breeding seabird assemblage qualifying feature) at several of these SPAs. Consequently, the HRA undertaken for the Sectoral Marine Plan for offshore wind energy in Scotland (the plan-level HRA – ABPmer 2019) identified that OWF developments within several of the Plan Options in the NE and E regions had the potential to result in an Adverse Effect on Integrity (AEoI) on these SPAs, resulting in these developments being subject to higher level ornithological constraints or (in two cases) a requirement for additional regional ornithology surveys to address evidence gaps.

Given the above, it is highly likely that at least some of the applications for ScotWind projects within the NE and E regions will need to be supported by a derogation case (either on a full or without prejudice basis), necessitating the provision of associated compensatory measures. An increasing number of OWF projects in the UK are having to develop compensation packages but, to date, the vast majority of these have been for projects in English waters, with the compensation measures still directed at a relatively small number of SPA populations (e.g. see McGregor *et al.* 2022). These compensation packages have been developed by individual projects working (largely) in isolation, so that the measures are essentially project-specific albeit that there have been some, limited, initiatives to collaborate and share resource burdens between projects[2].

As the requirement for compensation measures continues to increase in frequency, project-specific approaches are becoming less viable, and issues of scale and efficacy are likely to mean that delivery of compensatory measures will need to be at a regional (as opposed to project) level scale. This is particularly the case for the ScotWind projects in the NE and E regions, given the number of projects which will be

[1] 'Headroom' is defined as the difference between the predicted level of additional mortality to a given SPA population (in this case from OWF impacts) and the level considered to be acceptable (such that it is possible to conclude no AEoI).
[2] e.g. for the proposed establishment and management of a fenced nesting area for lesser black-backed gulls at the Alde-Ore Estuary SPA to exclude mammalian nest predators (MacArthur Green and Royal HaskoningDHV 2022a)

submitting applications over the next few years together with the predicted levels of existing impacts[3]. Furthermore, some of the compensatory measures being taken forward for projects in English waters may not be applicable to the situation on the east coast of Scotland. For example, the main compensatory measure proposed in relation to the Flamborough and Filey Coast (FFC) SPA black-legged kittiwake (*Rissa tridactyla*, hereafter kittiwake) population to date has been the provision and / or enhancement of additional (artificial) nest sites (MacArthur Green and Royal HaskoningDHV 2021, 2022b, Gobe Consultants and Niras 2023). However, this may be of limited value to populations on the east coast of Scotland, given that potential nesting areas in this region are possibly widely available (because of the substantial decline in the region's kittiwake population (Burnell *et al.* 2023), meaning that many previously occupied natural nest sites are now unoccupied). Ultimately, the range of species for which compensation may need to be provided and the situations in which the measures may need to be applied are likely to be considerably greater in the Scottish, than English, context. However, based upon the conclusions of the plan-level HRA, as well as the recent Berwick Bank submission and subsequent responses, the potential requirement for like-for-like compensatory measures for the ScotWind projects in the NE and E regions could be limited to northern gannet (*Morus bassanus*, hereafter gannet), kittiwake, common guillemot (*Uria aalge*, hereafter guillemot), razorbill (*Alca torda*) and Atlantic puffin (*Fratercula arctica*, hereafter puffin) (Royal HaskoningDHV 2022, NatureScot 2023a).

The challenges involved in developing compensatory measures which are practical and feasible, and which are considered acceptable by key stakeholders, has been brought into sharp focus with the submission of the Berwick Bank OWF application in the Forth and Tay region and the subsequent responses from key stakeholders on the supporting derogation case and associated compensation proposals. Thus, stakeholders have identified a number of concerns over the likely efficacy and practicality of the proposed measures, despite these representing a highly detailed and substantive package of potential measures (Pinsent Masons *et al.* 2022; NatureScot 2023b, RSPB 2023). This highlights the urgent need for careful consideration of the full range of potential options available for the provision of compensatory measures in relation to impacts on SPA seabird populations on the east coast of Scotland, including the extent to which application of the hierarchy of compensation measures (as proposed by Defra 2021 which includes non-like-for-like measures (defined in **Section 2.2.1.2.2**)) can contribute to identifying viable measures which will be sufficient to provide compensation at a regional scale.

1.2 Aims of this project

In order to minimise the risk associated with the reduction in availability of project-level compensation measures, a developer consortium progressing OWF projects in the NE and E Scotwind regions have set up this project to identify potential 'regional compensation measures' that could be utilised by the ScotWind projects. The intended outcome of the exercise would inform an individual project's derogations case under the Habitats Regulations Appraisal (HRA) Derogation Provisions through the delivery of regional scale compensation.

The scope of work is to identify the potential compensation measures that would be best suited for multiple projects being developed off the east and northeast coast of Scotland (as opposed to preparing any derogation cases or assessing the potential AEoI of any projects).

Also, this project aims to be complimentary to other work streams relating to compensation which are currently underway at both UK and Scottish level (such as the ongoing Defra-OWIC Collaboration on Offshore Wind Strategic Compensation (COWSC)[4] and work being undertaken by RSPB on behalf of Scottish Government). Through the workshops (see below), and other liaison undertaken as part of the

[3] *Current projects comprise Stour, Arven, Ayre, Stromar, Buchan, Caledonia, Broadshore, MarramWind, Muir Mhòr, CampionWind, Bowdun, Morven, Ossian and Bellrock.*
[4] *The Crown Estate and Offshore Wind Industry Council launch £3.5m project to test effectiveness of strategic environmental compensation measures | The Crown Estate*

current project, this project has sought, where possible, to take on board lessons from these other work streams (albeit without necessarily committing to follow the conclusions drawn by those projects which have very different remits) and contribute to finding workable solutions for strategic compensation.

2 Overview of approach

2.1 Approach

The approach involved a collaborative exercise to engage stakeholders in the process of defining potential measures in order to ensure that the fullest range or experience and perspectives are included and ensure that evidence has been sought from the widest range of sources. The initial long-list of measures was developed by the Project Team who then facilitated workshops and collated the resulting feedback from stakeholders.

The report details the work undertaken to meet the project aims, including the feedback on the long-list (from Workshop 1 and the Fisheries Meeting) and provides expansion upon each of the short-listed measures. A draft of this report was circulated prior to Workshop 2. Comments from stakeholders at Workshop 2 were then incorporated into this final report.

The approach is summarised in **Table 1.**

Table 1 Approach to the Project

Task	Approach	Deliverable
Long-list of potential compensation measures.	The project team developed the long-list of potential compensation measures. This was produced largely on the basis of the project team's experience and familiarity with measures that have been brought forward for existing OWF projects plus the work that has already been done on identifying and reviewing potential compensatory measures for key seabird species in Scotland and elsewhere in the UK (e.g. Furness *et al.* 2013, DTA Ecology 2020, Furness 2021, McGregor *et al.* 2022). For this long-list of measures, initial assessments were made against key specific requirements of the Habitats Regulations with a rationale and justification set out in each instance. Ranking of the potential measures was undertaken on the basis of this process of assessing against key requirements, again with associated rationale and justification.	**Long-list of potential compensation measures**, ranked on the basis of key requirements. Produced in format suitable for circulation to Workshop 1 participants.
Workshop 1: Appraisal of the long-list of potential compensation measures with stakeholders.	Based upon the circulated long-list of potential measures (see above) and associated (brief) presentation at the event, Workshop 1 engaged stakeholders in inputting to, and providing appraisal of, the options. The aim was to determine the extent of agreement with the ranking and the potential viability of the identified measures for providing regional scale compensation in the NE/E ScotWind regions. The workshop included consideration of the potential need for non-like-for-like compensation measures (as defined in **Section 2.2.1.2.2**) to assess the extent to which stakeholders consider this necessary and the perceived pros and cons of this.	**Refined shortlist of potential compensation measures** including only those from the original long-list which were considered to have some potential for providing regional

Task	Approach	Deliverable
		scale compensation in NE/E regions.
Fisheries Consultation	Consultation was held with fisheries stakeholders to discuss the outcomes of Workshop 1 with particular focus on potential interactions with fisheries.	**Additional input to the refined shortlist**
Draft Report on compensation measures	The refined shortlist of potential compensation measures from Workshop 1 was developed in the draft report. This development included any further insight into, and information on, the key specific requirements as set out for the initial long-list and following the discussions and input from Workshop 1. This Draft Report covered: a) Summary of proposed measures. b) Confidence in the likelihood of the measures offsetting impacts (i.e. ecological basis and rationale as determined from the available evidence). c) Species that would benefit (with the focus on those which are considered most likely to be potential candidates for regional-scale compensation). d) Estimation of the extent of compensation that may be required and could be achieved by the different measures (based on the expectation that agreement on broad categories with the NE/E ScotWind region developers would be established). e) Outline of the further work required on the shortlisted compensation measures to identify what is still needed to confirm the validity of each.	**Draft report (circulated prior to Workshop 2)**
Workshop 2: Discussion and consideration with stakeholders of the refined list and associated draft report.	Based upon the circulated refined shortlist, invited feedback and associated (brief) presentations at the event, Workshop 2 sought to determine the views of the stakeholders on these measures, the rationale/justification for them and their potential viability. This included consideration of the extent of agreement on key elements, such as the level of confidence in the measure as an option for delivering regional scale compensation and (where relevant) the further work required to provide adequate confidence.	**Details of stakeholder views** on the refined shortlist and key associated elements for incorporation into the Final Report.
Production of Final Report.	Updating of the draft report to reflect the discussions and views of stakeholders from Workshop 2.	**Final Report**

2.2 Definition of compensation

The term ‘compensatory measures’ is not defined in the Habitats Directive (EC, 2019). Having a definition for compensation is critical to justifying what measures may qualify as compensation. It is considered that this definition is particularly key where non-like-for-like measures are proposed, and it is therefore not immediately apparent how a measure may relate to the conservation objectives of SPAs or to the impacts that may be affecting one or more of the qualifying features.

This section therefore proposes a definition, and sets out a rationale for the definition. This section does not provide any rules for how measures would be comprised or judged (in terms of geography, scale, ratios etc), and it is assumed that these would be defined by Government or through further collaborative work outwith the scope of the current Project.

2.2.1 Proposed Definition

For the purposes of the Project, compensatory measures are defined as:

Measures taken to ensure that the overall coherence of the network of European sites as a whole is protected in the event that AEoI is concluded for a plan or project.

The compensatory measures should provide equivalent benefit to the site network that has been deemed to be lost and may comprise measures that (in order of preference):

1. *Address same impact at the same location*
2. *Provide the same ecological function at a different location*
3. *Provide comparable ecological function at the same location*
4. *Provide comparable ecological function at a different location*
5. *Deliver wider ecological systems benefits which have been determined to benefit the site network*

2.2.1.1 Ecological function definitions

Definitions are taken from Defra (2021):

"Same ecological function" refers to a feature, habitat, or species that provides the same environmental benefit to the environment as the one that is impacted as a result of a marine activity. This is usually the same species, feature or habitat.

"Comparable ecological function" refers to a feature, habitat, or species that provides similar but not exactly the same, environmental benefit.

2.2.1.2 Rationale

2.2.1.2.1 Overall coherence of the network

It is important to bear in mind that compensation should benefit the *site network*, not a single feature or species. This is critical as the options for measures directly related to the feature and location affected may be limited (or non-existent) and non-like-for-like options are required in order to provide the necessary compensation in such instances.

This principal is clearly stated in the Habitats Directive Article 6 (4) (EC, 1992)

"….the Member State shall take all compensatory measures necessary to ensure that the overall coherence of Natura 2000 is protected"

2.2.1.2.2 Hierarchy of measures

The wording is adapted from Defra (2021) which explains that:

The underlying principle is that compensatory measures that benefit the same feature which is impacted by the development will be the most preferable as they balance the damage caused by the development. Each step down the hierarchy moves away from like for like measures and therefore may decrease the certainty of success, and therefore increase the extent of compensation required. The key is to ensure the biological structure and function of the network is maintained. The more significant the impact to the protected feature or species, the more important it is that compensatory measures are developed within steps 1 and 2 of the Hierarchy of Compensatory Measures[5].

'Non-like-for-like' measures are considered to be any measures that do not directly relate to the original impact on the affected SPA population, in contrast to like-for-like measures such as compensating for collision mortality of a particular species from a specific SPA by increasing the breeding productivity of that population. Non-like-for-like measures follow a gradation of preference as the proposed measures target different populations of the same species (same ecological function), different species or different locations (comparable ecological function) with wider ecological systems benefits being least preferred. All measures with the exception of (1) are non-like-for-like.

The amount of compensation required needs to at least compensate on a 1:1 ratio with the features lost, and in practice the compensation ratio has usually been greater than 1:1 to allow for uncertainty of success[6]. Inherent in the above is the principal that going down the hierarchy increases the amount of compensation required.

The reality is that like-for-like solutions are limited to a few cases (and may be 'used up' as currently suggested by Natural England with regard to onshore artificial nests for kittiwakes on the east coast of England – Natural England 2023) therefore non-like-for-like solutions will be needed and this will require separate agreement on ratios.

The hierarchy above follows that proposed in Defra (2021) but with the addition of a final (lowest) level which, although not an explicit component of the hierarchy set out in Defra (2021), is considered to be a recognised requirement. This follows the statement in Defra (2021) that:

"On rare occasions it may be that other measures delivering wider ecological systems benefits will be the only option for compensation. These opportunities should be identified through developer discussions with SNCBs during the pre-application discussions. Delivery of these measures is likely to be through collaborative action between several developers in an area and with the agreement of the SNCBs. This could include developers working with other industries and regulatory bodies to secure environmental headroom for their activities."

Note that alternative hierarchies are available but were considered to be too prescriptive and not flexible enough for non-like-for-like options. For example, Defra (2012) and EC (2012 and 2019) provide other hierarchies for SPA compensatory measures, stating that the overall coherence of the Natura 2000 Network can be maintained by:

- compensation that fulfils the same purposes that motivated the site's designation;

[5] With reference to the hierarchy identified in the Proposed definition
[6] For example, the kittiwake compensation (artificial nests) proposed for Round 3 Projects in the Southern North Sea have provided between 2:1 and 4:1 ratios for compensation

- compensation that fulfils the same function along the same migration path; and,
- the compensation site(s) are accessible with certainty by the birds usually occurring on the site affected by the project.

The hierarchy proposed in the recent Defra (2024) consultation is quite different to that proposed in Defra (2021). Given that the current work had already been progressed to an advanced stage when the Defra (2024) consultation became available, it was not possible to take detailed account of it, whilst the fact that it is subject to consultation at the time of writing also limits the extent to which it can be relied upon to inform the current project. Nonetheless, it is worth noting that the Defra (2024) consultation proposes a move away from a hierarchy based upon like-for-like and non-like-for-like measures, suggesting that compensatory measures benefiting different qualifying features to those subject to the impacts in question, and which focus on providing functional equivalence, are unlikely to protect the overall coherence of the National Site Network. However, no clear justification is provided to support this position, whilst it is also proposed that such (non-like-for-like) measures could still be provided as part of a wider suite of measures at SPAs and may also be appropriate for Marine Conservation Zones. It is considered that the type of hierarchy approach outlined in the Defra (2024) consultation would create a greater challenge to delivering strategic, regional-scale, ornithology compensation measures in the NE / E ScotWind region than the hierarchy proposed by this project.

2.2.1.2.3 Examples of measures

The following are examples of what could be considered under each of the types of measure listed in the hierarchy in **Section 2.2.1.2.3**

1. *Address same impact at same location* e.g. measures to increase adult survival or productivity of the impacted species, thereby increasing population size to address an impact which acts to reduce population size, at the same SPA.
2. *Provide the same ecological function at different location* e.g. measures to increase adult survival or productivity of the impacted species, thereby increasing population size, at another SPA.
3. *Provide comparable ecological function at same location* e.g. measures to increase adult survival or productivity of a different, but comparable species, thereby increasing population size, at the same SPA.
4. *Provide comparable ecological function different location* e.g. measures to increase adult survival or productivity of a different, but comparable species, thereby increasing population size, at another SPA.
5. *Deliver wider ecological systems benefits which have been determined to benefit the site network* e.g. measures which enhance overall environmental quality but which cannot be directly linked to a specific population or feature (although via their wider environmental benefits these measures are considered likely to benefit relevant populations and features - e.g. restoration of marine habitats to increase abundance of seabird prey would, if successful, provide generic benefits to seabird species, including SPA populations of the target species).

3 Development of long-list

The long-list was developed by the Project Team through a combination of literature review followed by stakeholder workshops to refine the list derived from the literature review (**Appendix A**). The literature review drew upon a large body of material but relied heavily on several existing reviews of potential compensation measures for SPA seabird populations (e.g. Furness *et al.* 2013, DTA Ecology 2020, Furness 2021, McGregor *et al.* 2022) as well as consideration of the submissions of recent OWF projects both in

England and Scotland that have provided compensation measures (or compensation measures provided on a without-prejudice basis).

For the purposes of this exercise, measures were considered in relation to five 'target' species (i.e. those identified as being most likely to be subject to adverse effects from further OWF development in Scottish east coast waters), namely kittiwake, gannet, guillemot, razorbill and puffin (**Section 1.1**). This was on the basis that consideration in relation to these species provides an assessment of the likely potential for the delivery of like-for-like compensation, and is integral to determining the extent to which compensation could be delivered via tiers 1 and 2 of the proposed definition (**Section 2.2.1**). In addition, consideration was also given to whether a measure could be of benefit via a non-like-for-like pathway – either through benefits to other ('non-target') seabird species (relevant to tiers 3 and 4 of the proposed definition for compensation) or in terms of wider ecosystem resilience (relevant to tier 5 of the proposed definition for compensation). This approach of considering the compensation measures in relation to; (i) the five 'target' species; (ii) other seabird species; and (iii) wider ecosystem resilience is also carried through into the more detailed work on the viability of the different compensation measures within the refined list (**Section 7**).

For the long-list the following parameters were considered for each measure and for each attribute (i.e. the 'target' species, other seabird species and ecosystem resilience):

- Evidence-basis for positive effects;
- Strategic and regional scale;
- 'Proximity' to like-for-like compensation (on basis the measure has a population-level effect) based upon hierarchy presented in **Section 2.2.1**;
- Main issues affecting feasibility of implementing; and
- Timescales from implementation to response (in terms population sizes at breeding colonies).

For each attribute, the evidence basis was evaluated qualitatively via expert judgement as Strong, Moderate or Weak based upon the volume of information available, quality of the data etc. Given that this was a rapid assessment, it was considered that this approach was pragmatic and proportionate.

Full details of the long-list together with the evidence base for each is presented in **Appendix A**. The measures in the long-list were then grouped into broad categories for the purposes of expediting their consideration and discussion at Workshop 1. The measures in the long-list are shown in the **Table 2.**

Although **fisheries closures** were included on the long-list as potentially viable compensation measures, they were not put forward for discussion in Workshop 1 because it was considered that delivery would require government action and is beyond the remit of the NE / E ScotWind developers. Subsequently, government consultations have resulted in the recent decisions to close the sandeel fishery in both Scottish and English waters[7,8] (noting that amongst the different UK fisheries, the sandeel fishery is of greatest importance in terms of the potential effects on seabird populations, as detailed in the long-list – **Appendix A**). Therefore, closure of the sandeel fishery will occur irrespective of the compensation requirements associated with the offshore wind sector in Scotland. The implications of this closure in terms of the provision of compensation measures remain unclear, with the relevant Scottish documentation suggesting there may be circumstances in which it could be considered as a suitable measure[7]. It is also the case that the closure could facilitate the viability of other measures by reducing the extent to which prey availability limits seabird populations.

[7] *The Sandeel (Prohibition Of Fishing) (Scotland) Order 2024: business and regulatory impact assessment - final - gov.scot (www.gov.scot)*
[8] *Nature recovery to be accelerated as the government delivers on measures to protect land and sea - GOV.UK (www.gov.uk)*

Prior to Workshop 1 the long-list was provided to stakeholders for review.

Table 2 The Long-list of Measures and Broad Categories

Measure	Category
Sandeel fishery closure	Fisheries (Govt)
Other fisheries – closures / no-take zones / sustainable management	Fisheries (Govt)
By-catch mitigation	Fisheries (Non-Govt)
Mammalian predator control / management	Site management
Avian predator control / management (e.g. diversionary feeding, deterrents)	Site management
Biosecurity (prevention of threats via incursion response)	Site management
Reduce anthropogenic disturbance at colonies	Site management
Reduce anthropogenic disturbance at sea	Site management
Management of supporting habitats at colony	Site management
Establish new colonies at suitable natural sites	Nest provision
Provision of artificial nest sites	Nest provision
Supplementary feeding / 'head-starting' chicks	Nest provision
Seagrass restoration and recovery	Habitat creation
Oyster restoration	Habitat creation
Extend protection of kelp beds beyond 17 MPAs currently protected in Scottish waters	Habitat creation
Reduction / cessation of illegal harvesting of birds	Harvest
Reduction / cessation of legal harvesting of eggs, chicks and / or adult birds	Harvest
Reduce anthropogenic pollution from agricultural runoff / discharge from waste treatment facilities	Pollution control (Govt)
Marine (plastic) Litter Removal	Pollution control

4 Determining the refined list

4.1 Workshop 1

Workshop 1 was held on 19 October 2023. This was a Teams based meeting and was attended by the Project Team, Developers, Scottish Renewables and 10 representatives of the following stakeholders:

- NatureScot;
- Scottish Government;
- Marine Directorate Licencing Operations Team (MD-LOT);
- Marine Directorate Renewables & Ecology;
- Crown Estate Scotland;
- RSPB;
- Centre for Ecology & Hydrology;
- Defra; and
- Scottish Renewables.

The main aim of the workshop was to reduce the long-list of potential compensation measures down to a refined list containing measures that were broadly accepted as being viable options for strategic deployment and which merit further investigation. The Project Team presented the categories of measures (as presented in **Table 2**) and discussed the conclusions for each in terms of evidence, feasibility etc as set out in the long-list. There was then opportunity for discussion and comment (with written comment via a Miro Board). At the end of the session once all measures had been discussed, stakeholders were asked to vote for which measures they considered had merit to be taken forward.

In summary, the measures were grouped as shown in **Table 3,** primarily based upon whether a measure got three or more votes in the workshop (with each of the measures included on this basis obtaining three to seven votes (mean = 4.6), whilst of the six measures excluded on this basis, three had zero votes, two had single votes and one obtained two votes). For the three measures outlined in italics in **Table 3**, inclusion was on the basis that the project team considered there was potential justification for at least partial inclusion despite these measures obtaining fewer than three votes (see below).

.

Table 3 Determining the refined list - measures taken forward / not taken forward

In	Out
Establish new colonies at natural sites	Agricultural run-off
Artificial nest sites	Supplementary feeding
Seagrass	Disturbance at colony
Oyster	Disturbance at sea
Kelp	Illegal harvesting
Mammalian predator control/eradication	Legal harvesting
Avian predator control	
Biosecurity	
Mgmt. of supporting habitats	
Marine litter	
By-catch mitigation	

The voting system employed during the workshop was highly simplistic and arbitrary but further consideration by the Project Team of the measures assigned in this way led to the conclusion that it did accord broadly with identifying those measures which have little, or no, potential to be applied in a strategic way.

The Project Team identified three measures (based on the arbitrary vote-count) fell into the ‘Out’ category which they considered justified inclusion in the suite of measures to be taken forward for more detailed consideration (the options in italics in the ‘In’ column of **Table 3**). The reasons are as follows:

- **Provision of artificial nest sites** – given that the measure to establish new colonies at natural sites was identified as having potential as a strategic compensatory measure, it was considered that it must also follow that there is potential for artificial nest site provision in this regard. This would be particularly the case if it is used to augment or facilitate establishment of colonies.
- **Avian predator control** – it was considered that although not a viable strategic measure when considered in isolation there may be occasions in which this could be useful as an additional / adaptive management tool alongside mammalian predator management or eradication. Thus, the measure was included in this limited context to maximise the potential of predator management as a strategic compensatory measure.
- **By-catch mitigation** – several consented projects in England have had this included as a measure in their consents, this would therefore point to a reasonable level of interest in this measure and its viability. Given that further consultation was scheduled with fisheries

stakeholders, it was considered that this measure could be discussed further in that context and a decision on its inclusion made on this basis (see **Section 4.2**).

4.2 Fisheries Meeting

A workshop was held on 15 November 2023 with fisheries stakeholders. Representatives of the following organisations attended:

- The Scottish Fishermen's Federation (SFF);
- The Scottish White Fish Producers Association (SWFPA); and
- Orkney Fisheries Association.

The Project Team presented the materials from Workshop 1 together with an update covering the conclusions. In particular, discussion focused on potential by-catch measures. The conclusion of this discussion was that by-catch was not seen as a large problem in Scottish fisheries and stakeholders pointed to several ongoing initiatives aimed at mitigating impacts (e.g. Home - Clean Catch UK). Thus, the views expressed at this meeting were consistent with those of stakeholders from Workshop 1 in suggesting that by-catch measures were unlikely to provide a viable option for regional-scale compensation.

Other subjects discussed were the potential for any habitat restoration or creation measures to displace (inshore) fisheries and the need to ensure that compensation efforts taken into account other requirements such as Biodiversity Net Gain or the Scottish Marine Environmental Enhancement Fund (SMEEF).

5 Measures not taken forward

The following sections provide a summary of the rationale for not taking the rejected measures forward.

5.1 By-catch

The review for the long-list (see **Appendix A**) determined that there was Strong (gannet) to Weak (kittiwake, razorbill) to No (puffin) evidence of by-catch being a problem. In addition, for those species where this was recognised as a problem, the by-catch events were likely to occur largely outside Scottish or even UK waters, and therefore feasibility of delivering change in a Scottish context was a key issue. It was also unlikely to be scalable. The workshop attendees agreed with these points and there was limited support for the measure.

The measure was retained for discussion with fisheries stakeholders (as discussed in **Section 4.2**), who commented that by-catch was not regarded as an issue for Scottish fleets which do not operate significant levels of gill net, drift net or longline gear, where most of the interaction is understood to occur. In addition, there are a range of Scottish and UK on-going initiatives covering endangered, threatened and protected species including seabirds.

Significant levels of seabird by-catch have been reported in the past from long-lining (mainly in the north and west of Scotland), from gillnetting (mainly in English North Sea and the Celtic Sea) and mid-water trawls (mainly in the English Channel). Outside UK waters, by-catch affecting UK breeding birds, especially gannet, has been reported off the west coast of Africa and off Iberia (Gremillet *et al.* 2020, Calado *et al.* 2021). As the developers are unlikely to be able to influence measures to reduce by-catch off Africa or Iberia it is not considered worthwhile to include an in-depth investigation of the issue, or a plan to address it, in this final report.

The recent report on the UK long-line fishery by Kingston *et al.* (2023) concentrated on the impacts to northern fulmar *Fulmarus glacialis* (hereafter fulmar) from the hake fishery off northern and western Britain.

Whereas previous estimates (Northridge *et al.* 2020) suggested that the annual mortality in the fishery was around 4,500 birds, the new report provided a revised bootstrap estimated mortality of between 1000 and 4000 birds per year over the previous 20 years although the confidence intervals on those estimates were wide. Modelled estimates for fulmar, great skua *Stercorarius skua*, great shearwater *Ardenna gravis* and gannet indicated that the annual bycatch from the UK long-line fleet was most likely between 10 and 20 individuals of great skua and great shearwater per year, around 100 gannet per year and probably between 1000 and 2000 fulmar per year (Kingston *et al.* 2023). The authors advised that the data levels from which these estimates were derived were low resulting in wide confidence intervals about the estimates. Furthermore, the area from which seabirds interacting with the long-line fishery off northwest Scotland derive is potentially large involving breeding birds from Iceland and North Norway as well as the UK (Furness 2015).

This evidence therefore suggests that impacts to UK colonies from the long-line fleet are not large and mitigation actions already in place (e.g. night setting and streamers deployed while setting), which are voluntarily adopted by the fishers are likely to be reducing by-catch. It is estimated that available compensation from further reduction of the actions by the UK fleet in this area is small and it is not clear what further cost-effective action could be taken. This option was not explored further for those reasons.

The highest gillnet by-catch rates were found in the northeast of England, southeast Ireland, the south coast of England and off Shetland and involve diving species guillemot, razorbill and great cormorant *Phalacrocorax carbo* (hereafter cormorant). The northeast England by-catch hotspot was related to a salmon/sea trout net fishery close to Flamborough Head. A voluntary code of conduct is in action in this fishery which has reduced the by-catch substantially (Northridge *et al.* 2023). The south coast by-catch was related to drift net fishing for bass, whilst the Shetland by-catch hotspot related to the Norwegian and Faroese long-line fishery for cod. Again, influence over foreign fleets will be minimal and so it is expected that no valid compensation action would arise from addressing the cod long-line fishery. As the by-catch from salmon fishing in northeast England has already been addressed by the prevention of fishing close to Flamborough Head and with the voluntary code of action being adopted it was concluded that no significant compensation option was available there either. By-catch rates from midwater trawls are considerably lower than those from long-line fisheries (Northridge *et al.* 2023). By-catch in midwater trawls was only recorded in the southwest English Channel bass and sprat fisheries. The bass fishery is now closed. Consequently, this also appears to be an impact where the available compensation options are limited.

Overall, while bycatch was considered in the long-list of measures and is undoubtedly something that occurs involving species of interest, due to a combination of the locations that it mainly occurs in, the fleets involved and the voluntary actions already being undertaken to mitigate effects, it has been determined that by-catch reduction is not a suitable option to pursue for the NE and E ScotWind regional strategic compensation.

5.2 Agricultural run-off

The review for the long-list (see **Appendix A**) determined that there was Weak evidence for any benefit to seabirds from the measure. Whilst desirable as an outcome, the workshop attendees did not support this measure for the following key reasons;

- Undermining the polluter pays principle;
- Difficult to establish cause and effect (i.e. source and pathway);
- Additionality – this should be part of existing site management initiatives (where a SPA is affected)

Given the workshop feedback it was decided that this measure would not be considered further.

5.3 Supplementary feeding

The review for the long-list (see **Appendix A**) determined that there was Moderate to No evidence for benefits for the target species but Strong evidence for other species. There was no backing for this as a standalone measure, with key issues raised being:

- Practicality of undertaking supplementary feeding
- Other colony consequences (e.g. disturbance of other species, food source to predators etc)
- Source for supplementary food and implications of collecting it.

Given the conclusions of the long-list review and workshop feedback it was decided that this measure would not be considered further.

5.4 Disturbance at colony

The review for the long-list (see **Appendix A**) determined that there was Moderate to Weak evidence for the benefits of reduction in disturbance. Key issues were determined to be scalability (it is only relevant to those sites where access allows disturbance to occur) and potential conflict with management objectives for sites where public access is important. At the workshop the question of whether the measure would provide any additionality was also raised.

Given the conclusions of the long-list review and workshop feedback it was decided that this measure would not be considered further.

5.5 Disturbance at sea

The review for the long-list (see **Appendix A**) determined that there was Weak evidence the benefits of reduction in disturbance at sea (noting though that this is an effect which is assessed for EIA) and crucially the difficulty of reducing levels of disturbance for third parties (i.e. existing shipping traffic) means this is likely unfeasible. There was no support for this measure at Workshop 1.

Given the conclusions of the long-list review and workshop feedback it was decided that this measure would not be considered further.

5.6 Legal harvesting

The review for the long-list (see **Appendix A**) determined that there was Strong evidence of benefit from this measure for one target species (gannet) and Moderate evidence for some non-target species (herring gull *Larus argentatus* and lesser black-backed gull *Larus fuscus*) but for all other species there was Weak to No evidence of benefit. Although there was some support for this measure at the workshop, cultural considerations were raised as a potential constraint affecting compensation measures associated with the annual harvest of gannet chicks from the Sula Sgeir SPA population (reflecting recent advice provided by NatureScot to the Berwick Bank Wind Farm on this issue – NatureScot 2023c). In addition, for gannet, the review for the long-list concluded little potential for cessation of the harvest from the Sula Sgeir SPA population to provide regional scale compensation.

Given the conclusions of the long-list review and workshop feedback it was decided that this measure would not be considered further.

5.7 Illegal harvesting

The review for the longlist (see **Appendix A**) determined that there was only Evidence of benefit from harvest reduction for gannet, however this was from overseas activity and therefore more difficult to control. Fundamentally, illegal activity should not be taking place therefore it should not be badged as compensation.

Given the conclusions of the long-list review and workshop feedback it was decided that this measure would not be considered further.

6 Indicative potential compensation requirements

Given that the assessments for the OWF projects in the NE and E ScotWind regions have yet to be undertaken, it is not possible at this stage to provide any definitive estimate of the likely compensation requirement for seabird SPA qualifying features that will result from these projects. However, it is important to try to gauge this because it is critical to informing the likely extent to which the different compensation measures have the potential to meet this requirement, particularly where it is assumed that compensation is to be provided on a like-for-like basis.

As outlined above, the plan-level HRA identified that further OWF developments in the NE and E ScotWind regions had the potential to result in AEoI at several SPAs, with this being due to the level of predicted impact on populations of kittiwake, gannet, guillemot and / or razorbill at these SPAs (ABPmer 2019)[9]. Since publication of the plan-level HRA, there have been a small number of submissions for further OWF developments in these regions. Most notably, the Berwick Bank Wind Farm submission further highlighted the extent to which SPAs in these regions are considered to be subject to AEoI as a result of impacts from OWFs (RPS and Royal HaskoningDHV 2022, NatureScot 2023, Natural England 2023). The Report to Inform Appropriate Assessment (RIAA) for the Berwick Bank Wind Farm, together with the subsequent NatureScot and Natural England responses, provide a basis for identifying SPA seabird populations in the northeast and east of the UK for which the currently predicted level of impact may be sufficient to lead to a potential AEoI. These sources suggest that this may apply to between seven and 24 SPA populations from seven to 11 different breeding seabird SPAs, depending on the extent of precaution incorporated within the assessment and the interpretation of the outputs (**Table 4**).

Table 4 Species' populations at breeding seabird colony SPAs[1] for which the potential for an adverse effect as a result of the Berwick Bank Wind Farm in-combination with other plans and projects could not be excluded

SPA	Qualifying Feature	Potential for an adverse effect due to in-combination effects concluded by:	
		Berwick Bank submission[2]	NatureScot / Natural England response
Hermaness, Saxa Vord and Valla Field	Gannet	No	Yes
West Westray	Kittiwake	Yes	Yes
North Caithness Coast Cliffs	Kittiwake	Yes	Yes
East Caithness Coast Cliffs	Kittiwake	Yes	Yes
	Razorbill	No/Yes	Yes
Troup, Pennan and Lion's Head	Kittiwake	No/Yes	Yes
	Razorbill	No	Yes
Buchan Ness to Collieston Coast	Kittiwake	No/Yes	Yes
Fowlsheugh	Kittiwake	Yes	Yes
	Guillemot	No/Yes	Yes
	Razorbill	No/Yes	Yes
Forth Islands	Gannet	No	Yes

[9] Reference was also made to potential impacts on the East Caithness Cliffs SPA population of great black-backed gull in this context. However, any effects on this population are largely restricted to the Moray Firth projects and it is considered unlikely that this species will be a major concern for ScotWind projects given the species' limited foraging range in the breeding season (Moray West Offshore Wind Farm 2019, Woodward et al. 2019).

SPA	Qualifying Feature	Potential for an adverse effect due to in-combination effects concluded by:	
		Berwick Bank submission[2]	NatureScot / Natural England response
	Kittiwake	Yes	Yes
	Guillemot	No/Yes	Yes
	Razorbill	No/Yes	Yes
	Puffin	No/Yes	Yes
St Abb's Head to Fast Castle	Kittiwake	Yes	Yes
	Guillemot	No/Yes	Yes
	Razorbill	No/Yes	Yes
Farne Islands	Kittiwake	No/Yes	Yes
	Guillemot	No	Yes
	Puffin	No	Yes
Flamborough and Filey Coast	Kittiwake	Yes	Yes
	Razorbill	No	Yes

[1]The species' populations either qualifying features or named components of a breeding seabird assemblage qualifying feature of each SPA.
[2]The Berwick Bank assessment considered both 'developer' and 'scoping' approaches which made different assumptions on the magnitude of certain effects and extent of precaution, leading to contrasting conclusions in relation to AEoI for some SPA populations.

Assuming current approaches to the ornithology assessments for UK OWFs are maintained, further developments in the NE and E ScotWind region will inevitably result in further predicted impacts to many of the SPA populations identified in **Table 4**, leading to a requirement to provide compensation for the additional predicted impacts arising from these projects.

There is considerable uncertainty over the likely scale of these additional impacts to the SPA populations identified in **Table 4**. However, the NE and E ScotWind projects[10], when taken together, encompass an area that is approximately two and half times greater than the area encompassed by the existing OWF projects (constructed, consented and in-application) in the Forth and Tay and Moray Firth, whilst the difference in estimated generating capacity between the NE and E ScotWind projects and these earlier projects is of a similar scale[11]. This suggests that the level of predicted impacts from the NE and E ScotWind projects is likely to be higher than those associated with the existing projects in the Forth and Tay and Moray Firth, although it is also the case that the ScotWind projects tend to be considerably further offshore and (subject in some cases to limitations imposed by having floating turbines) will likely comprise larger turbines with higher blade tip clearance above the sea surface, both of which are likely to substantially reduce predicted impacts on breeding seabird populations (Johnston *et al.* 2014a,b, Wakefield *et al.* 2017). Furthermore, as submissions for ScotWind (and other leasing rounds, such as INTOG) projects progress, it is highly likely that the number of SPA qualifying features for which a potential for AEoI is concluded will increase, so adding to those identified in **Table 4**.

The Berwick Bank Wind Farm RIAA also presents predicted levels of in-combination mortality for the SPA populations in **Table 4**. For the guillemot and puffin populations from the Scottish SPAs, virtually all of this in-combination mortality is attributable to the existing Forth and Tay and / or Moray Firth projects, because all such mortality is assumed to derive from projects which are within breeding season foraging range of the relevant SPA[12]. For the gannet, kittiwake and razorbill populations from the Scottish SPAs, this is true for that part of the predicted in-combination mortality which is attributed to the breeding season (with this accounting for the majority of the annual mortality in most cases). Based on the information presented in Berwick Bank Wind Farm RIAA, the predicted in-combination annual mortality of breeding adult guillemots

[10] As defined in Section 1.1
[11] As derived from information at Global Offshore Renewable Map | 4C Offshore (sourced on 18/12/23).
[12] Noting that the small number of other existing Scottish OWF projects are considerably smaller than those in the Forth and Tay and Moray Firth, with much smaller associated impacts.

and puffins from the Scottish SPA populations in **Table 4** ranges from 368 to 1895 for guillemot and from 44 to 265 for puffin. Limiting consideration to breeding season mortality only, the equivalent estimates for the other three species are 585 to 816 for gannet, 677 to 902 for kittiwake and 53 to 298 for razorbill.

The wide range in the predicted mortalities for each species derives from the application of different assumptions (and levels of precaution) within the assessments, with the NatureScot-advocated approaches resulting in higher values. In terms of considering these predicted in-combination mortalities in the context of the compensation requirements for the NE and E ScotWind projects, it is important to note that they do not account for:

- The likely increase in the number of SPA populations for which compensation will be required as projects from the ScotWind (or other leasing rounds) progress.
- The full scale of the predicted in-combination mortality for gannet, kittiwake and razorbill attributable to the existing Forth and Tay and Moray Firth projects (because only the breeding season impacts have been included).
- The requirement for compensation for impacts to seabird populations from SPAs on the east coast of England.

At the same time, for gannet and kittiwake, the changes that are likely to be proposed to the avoidance rates used in estimating collision mortality (as derived from Ozsanlav-Harris *et al.* 2023 and, for gannet, possibly also Pavat *et al.* 2023) will act to reduce the predicted levels of in-combination mortality on these two species and, hence, the indicative compensation requirements. Similarly, should recent findings from post-consent monitoring at the Beatrice Wind Farm be pivotal to informing future advice on predicted displacement effects, then this could also lead to reductions in the scale of the resultant potential in-combination mortality for kittiwake and the three auk species (Trinder 2023).

Based on the above considerations and the existing predicted in-combination mortalities detailed above, a highly indicative gauge of the potential compensation requirements for the NE and E ScotWind projects can be derived by assuming that predicted impacts could be between one half to double those associated with the existing projects in the Forth and Tay (inclusive of the proposed Berwick Bank Wind Farm) and Moray Firth regions (**Table 5**). Such a calculation suggests that the compensation required from the NE and E ScotWind projects appears likely to extend to providing between several hundred and a small number of thousands of breeding adult birds per year for each of guillemot, gannet and kittiwake, together with substantially smaller numbers of adult razorbill and puffin.

Table 5 Indicative compensation requirements for the Northeast and East Region ScotWind projects, as derived from the predicted in-combination mortality on populations at Scottish SPAs for which an adverse effect was concluded in the Berwick Bank Wind Farm assessment (see text and Table 4).

Species	Annual mortality (number of breeding adult birds)[1] derived by assuming this equates to the predicted in-combination mortality for the existing Forth and Tay (inclusive of the proposed Berwick Bank Wind Farm) and Moray Firth projects multiplied by:		
	0.5	1	2
Gannet[2]	293 - 408	585 - 816	1170 - 1632
Kittiwake[2]	339 - 451	677 - 902	1354 - 1804
Guillemot	184 - 948	368 - 1895	736 - 3790
Razorbill[2]	27 - 149	53 - 298	106 - 596
Puffin	22 - 133	44 - 265	88 - 530

[1]The wide range in the predicted mortalities for each of the three multipliers for each species derives from the application of different assumptions (and levels of precaution) within the assessments, with the NatureScot-advocated approaches giving higher values than the developer-advocated approaches.

[2]The predicted in-combination mortality for these species is limited to that associated with the breeding season (because projects in English North Sea waters contribute to the non-breeding season mortality).

The approach outlined above provides a quantum of the impact against which the ‘return’ from the compensation measures would have to be assessed. However, it is not intended to account for any ratios in terms of the delivery of the compensation to address uncertainty in the success of the proposed measures or in terms of the extent to which these measures provide like-for-like or non-like-for-like compensation. In terms of non-like-for-like compensation, it is possible that measures would have to determine some form of ecological equivalence by which the measure (and the extent of its provision) is scaled against the impact to the affected SPA qualifying feature(s). Further consideration of what types of measures could be used for non-like-for-like compensation is required but may include the numbers of individuals of other SPA species (where compensation is targeted at species other than those affected by the impact) or the densities of potential prey species (where compensation is targeted at broader habitat measures).

7 Assessment of compensatory measures in the refined list

The measures considered in the refined list are reviewed below in terms of the main criteria which will determine the potential viability of each as a strategic measure which can provide compensation at the regional scale. For all measures, other than avian predator control (see **Section 4**), the following are assessed:

- Evidence that the measure is likely to be effective in producing a population-level response (in relation to tiers 1 to 4 of the proposed compensation definition) or increased ecosystem resilience (in relation to tier 5 of the proposed definition);
- The degree of scalability and practicality for application at a regional scale;
- Likely timescales for a response, either in terms of the relevant seabird populations (in relation to tiers 1 – 4 of the proposed compensation definition) and / or in terms of factors relating to increased ecosystem resilience (in relation to tier 5 of the proposed definition);
- Practical feasibility of implementing the measure;
- Estimation of the potential compensation return, either in terms of population demographics (for tiers 1 – 4 of the proposed compensation definition) and / or factors relating to increased ecosystem resilience (in relation to tier 5 of the proposed definition); and
- Likely duration over which the measure would have to be in place.

As for the work undertaken in producing the long-list, the different measures are considered in terms of the ability to provide compensation in terms of each of the five ‘target’ species (i.e. kittiwake, gannet, guillemot, razorbill and puffin), for other seabird species and in terms of wider ecosystem resilience.

The following section takes into account information received from and comments made by stakeholders at Workshop 2.

7.1 Establish new colonies at natural sites

7.1.1 Evidence for efficacy

Establishing new colonies at sites not currently occupied by a species could provide opportunities to increase breeding numbers if nesting sites elsewhere are limited. Other advantages could be the possibility to improve access to prey resource for the species, to reduce other pressures such as density dependent productivity or to release birds from predator pressure. Here, under ‘new’ colonies, we include sites which may have previously held a species but possibly not for a considerable period.

Establishing new colonies at natural sites requires overcoming any issue that previously prevented birds colonising naturally. Two methods are predominantly used to establish new colonies, being translocation of individual from the desired species and social attraction.

Social attraction is achieved through using decoys, visual, auditory, or possibly olfactory lures (Jones and Kress, 2012; Lu *et al.* 2020). Translocation involves physically moving birds, usually chicks prior to fledging, from one location to another (Kress and Nettleship 1978, Jones and Kress 2012, VanderWerf *et al.* 2023).

Factors that are important for establishing new or re-establishing colonies were reviewed by Kress (1997, 1998). Where re-establishment is the aim then the original cause of the extirpation must have been remedied. In the case of new sites no such negative impact should be present of course. It was also considered important that long-term funding for a colonisation project should be guaranteed. The species to be attracted should be well understood in terms of habitat and prey requirements (this is true for most UK seabirds).

Projects targeting auks, shearwaters and petrels and terns are considered to have relatively high chance of success whereas those aimed at restoring, and by extension establishing, colonies for gannets, storm-petrels or cormorants are less often successful (Jones and Kress 2012).

7.1.1.1 Key seabirds

Many seabird species are highly philopatric and will return to breed once mature at or near the site they were raised (Vanderwerf *et al.* 2023). Translocation would appear to be the most effective method to establish new colonies in these species. Social attraction will act on pre-breeding age birds or possibly breeding age birds that shift nest sites more regularly such as terns.

7.1.1.1.1 Kittiwake

Provision of artificial structures for new colonies was considered to be highly likely to be effective in the review of strategic compensation measures by Furness (2021), this might be extended to suggest that establishing new colonies at natural sites would be beneficial although that review did not suggest that. Christensen-Dalsgaard *et al.* (2019) state that kittiwake declines in Norway appear to be driven by reduced productivity and this is also suggested by Scottish data (JNCC 2023), although Burnell *et al.* (2023) state that there are still insufficient data to be certain that is the demographic factor that is responsible. However, actions that are likely to increase productivity would appear to be a good route for compensation to take. Therefore, it should be the aim of any new colonies to provide conditions suitable for high productivity.

Kittiwake shows relatively low philopatry for a seabird (Coulson 2011, Coulson and Coulson 2007, Danchin *et al.* 1998) (although for a slightly opposed view see Kildaw *et al.* (2008)), suggesting that social attraction will work as an effective method to establish new colonies. Kildaw *et al.* (2005) show that establishment of colonies is slow but once formed can grow rapidly fuelled by recruitment of established breeders relocating from other colonies. Decoys and calls can be used to attract kittiwake to structures and presumably also to natural sites. The Gateshead kittiwake tower was occupied by birds displaced from the adjacent Baltic Flour Mill after using clay decoys and disused nests taken from the Flour mill. Nesting success of all 'man-made' sites and natural sites in the Tyne area has been found to be comparable (Turner 2010).

Establishment of colonies at natural sites is likely to require shifting birds greater distances than establishment at artificial sites. Assuming that suitable nest sites already exist then distance from an existing colony is expected to be possibly the main reason that such a site had not been already occupied. If new foraging opportunities have appeared in recent times then a natural site would quite possibly be very suitable but may not be colonised because colonisers had not appeared. In this situation the use of decoys, calls and dummy nests would be expected to encourage colony establishment, although colonies at offshore rigs reported by Christensen-Dalsgaard *et al.* (2019) formed tens of kilometres from other sites without use of any decoys. This does tend to indicate that areas without at least historic evidence of nesting kittiwake are unlikely to be good candidate sites for establishing natural colonies unless the issue that is preventing establishment can be determined and remedied.

Population models show that kittiwake need to, on average, achieve a productivity level of about 0.8 chicks per nest to maintain the population. Productivity in excess of 0.8 chicks per nest could therefore be taken to compensate for predicted losses of birds (Furness 2021) as it would be assumed additional to what is required for population maintenance. Removal of density dependent suppression of productivity (if it is present) by establishing new colonies would help boost productivity.

The degree to which establishing new colonies at currently unused natural sites would contribute to compensation is not as straightforward to evaluate as for artificial sites (see later). If a site has suitable cliff structure but has not been colonised then the reason for that needs to be understood. It may be prey distribution makes the site unsuitable but most studies indicate that predator impacts are likely to be influential. In theory, colonies could be established using the same social attraction techniques that have proved effective for artificial sites but on the face of it opportunities to do so in the UK appear to be much more limited.

7.1.1.1.2 Gannet

Despite a few records of nesting attempts on artificial platforms by gannets and boobies, this does not seem to be a widespread adopted behaviour. Population models for gannet indicate that a significant level of immigration and emigration from breeding sites takes place (Trinder 2016) and while the north Atlantic population has been expanding at just over 2% per annum, new colonies have formed regularly at natural sites. The number of colonies in Britain and Ireland increased from eight in early 20th century to 16 by 1969-70 (Cramp and Simonds 1977) and to 28 by 2023 (Burnell *et al.* 2023). St Abb’s Head, near Bass Rock in the Firth of Forth, is the most recent in Scotland. The impact of Highly Pathogenic Avian Influenza (HPAI) in 2022 has reversed much of recent gains although no colony, even the small one at St Abbs Head, has been abandoned. If gannet do not succumb again to the virus as they did in 2022 then it is quite likely that the population will resume its increasing trend again but perhaps released from some density dependent pressure at individual sites.

Furness *et al.* (2013) suggested establishing new colonies for gannet as one of the priority actions for the species although it was also considered that the feasibility and practicality of the measure was Moderate or Low. The evidence suggests that feasibility of establishing a natural sites colony is low-moderate but with use of social attraction it looks possible to establish a new gannet colony given a suitable site, as it has been successful for Australasian gannet (*Morus serrator*) at artificial sites (Jones and Kress 2012). Where social attraction has been tried for northern gannet so far it has not been successful, possibly because the site chosen was distant from any source colony, although it would be sensible to establish a new site far from other colonies to maximise benefits. The advantage of establishing a new colony for gannet is probably reduced since the recent population reductions resulting from HPAI, and given the large foraging range of the species and preferred prey types (pelagic fish such as herring or mackerel (Cramp and Simmons 1977)) it may not provide significant benefit for foraging and productivity. In general, 2022 excepted (due to HPAI), productivity of UK breeding gannet is very stable, rarely outside of a range of 0.6-0.8 young per pair since 1986 (JNCC 2023). It is possible however that locating new colonies would provide a further buffer against future HPAI impact or reduce barrier impacts for birds. There are possibly few sites available for a large new colony to establish although a detailed search would need to take place to determine this. Island sites are preferred although mainland colonies, such as at Bempton Cliffs within the FFC SPA, can thrive and grow very large.

Potentially, the number of birds that could be compensated for is large given identification of a suitable site. Most gannet colonies number 1000s of birds, 21 of the 28 colonies listed in the fourth national census were larger than 1000 pairs (Burnell *et al.* 2023) and 5 of the 7 that were less than 1000 pairs had been established since the Seabird 2000 census (Mitchell *et al.* 2004).

7.1.1.1.3 Guillemot and Razorbill

Establishing new colonies is not one of the actions listed by Furness *et al.* (2013) in their review for Defra, nor was it considered in the compensation options review (Furness 2021). For both guillemot and razorbill evidence of directed establishment of breeding sites on natural or artificial structures is scarce. Nor do the 'large auks' feature in reports of seabirds nesting on oil and gas structures as do kittiwake or other gull species.

However, guillemot has been lured back to breeding at previous natural sites after very long (more than 100 years) absence using social attraction (Jones and Kress 2012). At Matinicus Rock, Maine, off the east coast of USA the first breeding pair was attracted after 17 years of deploying decoys and audio playback. Other colonies in the same scheme were restored after shorter absences in California (e.g. Devil's Slide Rock), again using social attraction methods (McChesney *et al.*; 2008). This last colony was extirpated for 10 years before restoration effort began, although some birds still bred at nearby sites a few kilometres away. Birds started breeding here one year after social attraction efforts were started but they continued to be deployed for another 20 years before being removed once the guillemot colony was considered secure. The resulting population of almost 400 pairs of guillemot is self sustaining with generally good breeding success although this is around one quarter of the size of population prior to extirpation in the 1980s. This colony was originally lost due to oil spill mortality.

In Greenland a cliff occupied by up to half a million Brunnich's guillemot (*Uria lomvia*) in 1920 was deserted 70 years later, and the same site also lost razorbill and kittiwake as breeding species. The main cause was considered to be hunting pressure (Boertmann 2023). In 2022 breeding Brunnich's guillemot was noted at the site and kittiwake and razorbill had also returned. This was an absence of around 40 years and no attraction effort was used to instigate recolonisation. The nearest Brunnich's guillemot colony was 270km distant and was in decline, with the nearest thriving colony 420km away. This is also a rare example of razorbill recolonising a site from which they had been extirpated, although locally populations of both razorbill and kittiwake had been increasing. As the hunting pressure on this colony had ceased then it appears straightforward to explain why colonisation of this suitable site occurred.

A similar occurrence in California was the discovery of breeding guillemot on Prince Island in 2011 after an absence of 100 years (Menard 2011). Although scientists at the time suggested that birds were taking advantage of current ocean conditions, the original loss of the colony was due to egg collecting and hunting which had ceased in the meantime.

Overall success rates of seabird restoration projects involving alcidae (mainly *Fratecula* and *Synthliboramphus* but also some *Uria*) was calculated at 60% by Jones and Kress (2012). These efforts prove that it would be possible to lure guillemot at least to new colony sites if all other factors were suitable. So far, no evidence has been seen that birds could be lured to occupy distant cliffs previously not known to host them although that is theoretically possible (but noting that the same caveats as mentioned for kittiwake would hold true). Identification of suitable locations would be a priority exercise to determine if this activity were possible to provide substantial input into any compensatory effort which may then take a considerable time before it was seen to work.

7.1.1.2 Puffin

The 'Project Puffin' reintroduction to Eastern Egg Rock Island, Maine has been used as a template elsewhere. Puffin became extinct at Eastern Egg Rock Island around 1900 due mainly to human persecution but was successfully reintroduced 80 years later using a combination of translocation of chicks from Newfoundland and social attraction (decoys, mirrors and calls) (Kress and Nettleship, 1988). Almost 1000 chicks were translocated into hand dug burrows between 1973 and 1986 and hand fed until fledged. In the 1980s around 15 pairs bred on the island but now that colony is greater than 150 pairs and throughout the Maine Islands over 1000 pairs breed. Some birds did breed on other Islands in Maine in the 1980s, particularly quite a large colony on Machias Seal Island in Canada.

It took eight years for the first returnee to appear following the start of translocations and 12 years until first breeding took place. Predator (gull) removal is also undertaken on the site.

The chicks in Maine were relocated into artificial burrows dug by humans (Kress and Nettleship 1988). Although this would not be necessary for returning adult birds, it isn't clear if the presence of burrows on a site would encourage breeding. In areas where no turf covering is available, puffin will nest in crevices and cracks although this may restrict breeding numbers.

7.1.1.3 Other seabirds

Petrels and shearwaters are generally highly philopatric and so translocation of young should be the preferred method to establish colonies, although audio (and olfactory) social attractants have been proven to work. Famously, Fisher translocated more than 3000 Laysan albatross only to have them return to the original natal site once they reached breeding age. It was later discovered that earlier translocation of younger chicks produced better results (Kress and Nettleship 1988). European storm-petrel *Hydrobates pelagicus* has been lured back to The Shiants to breed after removal of black rats by playback of calls though this work is not published[13].

Social attraction, consisting of playback of recorded Leach's storm-petrel calls and creation of artificial burrows were used to encourage Leach's Storm-petrel *Hydrobates leucorhous* to establish new colonies in islands off Maine. Small numbers of breeding birds were found and 15 years after ceasing the playback at least three pairs of Leach's Storm-petrels were found nesting in natural burrows near the site of artificial burrows at Old Hump Ledge, Maine (Kress 1997). Although these sites were all historical breeding locations there is high confidence that playback could be used to create petrel colonies in suitable areas. Manx shearwater *Puffinus puffinus* has not been encouraged to return to The Shiants although both Manx shearwater and European storm-petrel have been found breeding on the Isle of May though no action, other than general biosecurity, has been deployed to specifically encourage them.

Terns are renowned for exhibiting low philopatry and feed young after fledging, meaning that social attractants are by far the most suitable method for creating new colonies. This has been shown to work for several species at numerous sites (e.g. see Hartman *et al.* 2019 for Caspian tern *Hydroprogne caspia* attracted to sites where they had not previously nested and Hartman *et al.* 2020 for Forster's tern *Sterna forsteri* establishment). Tern colonies will establish quickly – often in the first or second year of social attraction being deployed (Hartman *et al.* 2019, Hartman *et al.* 2020). In Maine, common tern *Sterna hirundo* took three years to start breeding at a site that they had not bred at for 50 years. Gull control is seen as important in establishing colonies and often in ongoing management (Kress 1983). Under such a regime, common tern, Arctic tern *Sterna paradisaea* and roseate tern *Sterna dougallii* all recolonised islands in Maine (Kress 1997). Prevention of disturbance at natural sites, as well as suitable substrate, appear to be the main requirements for establishment of tern colonies. With decoys and call playback it is considered likely that tern colonies could be established.

Like kittiwake which was covered earlier, gulls are expected to show generally low philopatry. Little attention appears to have been paid to protection and establishment of gull colonies, despite the fact that lesser black-backed gull, great black-backed gull *Larus marinus*, common gull *Larus canus* and black-headed gull *Chroicocephalus ridibundus* are all amber listed in Birds of Conservation Concern 5 (BoCC5), while herring gull is red listed (Stanbury *et al.* 2021). In line with having generally low philopatry it would be expected that

[13] Project celebrates arrival of storm petrels on the Shiants - BirdGuides

social attraction rather than translocation techniques would be required for gulls although removal of chicks from nest sites that were to be destroyed under licence could provide opportunities for translocation source.

Cormorants are not expected to be highly philopatric but evidence for directed establishing of colonies is scarce. Cormorant is not expected to be a species that require compensation actions for the ScotWind projects as it is mostly a coastal foraging species. To a large extent the same is true of gulls, other than kittiwake, although developments closer to shore may need to address impacts to large gulls that forage in coastal waters.

Several other seabirds have been successfully restored or established using translocation techniques following the general principles here. Tropicbirds shearwaters and noddies have all been translocated in Mauritius. Ashy storm-petrel *Oceanodroma homochroa*, Cassin's auklet *Ptychoramphus aleuticus* and Xantus's murrelet *Synthliboramphus hypoleucus* in Baha California. It is unlikely but possible that shearwaters and petrels might be species of interest in terms of predicted impacts resulting from the ScotWind projects, although they may also be relevant in the context of non-like-for-like compensation.

7.1.1.4 Wider ecological benefits

Translocating top marine predators may have various impacts on general ecology. It could provide balance or it could result in predator pressure in an area previously without such predators. The influence of one predator on another through competition should also be considered (Wakefield 2013).

The benefits of increasing numbers of seabirds are common to any of these approaches not just establishing colonies at natural sites. Seabirds distribute nutrients that are beneficial to plankton growth, seagrass and other marine life. These are the nursery food sources for fish. This is an important step in carbon cycles which includes locking carbon up in 'blue carbon' storage for example nutrients from seabird colonies increasing coral growth rates (Savage 2019).

Nutrient cycling is one of the most important of the ecological functions that seabirds provide. Production of guano may increase primary production and trigger bottom-up effects on primary and secondary consumers (Bosman and Hockey 1986, Signe *et al.* 2021, Hentati-Sundberg *et al.* 2020). Spreading of colonies to new areas would distribute nutrients further and could lead to increased primary production across a wider area.

Aside from nutrient input, soil turnover by burrowing seabirds has been shown to affect invertebrate communities (Orwin *et al.* 2016) as well as having physical effects on soil structure and chemistry (Bancroft *et al.* 2005) which in turn affects plant and animal communities.

7.1.2 Degree of scalability

Mostly dependent on resource available. Natural sites suitable for occupancy by seabirds are likely to be restricted whereas in theory, any number of artificial platforms could be built for kittiwake but regional carrying capacity might have to be calculated and may well constrain the potential for colonisation. Similar constraints are likely to apply to other species.

A combination of natural sites and artificial sites is possible and may work to enhance each other.

7.1.3 Timescales for response

Periods to colonisation can be relatively short for some species and long for others but all may take several to many years to build a significant population. Timescales for the response may be expected to be 5-20 years.

Actions to provide nesting sites for kittiwake have been shown to produce almost immediate response when artificial sites are located very close to existing colonies, especially if birds from those colonies are being disturbed (Turner 2010) although sites more remote from a source population can take several years to be adopted if they are at all.

However, guillemot responded within hours to social attraction techniques in California at a recently abandoned breeding site and the first breeding took place in year 1 of the project (Parker *et al.* 2007) although nest site selection coincided with areas where previous nests existed indicating habitat suitability is still important.

Puffin populations took many years to establish in the Maine colonies and have not recovered to former size although colonies of 100s of pairs have been produced and sustained for many years.

Terns generally have a rapid response for colonisation (even without social attractant but following gull removal) but this also may be slower, possibly 3-5 years, where birds have not bred for many years and so no ‘folk memory’ of the site remained (Kress 1997).

7.1.4 Practical feasibility

Translocation requires a source population. The usual approach being exporting excess young but potentially taking young from a population that was considered to be doomed could be an option. Protocols for re-establishing populations of other species have been developed (e.g. for red kite and great bustard) in the UK and similar guidelines for seabirds could be developed.

The identification of suitable sites for natural colonies might also be difficult. If a suitable site exists it must be determined why it has not been colonised naturally. Areas of search will need to be subject to review and then on-the-ground survey. Potentially agreement with land-owners sought for establishing equipment for social attraction or any work requiring access to a site.

In theory most of the ‘target’ species could be encouraged to establish a colony although doubts about locations of suitable sites make this a less certain option than artificial nest site provision. For the other seabird species it is assumed that terns and gulls would be the most likely to be amenable to this approach. It is considered that shearwaters and petrels would be more likely to establish in suitable natural sites than artificial sites.

7.1.5 Estimation of the ‘compensation return’

Given the identification of suitable sites then potentially colonies of 100s of most of the ‘target’ species could be established. Gannet is the species most likely to increase to larger colonies but is one of the more difficult to identify suitable sites for.

For non-target species, 10s to 100s of pairs of gulls and terns could result from successful colony establishment.

Returns are generally therefore potentially moderate to large.

7.1.6 Duration

Once established colonies could persist for many decades and increase in size if factors are favourable. However, inputs may be required for up to 20 years and in some cases continued effort to ensure site suitability would be required.

7.1.7 Conclusion

The main question that hangs over sites that might be candidates for new colonies is why are the birds not already nesting there? Most of the evidence suggesting it would be possible to establish new colonies for seabirds comes from projects where birds have been re-established at sites where they formerly bred, albeit in some cases after a considerable time gap. It could therefore be assumed that the sites were already suitable, structurally at least. In several cases, known issues (existence of predators, human persecution) were rectified, so facilitating re-colonisation.

For ‘virgin’ natural sites it would need to be established that the nesting ground is suitable and that no issues, such as predator presence exist. It also requires evidence that forage opportunities for the colony exist, but this is often lacking. There should also be regard for impacts that any new colony might have on existing colonies, good and bad, especially regarding competition for prey. This may restrict locations that could be used for new colonies, possibly to areas that had no suitable habitat.

Depending on the group of birds for which a new colony was to be established there may be a requirement for a donor population (for translocation purposes) or for hardware to establish social attraction. The indications arising from most studies are that these efforts would need to be maintained for several years to establish a colony at least for the ’target’ species. The long term and somewhat relentless (pre HPAI outbreak) expansion by gannet into new colonies indicates that establishing new colonies would probably not be required for this species.

Establishing new colonies of terns at natural sites is considered a relatively straightforward and rapid process, although the provisos for all such colonies (site suitability and prey resource) would still be valid. Terns respond well to social attraction techniques and colonies may establish in the first year of application. Similar responses might be expected by gulls to such approaches, but this is less well known.

There is some value in exploring this option, but serious hurdles appear to exist in making this a feasible, scalable and timeous route to compensation.

7.2 Artificial nest sites

7.2.1 Evidence for efficacy

Establishing new colonies at sites not currently occupied by a species could provide opportunities to increase breeding numbers if nesting sites elsewhere are limited or could improve access to resources for the species or reduce other pressures such as density dependent productivity or release from predator pressure. New colonies need not be on natural substrates but could be on artificial, human made ‘cliffs’. An advantage of this would be that such structures could be placed where desired rather than where available as the natural sites and the fine scale design of the structure could provide ideal nesting conditions for the species. Anti-predator mechanisms could be designed in.

Two methods are predominantly used to establish new colonies – i.e. translocation of individuals from the desired species and social attraction.

Social attraction is achieved through using decoys, visual, auditory, or possibly olfactory lures (Jones and Kress, 2012; Lu *et al.* 2020). Translocation involves physically moving birds, usually chicks prior to fledging, from one location to another (Kress and Nettleship 1978, Jones and Kress 2012, VanderWerf *et al.* 2023).

Establishing new colonies at natural sites requires overcoming any issue that previously prevented birds colonising naturally. This was included in factors reviewed by Kress (1997, 1998) and Jones and Kress (2012). It was also considered important that long-term funding for a colonisation project should be guaranteed. The species to be attracted should be well understood in terms of habitat and prey requirements (this is true for most UK seabirds). This would be very important for artificial sites where the nesting platform needs to be designed for the species in question. Kess (1997) considered that traditional memory within a species of nesting at a site could be important and certainly a factor in how rapid colonisation might be.

Projects targeting auks, shearwaters and petrels and terns are considered to have relatively high chance of success whereas those aimed at restoring, and by extension establishing, colonies for gannets, storm-petrels or cormorants are less often successful (Jones and Kress 2012).

7.2.1.1 Key seabirds

7.2.1.1.1 Kittiwake

The first record of kittiwake nesting on an artificial platform was from 1931 at Granton, Edinburgh (Coulson 2011), which just preceded the establishment of the colony at Dunbar. Provision of artificial structures for new colonies was considered to be highly likely to be effective in the review of strategic compensation measures by Furness (2021). Christensen-Dalsgaard *et al.* (2019) state that declines in Norway appear to be driven by reduced productivity. Therefore, opportunity to increase productivity would appear to be a good route for compensation to take.

Kittiwake shows relatively low philopatry for a seabird (Coulson 2011, Coulson and Coulson 2007, Danchin *et al.* 1998) (although for a slightly opposed view see Kildaw *et al.* (2008)), suggesting that social attraction will work as an effective method to establish new colonies. Kildaw *et al.* (2005) show that establishment of colonies is slow but once formed can grow rapidly fuelled by recruitment of established breeders relocating from other colonies.

Decoys and calls can be used to attract kittiwake to structures. For example, in Lowestoft where approximately 1000 pairs breed in existing buildings but as yet none breed on newly constructed onshore and nearshore breeding structures, a plan to use just that method is being proposed[14]. Some structures have been designed and built in areas close to current colonies but have not been adopted by kittiwake although the reasons are unknown, but one of the earliest purpose-built sites, the 'Gateshead Kittiwake Tower' was colonised in its first season. The tower was built in 1997/98 close to the already occupied Baltic Flour Mill which was being converted and birds discouraged from nesting there. Some adopted the tower quickly, however many dispersed elsewhere and the tower has never held the same numbers as the original colony (Coulson 2011). Kittiwakes were lured to the site using clay decoys and disused nests taken from the Flour mill. The tower was relocated 1-2km further downstream in 2001 and the colony remained intact (Turner 2010). Nesting success of all 'man-made' sites in the Tyne area has been found to be comparable to that from natural sites (Turner 2010). In Lowestoft, Suffolk an artificial wall built in 1988 held 53 nests in 1991 (Casey and Hooton, 1991) with 259 nests producing 303 young in 1995. This site does not appear to have used any attractants but was very close to or adjacent to already well used nest sites. A kittiwake colony at Sizewell Rig (water outlet/ intake for the nuclear power station) became established in 1994 (Suffolk Wildlife Trust 2007). No social attractant actions were undertaken there.

An advantage of establishing colonies at artificial sites is that birds may not need to be attracted from great distance. As the example of the Gateshead Tower shows, the colony could even be moved once established, although the distance over which that may be effective is unknown. While use of decoys, calls and dummy nests is likely to be standard practice, it should be noted that colonies at offshore rigs reported by Christensen-Dalsgaard *et al.* (2019) formed tens of kilometres from other sites without use of any decoys.

Christensen-Dalsgaard *et al.* (2019) found over 1,200 pairs of kittiwakes nesting on four offshore oil installations (two of which were floating storage and production units). Breeding productivity was greater on the oil installations compared with coastal artificial colonies in coastal Norway, and also much greater than

[14] Decoy kittiwakes could soon be unveiled in Lowestoft | Lowestoft Journal

that recorded at natural colonies in the same part of Norway. They suggest that the higher breeding success on oil rigs is likely to be due to higher food availability (because the birds nesting offshore are adjacent to foraging grounds so do not have to commute as far as birds that nest at the coast) and also to fewer predators at the oil rigs. Of 39 rigs in Norwegian waters that reported the status six had breeding kittiwake and 33 did not. Thus, only a minority were occupied, although the reasons why only those six were colonised were not investigated. Goliat Rig first registered a kittiwake nest in 2016 but had 40 nests three years later. Therefore, colonisation of suitable structures, once underway, can be very rapid.

Within colonies there is competition for the best nest sites (Coulson 2011, Acker *et al.* 2017) which are most productive which indicates that provision of more nest sites could reduce density-dependent suppression of productivity if it is occurring.

Population models show that kittiwake need to, on average, achieve a productivity level of about 0.8 chicks per nest to maintain the population. Productivity in excess of 0.8 chicks per nest could therefore be taken to compensate for predicted losses of birds (Furness 2021) as it would be assumed additional to what is required for population maintenance. The productivity reported from Norwegian offshore structures was 0.88 (±0.02 SE) young per nest, just over the 0.8 chicks fledged suggested by Furness (2021) and was higher than that found in natural sites on land (0.32 ±0.01 SE) in the same study (Christensen-Dalsgaard *et al.* 2019). The conclusion from that study was that predation is a major influence on productivity of these colonies, and predation is largely removed from the offshore colonies. Access to food supplies may also have been better for the offshore structure based colonies but could not be confirmed.

In summary there is a large body of evidence that kittiwake will adopt artificial structures for nesting and that breeding success is as good or better on those structures than at established natural sites.
Colonies may establish at considerable distance from existing colonies but it may be more important to use social attraction cues to attract birds to nest at such sites. The number of kittiwake that could be compensated for is potentially very large provided sufficient prey resource is available. Potential colony location could be matched to high prey availability and reduce competition with existing colonies to improve productivity and artificial sites could be designed or located to reduce predation risk.

7.2.1.1.2 Gannet

Northern gannet is rarely recorded using artificial sites. Furness (2021) did not consider it as an option for compensation in their review, however some members of the genus *Morus* have established colonies on artificial structures. In central northern Bass Strait, Australia, around 500 pairs of Australasian gannet nest on artificial structures, such as old navigational beacons, scattered throughout Port Phillip Bay (Bunce *et al.* 2002) approximately 260-300km from an established colony. Australasian gannet would appear to be more readily accepting of artificial structures as nest sites than northern gannet.

Niras (2021) shows gannet using artificial structures onshore in very small numbers in France and Italy both successfully raising young and two nest building attempts by single birds in Denmark and England (also onshore locations). This compares with the more substantial colonies of up to 200 pairs that have established on artificial structures offshore by the congener Australasian gannet in Victoria and South Australia.

Grose *et al.* (2011) record a brown booby nesting on a lighthouse in a bay frequently used for feeding by birds from other colonies and suggest that the birds selected the site to have access to a good prey resource. Red-footed booby used artificial platforms to nest on when provided after fire destroyed their usual nesting trees (Rauzon and Drigot 1999). Despite these records, platform nesting by gannets and boobies does not seem to be widespread and northern gannet does not show a preference for nesting on artificial sites. However, based on the Australasian gannet evidence, it seems possible that under some circumstances a platform structure could be developed that they may adopt. Population models of northern gannet indicate that a significant level of immigration and emigration from breeding sites takes place (Trinder 2016) and while the North Atlantic population has been expanding at just over 2% per annum, new colonies have formed regularly (see natural sites above). The impact of HPAI in 2022 has reversed much of these recent gains although no colony, even the small one at St Abbs Head, has been abandoned. If gannet do not succumb again to the virus as they did in 2022, then it is quite likely that the population will start to increase again but now released from some density dependent pressure at individual sites at least for a few years.

Furness *et al.* (2013) suggested establishing new colonies for gannet as one of the priority actions for the species although suggested that the feasibility and practicality of the measure was Moderate or Low. With use of social attraction it has been possible to establish colonies for Australasian gannet (Jones and Kress 2012) which suggests that it may be possible for northern gannet, although so far there has been no success for this species in the attempt made (Jones and Kress 2012), possibly because the site chosen was distant from any source colony. The advantages of establishing new colonies for gannet are probably reduced since HPAI caused significant population reductions and given the large foraging range of the species and preferred prey (mostly pelagic fish species) it may not provide significant benefit for foraging and productivity. In general, 2022 excepted, productivity of UK breeding gannet is very stable at between 0.6 and 0.8 young per pair (JNCC 2023). It is possible that locating new colonies would provide a further buffer against future HPAI impact or reduce barrier impacts for birds by selecting sites that kept routes to potential feeding grounds more free of obstructions. Selection of the location for any artificial platform to support a colony should consider the likely distribution of exclusive foraging areas exhibited by gannet (Wakefield *et al.* 2013).

Potentially the number of birds that could be compensated for is large given identification of a suitable site. Most gannet colonies number thousands of birds; 21 of the 28 colonies listed in the fourth national census were larger than 1000 pairs (Burnell *et al.* 2023) and five of the seven colonies that were less than 1000 pairs had been established since Seabird 2000.

7.2.1.1.3 Guillemot and Razorbill

Establishing new colonies at natural or artificial sites is not one of the actions listed by Furness *et al.* (2013) in their review for Defra, nor was it considered in the compensation options review (Furness 2021). For both guillemot and razorbill, evidence of directed establishment of breeding sites on natural or artificial structures is scarce. Nor do the 'large auks' feature in reports of seabirds nesting on oil and gas structures as do kittiwake or other gull species.

However, guillemot has been lured back to breeding at previous natural sites after very long (more than 100 years) absence using social attractants (Jones and Kress 2012) or just naturally (Menard 2011). Similarly, razorbill and Brunnich's guillemot have recolonised previously abandoned nesting areas in Greenland (Boertmann 2023). These were not artificial sites however, and it appears that there have been few attempts to encourage these species to breed in human constructed sites.

Guillemot have occupied an artificial cliff face built for research surveillance in Norway (Hentati-Sunberg *et al.* 2012, 2023). The first breeding pair was in 2009 and in 2023 there were 93 pairs breeding. The artificial cliff 'auklab' also contains boxes specifically designed for razorbill and some of these have been occupied by razorbill, although some have also been taken over by guillemot. No social attractants were used for this artificial cliff face but it is built within a currently thriving colony at which both guillemot and razorbill numbers are increasing. There is some evidence indicating that birds may breed on oil and gas platforms in the North Sea although this has not been confirmed (Orsted 2021a).

Therefore, in principle, it is possible to provide artificial nest sites for these large auks. If sites are distant from current colonies then it might be a long lead-in time until they become occupied and require the use of social attraction. The review of restoration projects by Jones and Kress (2012) shows that large auks can be responsive to social cues, at least in natural situations. These efforts prove that it would be possible to lure guillemot at least to new colony sites if all other factors were suitable and the artificial structure was sufficiently like a standard breeding site. So far, no evidence has been seen that birds could be lured to occupy distant sites not previously known to host them although that is theoretically possible. Identification of suitable locations would be a primary exercise to determine if this activity were possible to provide substantial input into any compensatory effort which may then take some considerable time before it was seen to work.

7.2.1.1.4 Puffin

The 'Project Puffin' reintroduction to Eastern Egg Rock Island, Maine has been used as a template elsewhere. Puffin became extinct at Eastern Egg Rock Island in around 1900 due mainly to human persecution but was successfully reintroduced 80 years later using a combination of translocation of chicks from Newfoundland and social attraction (decoys, mirrors and calls) (Kress and Nettleship, 1988). Almost 1000 chicks were translocated into hand dug burrows between 1973 and 1986. In the 1980s around 15 pairs bred on the island but now that colony is greater than 150 pairs and throughout the Maine Islands over 1000 pairs breed. Some birds did breed on other Islands in Maine in the 1980s particularly Machias Seal Island in Canada. Artificial burrows are some of the most common modifications to nesting habitat and are typically used in chick translocations. Usually, artificial burrows are hand excavated into soil or consist of artificial wooden or plastic burrows placed in suitable habitat. Such burrows typically have a door on their top so that researchers can readily check the burrow for productivity and growth studies (Jones and Kress 2012).

The chicks in Maine were relocated into artificial burrows dug by humans (Kress and Nettleship 1988) although this would not be necessary for returning adult birds it isn't clear if the presence of burrows on a site would encourage breeding. In areas where no turf covering is available, puffin will nest in crevices and cracks although this may restrict breeding numbers.

7.2.1.2 Other seabirds

Petrels and shearwaters are generally highly philopatric leading to the conclusion that translocation of birds not audio (and olfactory) social attractants would be the preferred methods to establish a colony. Famously Fisher translocated more than 3000 Laysan albatross only to have them return to the original natal site once they reached breeding age. Some birds would return to the translocation site if moved when very young (Kress and Nettleship 1988).

Audio playback has been used successfully on the Shiants for European storm-petrel but not for Manx shearwater (RSPB unpubl.) following black rat eradication.

Social attraction, consisting of playback of recorded Leach's storm-petrel calls and creation of artificial burrows were used to encourage Leach's storm-petrels to establish new colonies on Ross Island and Old Hump Ledge, Maine. Nesting birds were found the first year of playback on Ross Island, near but not in the artificial burrows. The colony on Old Hump Ledge established in the second year of playing burrow calls. Old Hump Ledge was an historic nesting island. Fifteen years after suspension of the attraction program a survey found at least three pairs of Leach's storm-petrels in natural burrows near the site of artificial burrows at Old Hump Ledge (Kress 1997). A qualified success for artificial sites but certainly birds were lured back to the site by the playback although the colony has remained very small. There are many examples of colonies of procellariiformes re-establishing after removal of predators but none of artificial structures being adopted away from natural sites.

Terns have generally low philopatry and feed young for some time after fledging. Accordingly, translocation is not an appropriate method to establish new colonies but social attractants have been shown to work well (e.g. see Hartman *et al.* (2019) for Caspian tern attracted to sites where they had not previously nested and Hartman *et al.* (2020) for Forster's tern establishment). Tern colonies will establish quickly – often in the first or second year of social attraction being deployed (Hartman *et al.* 2019, Hartman *et al.* 2020). In Maine, common tern took three years to start breeding at a site that they had not bred at for 50 years. Control of large gull species is seen as important in establishing colonies and often in ongoing management (Kress 1983). Under such a regime common, Arctic and roseate terns all recolonised islands in Maine (Kress 1997). Terns also readily adopt created sites, such as shingle bars but also floating platforms that can offer enhanced protection from predators. It is considered very likely that new breeding sites for terns could be established if required.

Gulls exhibit fairly low philopatry. Little attention appears to have been paid to protection and establishment of gull colonies, despite the fact that lesser black-backed gull, great black-backed gull, common gull and black-headed gull are all Amber-listed in BoCC5, while herring gull is Red-listed (Stanbury *et al.* 2021). Lesser black-backed gull and herring gull readily breed on artificial structures with substantial colonies in towns and cities on rooftops (Burnell *et al.* 2023, Coulson 2009) and smaller numbers of great black-backed gull utilising this resource. Nevertheless, this does suggest that large gulls could be provided with nesting opportunities in artificial sites if required. Provision of floating rafts for terns and black-headed gull has been used successfully in many locations (e.g. Burgess and Hirons 1992, Dunlop *et al.* 1991, Manikowska-Slepowronska *et al.* 2021). In line with having generally low philopatry it would be expected that social attraction rather than translocation techniques would be required for gulls although removal of chicks from nest sites that were to be destroyed under licence could provide opportunities for translocation source.

Cormorants are generally regarded as only moderately philopatric so can be attracted away from natal sites more easily. Young are not fed after fledging which means that translocation could be used in conjunction with social attraction to create new colonies. Meier (1980) devised artificial nesting structures of simple pole mounted platforms for double-crested cormorant (*Phalacrocorax auritus*) in Wisconsin which were readily adopted. Red-legged cormorants (*Phalacrocorax gaimardi*) nested on artificial structures in Chile (Garcia-cegarra *et al.* 2020). Several other related species nest on artificial structures such as coastal defences and piers (e.g crowned cormorant (*Microcarbo coronatus*) in Namibia), whereas *P.c. carbo* the nominate subspecies of great cormorant (*P.c. carbo*) tends to nest on sea cliffs and stacks, while the 'continental' subspecies (*P.c. sinensis*) nests in dead trees, and European shag (*Gulosus aristotelis*) nests on cliffs and in sea caves. Despite both great cormorant and European shag regularly using artificial structures for roosting, they rarely appear to adopt them for nesting.

Gulls (other than kittiwake) and cormorants are not expected to be species that require compensation actions for the ScotWind projects as they are more inshore species. Where wind farm projects are closer inshore than the majority of the North and North-east Scotwind projects it is possible that herring gull and great black-backed gull may need consideration.

Several other seabirds have been successfully restored or established using translocation techniques following the general principles here. Tropicbirds shearwaters and noddies have all been translocated in Mauritius. Ashy storm petrel, Cassin's auklet and Xantus's murrelet in Baha California. It is unlikely but possible that shearwaters and petrels might be a species of high concern in the assessment of ScotWind projects, although they may also be relevant in the context of non-like-for-like compensation.

7.2.1.3 Wider ecological benefits

Translocating top marine predators may have various impacts on general ecology. It could provide balance or it could result in predator pressure in an area previously without such predators. The influence of one predator on another through competition should also be considered (Wakefield 2013).

The benefit of increasing numbers of seabirds common to any of these approaches not just establishing colonies at natural or artificial sites. Seabirds distribute nutrients that are beneficial to plankton growth, seagrass and other marine life. These are the nursery food sources for fish. This is an important step in carbon cycles which includes locking carbon up in 'blue carbon' storage for example nutrients from seabird colonies increasing coral growth rates (Savage 2019). In theory artificial sites could be created near habitat creation activities to provide some synergistic benefit.

Nutrient cycling is one of the most important of the ecological functions that seabirds provide. Production of guano may increase primary production and trigger bottom-up effects on primary and secondary consumers (Bosman and Hockey 1986, Signe *et al.* 2021, Hentati-Sundberg *et al.* 2020). Spreading of colonies to new areas would distribute nutrients further and could lead to increased primary production across a wider area.

Aside from nutrient input soil turnover by burrowing seabirds has been shown to affect invertebrate communities (Orwin *et al.* 2016) as well as having physical effects on soil structure and chemistry (Bancroft *et al.* 2005) which in turn affects plant and animal communities. These effects will be smaller for artificial sites, unless that includes creating turfed areas for burrow nesters for example.

One benefit of artificial nests sites is that they can be designed for research aspects allowing access to breeding birds or even some automated monitoring.

7.2.2 Degree of scalability

Mostly dependent on resource available. In theory any number of artificial platforms could be built for kittiwake but regional carrying capacity might have to be calculated and may well constrain the potential for colonisation. Similar constraints are likely to apply to other species.

Natural sites are likely to be highly restricted. A combination of natural sites and artificial sites is possible and may work to enhance each other.

7.2.3 Timescales for response

Colonisation of artificial nesting sites can be rapid. Guillemots responded within hours to social attraction techniques in California at a recently abandoned breeding site and the first breeding took place in year one of the project (Parker *et al.* 2007). In that case, nest site selection coincided with areas where previous nests existed indicating the importance of habitat suitability underpinning social attraction. This potentially could be a similar situation for an artificial site close to an existing nesting location. The artificial kittiwake tower in Gateshead was occupied by some birds the year after construction. Timescales for colonisation can be highly variable though and in Maine it took eight years for the first returnee puffin to appear following start of translocations and 12 years until first breeding took place.

7.2.4 Practical feasibility

For a few species there are already designs of artificial nesting areas that have been shown to work, notably kittiwake. For others there is some knowledge (e.g. gannet, guillemot) but further development will be required. The costs of producing and siting artificial sites at sufficient scale could be prohibitive. Translocation requires a source population; the usual approach involves exporting excess young, but potentially a source population that was considered to be doomed could be used.

Identification of locations for artificial nesting areas will require a project to search for locations with all required elements. For some species (e.g. kittiwake) offshore oil and gas platforms may provide ready-made infrastructure but obligations surrounding safety of structures and decommissioning requirements may make taking over ownership less attractive. Potentially, there would also need to be agreements in place with landowners for establishing equipment for social attraction or any work requiring access to a site.

It is likely that artificial nest sites suitable for kittiwake could be developed, but less likely that auks or gannet would adopt such sites. For 'non-target' species it is very likely that artificial nest sites for terns or gulls could be created but much less likely for shearwaters and petrels.

7.2.5 Estimation of the 'compensation return'

The number of birds that could be supported by artificial structures will be to a large extent reliant upon the resource available to construct and maintain a number of artificial sites. Given the successful identification of suitable sites then potentially colonies of 100s of most of the 'target' species could be established. Gannet is the species most likely to increase to larger colonies but would require large (or many) structures and there is much less certainty that any artificial sites would be adopted by that species.

For 'non-target' species 10s to 100s of pairs of gulls and terns could result from successful colony establishment and these species readily adopt artificial sites.

Returns are generally therefore potentially moderate to large but risk of non-adoption is high for gannet and moderately high for auks.

7.2.6 Duration

Artificial nesting platforms would require some attention for their expected life although the initial construction and siting of the devices would be the greatest cost.

Once established it is considered probable that colonies would persist for decades.

7.2.7 Conclusion

The great advantage of schemes to establish new colonies at artificial sites is that the structure can be designed to provide optimal nesting conditions and sited to reduce interference and promote access to prey resource. It could be combined with wider environmental measures such as enhanced foraging provision to take advantage of synergistic impacts. Given resource (time, money and source populations) it is possible that this option could provide compensatory breeding populations at strategic and scalable levels.

This measure is not suitable for all species however. Gannet appears to be resistant to establishing on artificial structures. Even when species are more easily attracted to such structures building at sufficient scale could be prohibitively expensive. A single structure could, however, house several hundred pairs of kittiwake for example. Among the 'target' species, kittiwake is the one with most prior knowledge of success and although cliff nesting auks have adopted artificial structures at research sites it is not thought that this is particularly scalable.

Designs for artificial structures suitable for puffin colonies were not identified. It is not inconceivable that a working design could be developed, and even combined with a kittiwake nesting structure perhaps, but feasibility is unknown.

Among 'non-target' species, gulls and terns appear likely to adopt artificial nest structures most readily and cormorants may also do so. Simple shingle banks in the correct location may be enough to provide nesting areas for terns which would probably represent the cheapest option in terms of establishing new seabird colonies on artificially created sites.

What all artificial sites have in common is that they allow the nesting colony to be placed in the most advantageous location. This could be to take the colony away from high risk areas or to provide access to foraging opportunities for species that do not have the very large foraging ranges of fulmar or gannet for example. By placing structures sufficiently far offshore and / or building in protective features problems with invasive predators could be removed entirely.

It should be remembered that it could take some years before an artificial colony would be adopted, if at all, and ongoing maintenance of the structure would be required.

Finally, artificial structures could be designed to provide access to nests for research purposes facilitating post construction monitoring activity.

7.3 Seagrass restoration

7.3.1 Evidence for efficacy

7.3.1.1 Key seabirds

Seagrass restoration could provide a compensation return for the ‘target’ seabird species by increasing the area of shelter, foraging and nursery habitat for forage fish which form a significant proportion of their diet. In the UK, studies have revealed that seagrass harbours 4.6 times the abundance of fish of unvegetated habitats (at a density of 6,000 fish per hectare) and is of particular importance as a nursery ground for juvenile forage fish including Atlantic cod (*Gadus morhua;* hereafter cod*)*, pollock *Pollachius pollachius*, whiting *Merlangius merlangus*, plaice *Pleuronectes platessa* and herring *Clupea harengus* (Bertelli and Unsworth 2014). There is strong evidence to suggest that seagrass meadows are important to contributing to cod stocks, and available literature suggests this species will use seagrass as a nursery habitat where it occurs in high densities (Lilley and Unsworth 2014). Juvenile fish found residing in structurally complex seagrass habitats have been found to have reduced predatory pressure, lower energy requirements and higher feeding and growth rates than those in other temperate coastal habitats (Heck *et al.* 2003). An analysis of 51 papers on seagrasses globally concluded that seagrass habitat supported higher densities and increased growth of juvenile fish relative to bare sediment or other structured habitats, particularly in temperate regions (McDevitt-Irwin *et al.* 2016). Such effects may result in population-level responses. Thus, coastal habitats are well recognised as important nurseries for fish, with the habitat size and quality strongly influencing stock size of commercially important species through growth, survival and connectivity with spawning areas (Gibson, 1994, van de Wolfshaar *et al.*, 2015).

Furthermore, there is an increasing understanding of the importance of juvenile life stages in overall fisheries conservation and management and an International Council for the Exploration of the Sea (ICES) Working Group has been established across UK and European scientific bodies on the Value of Coastal Habitats for Exploited Species (WGVHES). The WGVHES aims to determine the relative value of coastal nursery habitats (including seagrass beds and kelp beds, as well as spawning and nursery grounds) and integrate this into population dynamics models for commercially exploited species (ICES, 2021). In 2015 the WGVHES found that 44% of all ICES assessed species utilise coastal habitats in some way, with the relevant stocks contributing 77% of all commercial landings of species for which ICES provide advice. WGVHES concluded that these statistics confirm *“the significance of coastal habitats for both a self-sustaining population and potentially for fishery yields of ICES species”* (ICES, 2015). The most recent WGVHES report (ICES, 2021) analysed the potential for juvenile abundance indices to be used in forecasting stock recruitment, demonstrating that survey-based pre-recruit abundance indices were sufficiently accurate for predicting future recruitment. This relates to recruitment of the juveniles in coastal areas to the stocks exploited further offshore.

Of the ‘target’ seabird species, kittiwake feeds predominantly on sandeels *Ammodytidae* but clupeids such as herring and sprat *Sprattus sprattus* are also important (Harris and Wanless 1997). However, kittiwake does not have a highly specialised diet and will feed on a range of small-sized Atlantic fish species including capelin *Mallotus villosus*, cod and haddock (Vihtakari *et al.* 2018) if available near the surface. Guillemot, razorbill and puffin rely heavily on sandeels and clupeids (Engelhard *et al.* 2014) although guillemot in particular is also capable of consuming gadoids including cod and whiting (Anderson *et al.* 2014). Gannets are opportunistic feeders, obtaining their prey through plunge-diving, surface feeding and scavenging behind fishing vessels (Camphuysen 2011). Plunge dives target shoal forming species including whiting, cod, haddock, sandeel and sprat (Cornell University 2019). When following trawlers, gannet has been observed focusing mostly on roundfish, showing a preference for smooth fish species (gadoids, clupeids) over spiny species (gurnards) (Camphuysen 2011).

An extensive review of the ecological evidence surrounding seagrass restoration as a potential ornithological compensation measure for 'target' seabirds (kittiwake, guillemot, razorbill and gannet) was recently carried out in relation to the Hornsea Project Four OWF (Ørsted 2021b). The review did not identify any literature that directly connects seabird species with seagrass habitats in the UK, and acknowledged several evidence gaps in the understanding of the level of support seagrass provides to prey species and the links with kittiwake, guillemot, razorbill and gannet. the review concluded that seagrass meadows in the UK are likely to have an indirect positive effect on seabirds by acting as a nursery habitat for prey species, and connections can be made between of seabird diets and knowledge of how individual fish species utilise seagrass (Ørsted 2021b).

7.3.1.2 Other seabirds

By providing shelter, foraging and nursery habitat for a variety of fish species, seagrass restoration could also benefit other seabirds which prey on fish, including divers, shearwaters, terns and gulls. Sediment stabilisation and reduced turbidity due to the presence of seagrass (Moksnes *et al.* 2021) can provide habitat conditions that are potentially suitable for a more diverse assemblage of fish species, as opposed to a more limited suite of species suited to highly turbid environments. Such increased diversity at these lower trophic levels may potentially benefit a range of seabirds via reduced competition for prey resources.

7.3.1.3 Wider ecological benefits

Seagrass is one of the most important habitats found in coastal and marine environments, providing a range of highly valuable ecosystem services. In addition to the benefits provided to fish and seabirds already discussed, these services include (from Gamble 2021 unless stated):

- **Biodiversity -** seagrasses are productive ecosystems supporting greater invertebrate diversity than adjacent sand and mud environments. This increased complexity provides shelter from predation, more ecological niches and a wide range of food resources that enriches faunal species, ensuring the ecosystem's resilience.
- **Habitat connectivity** - Seagrasses typically exist near saltmarshes, kelp forests and bivalve reefs (e.g. mussel and oyster beds). This connectivity allows for a direct transfer of carbon and nutrients, and is also important for the ontogenetic and foraging movements of marine fauna across different habitats.
- **Carbon sequestration** – seagrass beds are significant carbon sinks on a global scale, with high capacity for taking up and storing CO_2 in the sediment, also known as blue carbon. Concentration of organic carbon has been shown to be significantly higher in areas with greater seagrass coverage (Potouroglou *et al.* 2021).
- **Ocean acidification** - Seagrass beds can alleviate low pH (more acidic) conditions for extended periods of time, sometimes by up to 30% (Ricart *et al.* 2021). Time of year is an important factor as are the local oceanographic conditions, with more buffering occurring in springtime when seagrasses are highly productive.
- **Nutrient cycling/water filtration** - seagrasses help improve and maintain high water quality by contributing to the benthic-pelagic coupling, or the exchange of nutrients from the benthic to pelagic

layer. Seagrass is known to play a crucial role in nutrient cycling by acting as both a sink and a source for nutrients in varying areas of nutrient availability.

- **Disease control -** compared with non-vegetated areas, seagrass can reduce general bacteria (and more specifically, those belonging to the genus *Vibrio*) by 39% for all *Vibrio* species, and 63% for the potentially harmful *V. vulnificus/cholerae* subtype.
- **Coastal protection -** seagrasses have a well-developed network of rhizomes and roots that secure and consolidate sediment, while their canopies reduce current speeds, aiding the settlement of suspended material. Once a restored seagrass meadow reaches a critical size, it can create a self-generating effect that stabilises the bottom, improving water conditions and consequently growth conditions for seagrass (Moksnes *et al.* 2021).

7.3.2 Degree of scalability

It has been estimated that up to 92% of seagrass has been lost from UK waters, including 39% lost since the 1980s, although trends for Scottish seagrass beds remain largely unknown (Green *et al.* 2021). This estimated loss is the result of a combination of factors, including coastal development, poor water quality and (previously) outbreaks of a wasting disease (Gamble *et al.* 2021). Seagrass beds in Scotland tend to occur in sheltered areas up to 10 m deep, with a sufficient amount of water exchange to maintain low turbidity levels, with sufficiently low exposure for a bed to stabilise and develop. The complex coastline, sheltered sea lochs and firths therefore make Scotland a good place for seagrass to thrive (Kent *et al.* 2021). A habitat suitability map has been developed to identify the most suitable, least suitable and unsuitable areas for seagrass beds in Scotland (Huang 2021); this indicates that the areas most suitable for seagrass in Scotland include the Firth of Forth (particularly along the southern coast), the Moray Firth, Cromarty Firth, Durnoch Firth and the Firth of Clyde, as well as around the coastlines of Orkney and the Inner and Outer Hebrides.

Two seagrass restoration projects have been initiated in Scotland in recent years. Seawilding is a community-led project in Loch Craignish, which is trialling small-scale planting using a novel method but has identified 80 hectares of seabed as suitable for seagrass restoration[15]. The Restoration Firth Project is a conservation partnership between charities, local community groups and scientists which aims to restore four hectares of seagrass in the Firth of Forth by 2024[16]. Opportunities exist for large scale seagrass restoration in Scotland. In addition, rapidly evolving technology in seed collection and distribution is increasing the probability of success of large-scale seagrass restoration projects worldwide, including the well documented example of Chesapeake Bay in the US where the use of a mechanical harvesting and seed scattering vessel has been instrumental in the restoration of 3600 hectares of seagrass (Orth *et al.* 2020).

7.3.3 Timescales for response

The response timescale would consist of three sequential stages: a) the timeframe required to restore seagrass habitats to a condition suitable to support forage fish; b) the response time for fish populations associated with seagrass to increase, and c) the associated response time for seabird populations to benefit from the increased fish populations. Successful restoration can take several years (Gamble *et al.* 2021); at Chesapeake Bay, ecosystem services from increased shoot density occurred between four and 10 years post-restoration (Oreska *et al.* 2020). Fish reproduction cycles vary greatly between species and stocks; sandeels can reproduce at around two years of age[17] whereas cod can take up to nine years to reach sexual maturity[18]. It is considered that relatively rapid response times could be observed in seabird populations where there is an increase in forage fish availability, as this could lead to a greater number of chicks being

[15] *https://www.seawilding.org/seagrass-project*
[16] *https://www.theecologycentre.org/seagrass*
[17] *https://www.nature.scot/gd/print/pdf/node/4278596*
[18] *https://www.nw-ifca.gov.uk/managing-sustainable-fisheries/cod/*

provisioned during the subsequent breeding season. However, amongst the five 'target' species, age of first breeding varies between four and six years, so delaying the period before any increase in breeding productivity leads to increased recruitment to adult populations (Horswill and Robinson 2015). This period would be reduced in some other, 'non-target', seabird species (e.g. terns). Taking the three stages into consideration, the response timescale for seagrass restoration is considered to be long term (>10 years).

7.3.4 Practical feasibility

Detailed feasibility studies of potential seagrass restoration projects are required in order to design restoration with the highest chance of success. There are several factors to consider and recommendations when choosing a restoration site (from Kent *et al.* 2021 unless stated):

- Habitat suitability modelling, baseline surveys and an assessment of the biological and environmental risks to the project should be carried out in advance of restoration.
- Historic information should be studied carefully to determine the natural variability, direction of change and likely cause of change to existing seagrass beds in the vicinity.
- Early engagement with any local community groups or organisations involved in previous work at the site is also recommended.
- Seagrass beds that are considered to be in a degraded condition should not be used as a donor site.
- Seagrass planting should not go ahead if known pressures from human activity (e.g. aquaculture) will continue to exist. Research shows that when transplanting adult plants, it is important to match the conditions of the donor site and the restoration site (Moksnes et al. 2021).

The chosen method of seagrass restoration is likely to be key to its feasibility and success. Seagrass seed collections by hand are considered time-consuming, expensive and difficult, particularly for deeper subtidal beds, which restricts the scale of seed collection for restoration projects (Gamble *et al.* 2021). Mechanised seed collection and distribution approaches such as that used at Chesapeake Bay have the potential to significantly upscale seagrass restoration but it would be necessary to demonstrate that these methods do not damage existent marine habitats and fauna and the seeds would not be rapidly consumed by predators (e.g. crabs – see Infantes *et al.* 2016). Alternatively, use of hessian bags containing seagrass seeds, termed the bags of seagrass seeds line (BoSSLine) system (Unsworth *et al.* 2019), has already been used in Wales and is considered the method most likely to succeed in Scotland for subtidal seagrass due to the similar environmental conditions as in the Welsh trials (Kent *et al.* 2021).

Other issues potentially affecting feasibility of implementation include:

- Potential conflict with other industries e.g. fishing, so proposals and management initiatives may be contested.
- Costs of monitoring success of the restoration and potential requirement for maintenance management or further intervention.
- Licencing/permitting requirements.
- Ensuring non-native seagrass species don't outcompete native species.

It is also necessary to ensure seagrass restoration projects are resilient to climate change-related stressors such as rising sea levels, ocean warming and marine heatwaves, and increased storm frequency and intensity. Genetic interventions can enable and speed up the rate of natural evolutionary processes that lead to climate change adaptation, and therefore restoration projects should aim to maximise genetic diversity in new populations to increase long-term success. Introducing the best possible genetic mix of individuals is of utmost importance (Gamble *et al.* 2021).

7.3.5 Estimation of the 'compensation return'

Existing reviews of strategic compensation measures (e.g Furness 2013, Furness 2021, McGregor *et al.* 2021) do not mention seagrass restoration as a potential compensation option for UK seabirds impacted by OWFs. The evidence review carried out in relation to the Hornsea Project Four OWF did not attempt to quantify the compensation return to seabirds from seagrass restoration, largely due to evidence gaps in the understanding the level of support seagrass provides to prey species and the subsequent links between increases in prey abundance and population responses of kittiwake, guillemot, razorbill and gannet (Ørsted 2021b). Based on the information currently available, it is very difficult to quantify (even approximately) how many seabirds would benefit from a measurable amount of seagrass restoration, and further studies would be needed to improve understanding of the extent to which restored seagrass meadows in UK waters increase productivity of forage fish populations before such a measurement could be made. An alternative method of providing an estimate of the compensation return could involve a comparison of forage fish densities in seagrass habitats with unvegetated marine habitats and relating this to the average fish consumption by individual seabird species. The range of ecosystem services that seagrass habitats offer is well established and could deliver compensation in terms of wider ecosystem resilience that would benefit the site network (relevant to tier 5 of the proposed definition for compensation).

7.3.6 Duration

Successfully restored seagrass habitats as a compensation measure has the potential to provide long-term benefits to forage fish populations, providing that an adaptive management strategy is implemented to allow for interventions if restoration isn't going to plan (e.g. poor seagrass establishment due to predation or invasive species). If compensation is required for the lifetime of an OWF (e.g. 30-35 years), it would be expected that monitoring and adaptive management would be required throughout this period.

7.3.7 Conclusion

Seagrass habitats are widely recognised as providing nursery grounds for fish, including prey species for kittiwake, gannet, guillemot and a range of other UK seabirds. However, there is a lack of direct evidence linking seabirds to seagrass habitats in Scotland, and quantifying these linkages has not been attempted (and may not be possible). Nevertheless, connections can be made between the diets of seabirds and knowledge of how individual fish species utilise seagrass, and a range of other ecosystem services are provided by seagrass habitats including carbon storage, nutrient cycling and increased biodiversity.

Potential opportunities for seagrass restoration occur widely in Scottish inshore waters, particularly in sheltered sea lochs and firths, where a number of small-scale restoration projects have recently been established. One of the main issues affecting potential feasibility of larger schemes is seagrass seed collection and distribution, which (if done by hand) can be expensive, time-consuming and difficult. Novel technologies and methods such as mechanised seed harvesting / distribution have the potential to significantly upscale seagrass restoration, but there are associated concerns surrounding possible impacts to existing habitats, invasive and predatory species, conflict with other industries and (more broadly) resilience of seagrass habitats to climate change-related stressors such as storms and marine heatwaves.

Restoration of seagrass habitats as a potential compensation measure for the 'target' seabird species would be a long-term initiative, due to the response times for fish populations associated with seagrass to increase and the subsequent response time in seabird populations (depending on species). Adaptive management would be necessary to respond to potential problems preventing successful establishment of seagrass meadows, however the requirement for compensation for the lifetime of an OWF project (e.g. 35 years) would provide the necessary mechanism for intervention. Annual monitoring could deliver measurable information on fish abundance and potentially allow for some degree of quantification of impacts on seabird populations and other ecosystem services.

7.4 Oyster reef restoration

7.4.1 Evidence for efficacy

7.4.1.1 Key seabirds

As for seagrass, native (European) oyster *Ostrea edulis* reef restoration could provide a compensation return for the 'target' seabird species by improving the habitat for forage fish which form a significant proportion of their diets (described in **Section 7.3.1.1**). Oyster reefs can increase fish production by providing a protective nursery ground for juveniles, that acts as a refuge from predation and provides a source of food through increasing the abundance of prey (Preston *et al.* 2020). Increasing habitat complexity within an oyster reef has been linked to an increase in transient fish size and abundance (Harding *et al.* 2001). It has been estimated that 10m^2 of restored eastern oyster reef in the southeast US produces approximately 2.6 kg of fish and large crustaceans per year (Peterson *et al.* 2003). In the UK and Ireland, intertidal concretions of native oysters have been recorded forming reef structures, which provide habitat and refuge for a range of organisms including juvenile fish and crabs (Preston *et al.* 2020). As outlined in **Section 7.3.1.1**, there is evidence to suggest that habitat conditions facilitating increased densities of juvenile fish may have population-level benefits.

7.4.1.2 Other seabirds

By providing shelter, foraging and nursery habitat for a variety of fish species, oyster restoration could also benefit other seabirds which prey on fish, including shearwaters, terns and gulls, although evidence for this is limited and comes mainly from the US. Oyster restoration on the Atlantic and Gulf coasts was found to enhance habitat for fish and shellfish by 34-97% (Smith *et al.* 2023) and increase the relative abundance of fish over time as reefs aged (Smith and Castorani 2023). In North Carolina, restored oyster reefs harboured more unique species than unstructured bottom, thereby enhancing the overall diversity of estuarine fish assemblages (Pierson and Eggleston 2013).

7.4.1.3 Wider ecosystem benefits

There is clear evidence for the provision of ecosystem services from oysters, although the specific benefits of native oysters specifically are poorly quantified (zu Ermgassen *et al.* 2020). In addition to the benefits provided to fish and seabirds already discussed, ecosystem services provided by native oysters include (from Preston *et al.* 2020 unless stated):

- **Biodiversity** – oysters form a complex structure that provides food and shelter for a diversity of species.
- **Water clarity** – can benefit recovery of seagrass and other coastal aquatic plants.
- **Water quality** – removes pollutants from the water column. A single oyster can filter as much as 200 litres of water per day.
- **Denitrification** (conversion of nitrates into nitrogen gas) – removes excess nutrients.
- **Sediment stabilisation** – reduces the resuspension of fine sediment, improving water clarity.
- **Flood risk** – oysters may act to reduce flood risk and coastal erosion potential (Thomas et al. 2022).

7.4.2 Degree of scalability

The decline of the native oyster across its biogeographic range has been driven largely by over-fishing and anthropogenic habitat destruction, with other negatively interacting factors including disease, invasive species and pollution (Helmer *et al.* 2019). Native oyster reefs are now among the most threatened marine habitats in Europe; in the UK and Ireland populations have declined by 95%, with remnant populations found in the south-east of England, west coast of Scotland and the south coast of Ireland (Preston *et al.* 2020). Oyster restoration projects are underway in a number of Scottish sites. The Durnoch Environmental Enhancement Project (DEEP) is using waste shell from the shellfish industry to stabilise the substrate and mimic conditions in the Dornoch Firth before oysters became extinct, prior to releasing up to four million oysters in the Firth by 2030. At Loch Craignish, Seawilding has released 300,000 native oysters into the loch with a further 250,000 growing in nursery cages[19], and Restoration Forth plans to restore 30,000 oysters in the Firth of Forth by 2024[20].

Oyster reef restoration is potentially expandable to sea lochs throughout much of Scotland where suitable environmental conditions exist. However, the end goal of restoration is often a sustainable population, and it is not yet known how this relates to density or area of oyster reef habitats (Preston *et al.* 2020). Large numbers of oysters are required for restoration projects, and the density achieved immediately after deploying oysters needs to be substantially greater than the intended established density. The European Native Oyster Restoration Handbook recommends taking into account a retention rate of 5% when setting deployment densities (Preston *et al.* 2020); the use of shell or stone material to create stable reef structures (such as that used in the Durnoch Firth) could increase the rugosity (surface roughness) of the seabed and therefore oyster retention on the target area.

7.4.3 Timescales for response

The response timescale would consist of three sequential stages: a) the timeframe required to restore oyster reefs to a condition suitable to support forage fish; b) the response time for fish populations associated with oyster reefs to increase, and c) the associated response time for seabird populations to benefit from the increased fish populations. A minimum five-year project is considered necessary for oyster restoration (Preston *et al.* 2020); in the US, restored oyster reefs were found to take at least eight years to yield long-term benefits (Smith and Castorani 2023) however there are some suggestions that it can take decades for oyster reefs to become self-sustaining (Chris Eastham, pers. comm.). Fish reproduction cycles vary greatly between species and stocks; sandeels can reproduce at around two years of age[21] whereas cod can take up to nine years to reach sexual maturity[22]. It is considered that relatively rapid response times could be observed in seabird populations where there is an increase in forage fish availability, as this could lead to a greater number of chicks being provisioned during the subsequent breeding season. However, amongst the five 'target' species, age of first breeding varies between four and six years, so delaying the period before any increase in breeding productivity leads to increased recruitment to adult populations (Horswill and Robinson 2015). This period would be reduced in some other, 'non-target', seabird species (e.g. terns). Taking the three stages into consideration, the response timescale for oyster reef restoration is considered to be long term (>10 years).

7.4.4 Practical feasibility

The first stage in assessing the viability of an oyster restoration project should involve feasibility studies, site selection processes and determining if there are significant ecological, logistical, legislative or financial barriers to restoration (Preston *et al.* 2020). One of the key limiting factors in native oyster restoration is the provision of sufficient number of oysters to keep pace with restoration; the supply of native European oysters continues to be a bottleneck in expanding and scaling up restoration efforts (NORA website). Oyster seed can be produced by three differing techniques: from sea-based collectors, in a spatting pond, or in a hatchery. Each technique has its own benefits and drawbacks, which should be considered when selecting which supplier to partner with for a restoration project (Strand *et al.* 2021). Private aquaculture enterprises

[19] *https://www.seawilding.org/native-oyster-project*
[20] *https://nativeoysternetwork.org/portfolio/restoration-forth/*
[21] *https://www.nature.scot/gd/print/pdf/node/4278596*
[22] *https://www.nw-ifca.gov.uk/managing-sustainable-fisheries/cod/*

(e.g. The Oyster Restoration Company) may be able to provide a sufficient number of oysters for restoration projects where it is impractical or unacceptable to obtain oysters from wild populations.

Other issues potentially affecting feasibility of implementation include:

- Potential conflict with other industries e.g. fishing, so proposals and management initiatives may be contested.
- Ensuring biosecurity - the introduced parasite, *Bonamia ostreae*, caused catastrophic mortality in native oysters during the 1980s, furthering the decline of this species, and is now present throughout much of the natural range of *O. edulis*. It is therefore important that restoration attempts avoid further introduction and spread of this parasite, which can cause lethal infections of *O. edulis* (Sas *et al*. 2020).
- Licencing/permitting requirements – a range of licences and authorisations may be required in order to establish an oyster restoration scheme e.g. marine licence, Crown Estate lease, Fish Health Inspectorate authorisation.
- Costs of monitoring success of the restoration and potential requirement for maintenance/ management or further intervention.

It is also necessary that oyster restoration initiatives can withstand and adapt to climate change-related stressors such as rising sea levels, ocean warming and marine heatwaves, and increased storm frequency and intensity, as well as maintain resilience to biosecurity threats from disease and invasive species. Genetic differentiation has been linked to both adaptations and disease resilience at local scales, therefore it is important that restoration practices, at a minimum, maintain local or regional genetic diversity and adaptations. In addition, restoration projects should seek to utilise breeding techniques that maximise the genetic diversity in the offspring to enable resilience to future change (Preston *et al.* 2021).

7.4.5 Estimation of the 'compensation return'

Existing reviews of strategic compensation measures (e.g Furness 2013, Furness 2021, McGregor *et al.* 2021) do not mention oyster restoration as a potential compensation option for UK seabirds impacted by OWFs. Based on the information currently available, it is very difficult to quantify (even approximately) how many seabirds would benefit from a measurable amount of oyster restoration, not least because a sustainable density or area of restored oyster reef habitat is not yet known. Further studies would be needed to improve understanding of the extent to which restored oyster reefs in UK waters increase productivity of forage fish populations before such a measurement could be made. An alternative method of providing an estimate of the compensation return could involve a comparison of forage fish densities in oyster reefs with marine habitats containing bare substrate, and relating this to the average fish consumption by individual seabird species. The range of wider ecosystem services that oyster reefs offer is well established and could deliver compensation in terms of wider ecosystem resilience that would benefit the site network (relevant to tier 5 of the proposed definition for compensation).

7.4.6 Duration

Successfully restored oyster reef habitats as a compensation measure has the potential to provide long-term benefits to forage fish populations, providing that an adaptive management strategy is implemented to allow for interventions if restoration isn't going to plan (e.g. *Bonamia ostreae* infection or poor colonisation of reef substrate). If compensation is required for the lifetime of an OWF (e.g. 30-35 years), it would be expected that monitoring and adaptive management would be required throughout this period.

7.4.7 Conclusion

The complex three-dimensional environment of oyster reefs has been found to provide a protective nursery ground for juvenile fish, increase fish abundance over time and therefore increase potential prey for seabirds. However, the majority of evidence comes from overseas and there is no evidence directly linking seabirds with the distribution of oyster habitats in Scottish waters, with a sustainable area or density of restored oyster reef habitat still unknown. Nevertheless, links between oyster restoration and beneficial effects on seabird prey can be made, and the range of wider ecosystem services that oyster reefs offer are well established (e.g. improving water quality, removing excess nutrients, sediment stabilisation).

Oyster restoration projects have recently been established at several locations on the Scottish coast, and are potentially expandable to sea lochs throughout much of Scotland where suitable environmental conditions exist. However, large numbers of native oysters are required to deliver sufficient densities for successful establishment, and supply chain issues mean that the supply of disease-free, genetically robust native oysters is a key limiting factor to scaling up restoration. The use of waste shell from shellfish industries may accelerate oyster retention by creating stable reef structures for oysters to colonise. Other potential issues include potential conflict with other industries, biosecurity, licencing/permitting requirements and resilience to climate change-related stressors such as storms and marine heatwaves.

Restoration of oyster reefs as a potential compensation measure for the 'target' seabird species would be a long-term initiative, due to the response times for fish populations associated with seagrass to increase and the subsequent response time in seabird populations (depending on species). Adaptive management would be necessary to respond to potential problems preventing successful establishment of oyster reefs, however the requirement for compensation for the lifetime of an OWF project (e.g. 35 years) would provide the necessary mechanism for intervention. Annual monitoring could deliver measurable information on changes to fish abundance and potentially allow for some degree of quantification of impacts on seabird populations and other ecosystem services.

7.5 Kelp bed extension

7.5.1 Evidence for efficacy

7.5.1.1 Key seabirds

As for seagrass and oyster restoration, extending kelp beds could provide a compensation return for the 'target' seabird species by improving/increasing the habitat for forage fish which form a significant proportion of their diets (described in **Section 7.3.1.1**). The importance of kelp habitat as a nursery area for the development of juvenile fish has been widely recognised. In Norway, several studies have identified kelp forests as being important nursery habitat for juvenile gadoids (Fossa, 1995; Sjøtun and Lorentsen, 2003) and experiments with Atlantic cod showed that kelp helps to provide shelter and safety to juvenile cod (Gotceitas *et al.* 1995). Studies elsewhere have also demonstrated the benefits of kelp to juvenile fish (e.g. Lazzari and Stone 1996, Anderson 1994, Carr, 1989) and a review of relevant literature showed a positive kelp-fishery relationship in most studies considered (Bertocci *et al.* 2015). As outlined in **Section 7.3.1.1**, there is evidence to suggest that habitat conditions facilitating increased densities of juvenile fish may have population-level benefits. Sandeel, an important prey species for the 'target' seabirds, has been recorded within Norwegian kelp forests (Hoeiaseter and Fossaa 1993) although sandeel nursery grounds occur primarily on sandy substrata and no evidence has been identified linking specific benefits of kelp forests to sandeels. Kelp beds also provide habitat for molluscs and crustaceans which can be prey for some seabird species, including on occasion kittiwake (e.g. Cramp and Simmons 1983).

7.5.1.2 Other seabirds

By providing shelter, foraging and nursery habitat for a variety of fish species, kelp restoration could also benefit other seabirds which prey on fish, including cormorants, terns, divers and sea ducks which prefer inshore habitats where kelp is found. In Norway, the higher prey abundance associated with kelp beds was linked to increased foraging efficiency of cormorants *Phalacrocorax carbo* (Lorentsen *et al.* 2010) and a large spatial and temporal overlap was observed in areas used by foraging shags *Gulosus aristotelis* and kelp harvest (Christensen-Dalsgaard *et al.* 2020). Three species of eider have been recorded foraging within kelp forests in Norway (Bustnes & Lønne 1997, Bustnes & Systad, 2001). In Argentina, kelp beds were associated with higher seabird abundance, attributed to high prey species diversity (Raya Rey and Schiavini, 2000).

7.5.1.3 Wider ecological benefits

Kelp forests along temperate and polar coastlines represent some of most diverse and productive habitats on the planet (Smale *et al.* 2013). Recent research suggests that kelp forests generate up to $562 billion each year globally by boosting fisheries productivity, removing harmful nutrients from seawater, and sequestering carbon dioxide (Eger *et al.* 2023). Specific UK-based examples of ecosystem goods and services include (from Smale *et al.* 2013 unless stated):

- **Biodiversity.** Kelp forms extensive forests that provide three-dimensional habitat for a vast array of marine organisms. Within the UK alone, more than 1800 species of flora and fauna have been recorded from kelp-dominated habitats (MNCR, unpubl. data). A study in Norway showed that on average, a single kelp plant supports approximately 40 macroinvertebrate species represented by almost 8000 individuals (Christie et al. 2003). Elevated fish and shellfish densities in kelp forests support larger fish and marine mammals such as seals and otters (SIFT 2018).
- **Enhance nutrient cycling and carbon assimilation, storage and transfer.** Kelp is the main pathway for long-term carbon storage in sediments and has the highest rate of carbon sequestration in Scottish marine habitats (Burrows et al. 2014). The kelp beds themselves do not store the carbon but dislodged/ eroded plants are broken down and the carbon in detritus is sequestered in sediments or drift to deep sea environments where atmospheric exchange is no longer possible (Krumhansl and Scheibling 2012, Krause-Jensen and Duart 2016). Increased sequestration has the potential to reduce impacts from climate change on a range of marine species (including seabirds). In turn, this may make species moreresilient to other pressures, including negative impacts of OWFs.
- **Coastal defence.** Kelp forests can prevent and alleviate the damage caused by flooding and storm events by altering water motion and provide a buffer against storm surges by reducing the velocity of breaking waves (Lovas and Torum 2001). However, there is a there is a paucity of information on the degree of storm protection offered by kelp forests, and some studies have questioned their effectiveness as a coastal defence (e.g. Morris *et al*. 2020).

7.5.2 Degree of scalability

Climate change and rising sea temperatures have been widely implicated in the decline of kelp ecosystems along European coasts (e.g. Raybaud *et al.* 2013, Wernberg *et al.* 2019) although other contributory factors have included increased sediment and nutrient loading, overgrazing by sea urchins, unsustainable harvesting, and destructive fishing practices such as bottom trawling. Restoration attempts around the world have employed different methodologies, with the majority conducted at sites of less than 1ha and the most successful occurring near existing kelp forests (Eger *et al.* 2022b). However, active kelp forest restoration has had limited success globally and been expensive and unable to address the increasing level of ecosystem deterioration (Fredriksen *et al.* 2020). There are few large-scale UK examples but the Sussex Kelp Restoration Project, established following the passing of a byelaw preventing trawling on over 300km^2 of seabed along the Sussex coast in 2021, aims to support and monitor the natural recovery of kelp and is conducting research to establish whether active restoration is necessary or practical.

In Scotland, kelp beds are a Priority Marine Feature and are protected in 17 locations by a suite of MPAs. The Marine Scotland NMPi map[23] shows kelp beds widely distributed around the Scottish coast, particularly around the west coast and Hebrides, Orkney and Shetland. Extending or restoring kelp beds in Scottish

[23] *https://marinescotland.atkinsgeospatial.com/nmpi/default.aspx?layers=968*

waters is theoretically achievable over large areas, but there are a range of practical considerations (see below), and large-scale restoration would require cost-effective measures to be financially viable. The use of novel tools such as the 'green gravel' approach, whereby small rocks are seeded with kelp in a laboratory before out-planting (see Fredriksen *et al.* 2020) could be scaled up effectively to help overcomes some of the current limitations. Major kelp restoration projects in Korea and Japan have demonstrated that with the right mechanisms and funding streams, kelp forest restoration is achievable at large scales and relatively low costs (Eger *et al.* 2022a).

7.5.3 Timescales for response

The response timescale would consist of three sequential stages: a) the timeframe required to restore kelp habitats to a condition suitable to support forage fish; b) the response time for fish populations associated with kelp habitats to increase, and c) the associated response time for seabird populations to benefit from the increased fish populations. Kelp restoration can be achieved in a relatively short timeframe; in Norway, for example, culling sea urchins with quicklime has been shown to reduce their densities to such a level that allowed for rapid kelp recovery within one year of treatment (Verbeek *et al.* 2021). However, where seeding or transplanting is required, restoration is likely to take multiple years. Fish reproduction cycles vary greatly between species and stocks; sandeels can reproduce at around two years of age[24] whereas cod can take up to nine years to reach sexual maturity[25]. It is considered that relatively rapid response times could be observed in seabird populations where there is an increase in forage fish availability, as this could lead to a greater number of chicks being provisioned during the breeding season. However, amongst the five 'target' species, age of first breeding varies between four and six years, so delaying the period before any increase in breeding productivity leads to increased recruitment to adult populations (Horswill and Robinson 2015). This period would be reduced in some other, 'non-target', seabird species (e.g. terns). Taking the three stages into consideration, the response timescale for kelp bed extension/restoration is considered to be medium term (five-10 years) but potentially long term (>10 years).

7.5.4 Practical feasibility

Issues potentially affecting feasibility of implementation include:

- Potential conflict with other industries e.g. fishing, so proposals and management initiatives may be contested.
- Conflict with commercial harvesting. Many kelp beds are threatened by large-scale harvesting for commercial interests, so any requirement to reduce/prevent harvesting could lead to conflict with other industries. Potentially one of the biggest anthropomorphic threats to kelp to emerge in Scotland recent years was a proposal to commercially dredge kelp forests in response to the demand for alginate (SIFT 2018). Ameliorating such potential stressors should always be a critical early focus of any restoration initiative (Eger et al. 2022a).
- Local environmental conditions. Environmental stressors such as sedimentation and nutrient pollution should be considered before successful restoration can occur. Controls on water pollution are essential for kelp forest restoration (Eger et al. 2022a).
- Grazer presence and density. High populations of grazers (such as sea urchins) can reduce kelp biomass and prevent new populations from developing. During the 1970s, an estimated 8400km2 of kelp forests were lost due to overgrazing by the green sea urchin *Strongylocentrotus droebachiensis* (Gundersen et al. 2011). However, a range of measures are potentially available to manage/control urchin populations, including culling with quicklime, fisheries harvesting and manual collection (Verbeek et al. 2021).

[24] *https://www.nature.scot/gd/print/pdf/node/4278596*
[25] *https://www.nw-ifca.gov.uk/managing-sustainable-fisheries/cod/*

- Potential difficulty of sourcing kelp material (wild v cultured) and practicalities of active restoration (seeding v transplanting).

It is also necessary to ensure kelp restoration projects are resilient to climate change-related stressors such as rising sea levels, ocean warming and marine heatwaves, and increased storm frequency and intensity. There are three general and intersecting strategies for future-proofing kelp restoration projects: genetic rescue, assisted gene flow, and genetic manipulation and assisted expansion (Van Oppen *et al.* 2017; Coleman *et al.* 2020; Wood *et al.* 2021, in Eger *et al.* 2022a):

- **Genetic rescue.** The strategy of 'genetic rescue' focuses on enhancing the genetic diversity of such populations to boost their adaptive potential and resilience to future conditions. This might include planting and restoring individuals from genetically diverse populations (but the same species) to disconnected or depauperate populations.
- **Assisted gene flow.** An 'assisted gene flow' strategy focuses on the movement and restoration of naturally adapted or tolerant individuals into threatened populations to increase resilience to an identified stressor (e.g., ocean warming). This approach may suit circumstances with current or anticipated near-future climate-drivers of kelp forest loss.
- **Genetic manipulation and assisted expansion.** Genetic manipulation could include genetic engineering to enhance or introduce specific traits. Assisted expansion may aim to move a species of kelp to a more suitable location in response to climate change, or the introduction of new species of kelp to an area which might be better suited to future conditions.

7.5.5 Estimation of the 'compensation return'

Existing reviews of strategic compensation measures (e.g Furness 2013, Furness 2021, McGregor *et al.* 2021) do not mention kelp bed extension/restoration as a potential compensation option for UK seabirds impacted by OWFs. Based on the information currently available, it is very difficult to quantify (even approximately) how many seabirds would benefit from a measurable amount of kelp bed extension/restoration, and further studies would be needed to improve understanding of the extent to which restored kelp beds in UK waters increase productivity of forage fish populations before such a measurement could be made. An alternative method of providing an estimate of the compensation return could involve a comparison of forage fish densities in kelp habitats with unvegetated marine habitats and relating this to the average fish consumption by individual seabird species. The range of wider ecosystem services that kelp beds offer is well established and could deliver compensation in terms of wider ecosystem resilience that would benefit the site network (relevant to tier 5 of the proposed definition for compensation).

7.5.6 Duration

Successfully extended/restored kelp beds as a compensation measure has the potential to provide long-term benefits to forage fish populations, providing that an adaptive management strategy is implemented to allow for interventions if restoration isn't going to plan (e.g. excessive sea urchin predation). If compensation is required for the lifetime of an OWF (e.g. 30-35 years), it would be expected that monitoring and adaptive management would be required throughout this period.

7.5.7 Conclusion

The importance of kelp habitats as a nursery area for the development of juvenile fish has been widely recognised, with numerous studies showing a positive relationship between kelp and fisheries. However, as for seagrass and oyster habitats, there is a lack of direct evidence linking the seabirds to kelp habitats in the UK (although studies of some species have taken place in Norway) and quantifying these linkages has not been attempted. Nevertheless, connections can be made between the diets of seabirds and knowledge of how individual fish species utilise kelp habitats, and a range of other ecosystem services are provided by kelp including nutrient cycling, carbon sequestration, and provision of habitat for a range of other marine organisms.

Kelp beds are a Priority Marine Feature in Scotland and are protected in 17 locations by a suite of MPAs. Extending the protection of these beyond existing MPA boundaries, and restoring degraded kelp beds is theoretically achievable over large areas due to the current and historic distribution of kelp habitats, but there are a range of feasibility concerns including potential conflict with commercial harvesting, grazer pressure and density (e.g. from sea urchins) and water pollution. Active kelp forest restoration has had limited success globally, partly due to the difficulty of sourcing kelp materials and practical considerations, but there are a number of large scale examples and novel tools could help overcome some of the current limitations. Genetic strategies may be required to future-proof kelp restoration against climate change.

Restoration of kelp habitats as a potential compensation measure for the 'target' seabird species would be a long-term initiative, due to the response times for fish populations associated with seagrass to increase and the subsequent response time in seabird populations (depending on species). Extending protection beyond existing MPAs would potentially see a quicker response, but this would be dependent on the condition of the habitat at the time of designation. Adaptive management would be necessary to respond to potential problems preventing successful establishment of restored kelp habitats, however the requirement for compensation for the lifetime of an OWF project (e.g. 35 years) would provide the necessary mechanism for intervention. Annual monitoring could deliver measurable information on fish abundance and potentially allow for some degree of quantification of impacts on seabird populations and other ecosystem services.

7.6 Mammalian predator management and eradication

7.6.1 Evidence for efficacy

7.6.1.1 Key seabirds

7.6.1.1.1 Kittiwake

There is little evidence that mammalian predator management or eradication is likely to provide significant benefit to breeding kittiwakes. In general, it is considered the species has low vulnerability to mammalian predation, with few recorded instances of mammalian predation affecting nesting kittiwakes, although breeding productivity (in some years at least) was considered to be reduced due to predation by brown rats and cats at colonies on the Isles of Scilly, by mink at St Abb's Head and by foxes at Lowestoft (Furness 2013). It is also considered likely that many colonies are inaccessible to many mammalian predators (Furness 2021).

Monitoring following rat eradication programmes at seabird colonies provides little evidence for any beneficial effects on kittiwakes. On Lundy, there was a continued decline of the species following successful rat eradication in 2003/04 until 2013. More recent increases in kittiwake numbers are thought to be due to immigration from other colonies, as productivity for this species remains poor on Lundy (St Pierre *et al.*, 2023). Similarly, there was no evidence of any change in the kittiwake population trend on Canna and Sanday (where the species was increasing in numbers) following rat eradication between 2005 and 2008 (Luxmoore *et al.* 2019), whilst Furness (2021) reports that rat eradication on Ailsa Craig does not appear to have affected kittiwake breeding success.

It is therefore considered unlikely that mammalian predator management or eradication would provide an effective compensation measure for this species.

7.6.1.1.2 Gannet

Existing reviews of potential compensation measures provide no evidence that mammalian predation is a problem at UK gannet colonies (Furness 2013, Furness 2021, McGregor *et al.* 2021). It is therefore considered unlikely that such management would provide an effective compensation measure for this species.

7.6.1.1.3 Guillemot

There is strong evidence that rat eradication on Lundy has resulted in a significant increase in the breeding guillemot population, from 2,348 individuals in 2000 to 9,880 individuals in 2021 following eradication in 2003/04 (St Pierre *et al.* 2023). These increases are greater than those recorded for guillemot at two neighbouring colonies (Gobe Consultants Ltd. 2021). Furness (2021) states that the increase on Lundy appears to be due to colonisation of previously unoccupied habitat where nests would have been accessible to rats and hence vulnerable to predation. The results from Canna are less clear, with rat eradication having been associated initially with a marked slowing of the ongoing decline in the numbers of breeding guillemot, rather than an actual reversal of this trend (Luxmoore *et al.* 2019), although more recent counts suggest numbers may now be increasing gradually (Swann *et al.* 2019, cited in Gobe Consultants Ltd. 2021). Thus, on Canna other factors (possibly including weather effects and food availability) may be acting to limit the breeding guillemot population or at least the extent (and speed) of response to rat eradication, demonstrating that eradication of rats (and presumably other invasive mammalian predators) may not always result in rapid population increases.

Rat eradication on islands in the Channel Islands has been agreed as a viable compensatory measure for Hornsea Four OWF (DESNZ 2023a) but has not yet been implemented, whilst it has also been proposed on Handa Island as compensation for the Berwick Bank OWF (Skeate 2022). However, the evidence that such measures would benefit guillemots breeding on Handa has been considered as weak because the cliff-nesting sites used by guillemots on Handa may be largely inaccessible to rats and there appears to be no evidence that breeding success is being suppressed by rat predation (NatureScot 2023). Other islands where guillemots nest and that have been subject to rat eradication include:

- Ailsa Craig: Rat eradication occurred in 1991 but available colony count data for guillemot from the Seabird Monitoring Programme (SMP) database do not pre-date 2001 (with no indication of a consistent trend in abundance since 2001).
- Shiant Isles: Rat eradication began in 2015 but no subsequent colony count data for guillemot are available on the SMP database.
- Ramsey Island: Rat eradication undertaken in 2000 with colony count data from the SMP indicating an increase in guillemot numbers from 3,031 individuals in 2000 to 5,395 in 2021.

Given the above, there is evidence of benefits from mammalian predator management to breeding guillemot populations, specifically where this concerns rat eradication from islands. However, such beneficial effects may be restricted to particular situations and may not occur consistently. Factors such as the relative availability of rat-accessible and rat-inaccessible nesting sites at the colony and the extent to which other environmental effects (e.g. food availability) limit breeding populations are likely to be important in determining the response to mammalian predator management. It seems likely that there is also potential for other mammalian predators to have effects on abundance and / or breeding productivity at some guillemot colonies, and foxes have been recorded accessing colonies at Badbea Cliffs (within the East Caithness Cliffs SPA) and Longhaven Cliffs (within the Buchan Ness to Collieston Coast SPA) (Skeate 2023).

7.6.1.1.4 Razorbill

As with guillemot, there is strong evidence that rat eradication on Lundy has resulted in a significant increase in the breeding razorbill population, from 950 individuals in 2000 to 3,533 individuals in 2021 (St Pierre *et al.*, 2023). Comparison with the smaller increases recorded in razorbill numbers at two nearby colonies indicates rat eradication has benefited the Lundy population (Gobe Consultants Ltd. 2021). Razorbill breeding abundance on Canna showed an initial, marked, increase in the short-term (2006 and 2007) following rat eradication, with this being associated with nesting in areas from which the species had been absent for several years (Luxmoore *et al.* 2019). Numbers subsequently remained approximately stable until 2016 (with low levels of breeding success considered likely to be due to low food availability), although more recent counts indicate further increases with numbers in 2019 at the highest level since 1995 (Luxmoore *et al.* 2019, Swann *et al.* 2019, cited in Gobe Consultants Ltd. 2021).

Rat eradication on islands in the Channel Islands has been considered as a “without prejudice” compensatory measure for razorbill for the Hornsea Four OWF (DESNZ 2023a), whilst it has also been proposed on Handa Island as compensation for the Berwick Bank OWF (Skeate 2022). In relation to the previous rat eradication programme undertaken on Handa in 1997, NatureScot (2023) acknowledge evidence of potential benefits to razorbill (due to it enabling birds to occupy boulder fields accessible to rats, as opposed to being restricted to cliffs). Although the 1997 rat eradication on Handa Island subsequently failed (either because rats were not completely eradicated, or due to a new incursion from the mainland), razorbill numbers increased in some areas considered susceptible to nest predation by rats before declining again in these areas as rats recolonised (Skeate 2022). Other islands where razorbills are present and that have been subject to rat eradication include:

- Ailsa Craig: Rat eradication occurred in 1991 but available colony count data for razorbill from the SMP database do not pre-date 2001 (with no indication of a consistent trend in abundance since 2001 (1992).
- Shiant Isles: Rat eradication began in 2015 but no subsequent colony count data for razorbill are available on the SMP, although breeding productivity was reported to be higher in 2018 (post-eradication) than in the single year (2015) of pre-eradication productivity monitoring (with average productivity being 0.79 and 0.72 chicks per pair in each year, respectively (Gobe Consultants Ltd. 2021).
- Ramsey Island: Rat eradication undertaken in 2000 with colony count data from the SMP indicating an increase in razorbill numbers from 1,490 individuals in 2000 to 2,160 in 2021.

Based on the above, there is evidence that mammalian predator eradication (or other management) benefits breeding razorbill populations. This is particularly the case in relation to the eradication of rats from islands, but it is also likely to extend to other mammalian predators at some colonies, e.g. recolonisation of an island colony in the Baltic Sea was recorded following eradication of mink, whilst foxes have been recorded accessing the colony at Badbea Cliffs (within the East Caithness Cliffs SPA) (Nordström *et al.* 2003, Skeate 2023). As for guillemot, it is likely that the extent of the response to the eradication (or management) of mammalian predators will vary according to a range of factors (e.g. the relative availability of predator-accessible and inaccessible nesting sites at the colony and the extent to which other environmental factors limit breeding populations).

7.6.1.1.5 Puffin

Puffins predominantly nest in burrows on offshore islands or coastal cliffs although they may nest among boulder fields and sometimes crevices in cliffs where suitable habitat for burrows is absent. Such nest site preferences make the species particularly vulnerable to a range of mammalian predators (Mitchell *et al.* 2004). Consequently, there is strong evidence of benefits of rat eradication where this has been undertaken on offshore islands. Thus, rat eradication programmes have been associated with increases in puffin populations on Lundy (where numbers increased from 13 individuals in 2000 to 848 individuals in 2021), Handa Island (where numbers underwent a short-term increase from 472 individuals in 1996 to 735 in 2001 before subsequently declining again when rats recolonised) and Canna (where counts of rafting birds showed a near doubling between 1995 and 2016) (Luxmoore *et al.* 2019, Skeate 2022, St Pierre *et al.* 2023). The increases in numbers recorded on both Handa and Canna were associated with (at least some) re-colonisation of areas previously accessible to rats. Rat eradication on Ailsa Craig has also been associated with recolonisation by breeding puffins (Zonfrillo 2002, 2007), with recent counts in the SMP database suggesting that the population may number approximately 150 - 200 individuals.

Although direct evidence of efficacy appears to be lacking, it seems likely that the management or eradication of some other mammalian predators (in addition to rats) at active or historical nesting colonies would also have the potential to benefit breeding puffin populations.

7.6.1.2 Other seabirds

There is substantial evidence of negative effects of mammalian predators on the breeding populations of a range of other SPA seabird species including Manx shearwater, European storm petrel, shag, and several gull and tern species (e.g. as reviewed in Furness 2021).

Rat eradication programmes on various islands have been associated with positive responses in several such species, and have been shown to be particularly effective for burrow-nesting seabirds such as Manx shearwater and European storm petrel (and also puffin, as above). Following rat eradication on Lundy, the SMP database shows an increase from 297 occupied Manx shearwater burrows in 2001 to 12,638 occupied burrows in 2023. European storm-petrel numbers increased from zero to 161 apparently occupied sites in the same period, indicating that rat eradication enabled recolonisation by this species. Furness (2021) considered that such management could also allow recolonisation of some islands by Leach's storm petrel. On Ramsey Island, rat eradication in 1999/2000 resulted in an increase from 849 Manx shearwater pairs pre-eradication to 4,796 pairs in 2016 (Bell *et al.* 2019), with 6,225 apparently occupied sites recorded in 2022 (as derived from the SMP database). As with Lundy, it is also thought that European storm-petrel recolonised Ramsey Island post-eradication.

Rat eradication on Canna and Sanday has also been associated with a marked slowing in the rate of ongoing declines in the abundance of several species, such as shag, lesser black-backed gull and great black-backed gull, whilst common gull numbers have increased in contrast to the previous declining trend (Luxmoore *et al.* 2019). For shags on Canna, there is evidence that breeding productivity has increased amongst pairs nesting in boulders (accessible to rats) following rat eradication, whilst remaining approximately stable amongst cliff nesting pairs (which were less likely to have been accessible to rats).

Measures to control (or exclude from colonies) predators such as foxes and mink are often associated with beneficial effects on breeding gull and / or tern populations (e.g. Furness 2021), whilst failure of the shag colony at Badbea Cliffs (within the East Caithness Cliffs SPA) was attributed to fox predation (Skeate 2023). Measures to provide compensation for predicted mortality arising from the Norfolk Boreas and Vanguard OWF projects have recently been accepted and implemented at the Alde-Ore Estuary SPA, involving the installation of predator-proof fencing to benefit the breeding lesser black-backed gull population (MacArthur Green/Royal HaskoningDHV, 2022a). At South Walney (part of Morecambe Bay and Duddon Estuary SPA), productivity in herring, lesser black-backed and great black-backed gulls was shown to increase following installation of a predator fence (Dalrymple, 2023). In 2022 (i.e. only one year after installation) the number of nesting gulls increased by 151%, with productivity increasing from 0.20, 0.15, and 1.05 fledglings per nest to 0.4, 0.61 and 1.21 for herring, lesser and great black-backed gulls, respectively.

7.6.1.3 Wider ecological benefits

When applied across a number of sites/colonies, it is considered that the management or eradication of predators has high potential to increase ecosystem resilience via likely increases in breeding productivity in a range of seabird species and expansion of the available nesting habitat for several species at some colonies, which will in turn lead to increased population sizes (at the colony scale at least). There is also the potential to increase the number of breeding colonies for several species (both through recolonisation of former colonies and potentially the establishment of new sites) and potentially expand the UK breeding range for some species (e.g. Manx shearwater and Leach's storm petrel).

7.6.2 Degree of scalability

Determining whether the management or eradication of mammalian predators could provide compensation at a regional scale is likely to depend on a number of factors, including the extent to which such predator management is feasible in non-islands situations (e.g. in terms of reducing, as opposed to eradicating, predators on headlands with nesting seabirds) and the extent to which non like-for-like measures are to be applied (because some of the 'target' species are unlikely to benefit from this measure (see above), whilst applying the measure to a wider range of SPA populations and to the 'other seabird' species would increase the scale of application). Therefore, development as a strategic, regional-scale, measure would probably rely upon using tiers 2 – 4 of the proposed compensation definition.

Undertaking this measure in tandem with biosecurity measures to prevent invasive species from colonising, or re-colonising, islands which support breeding seabirds would also increase the potential to develop a strategic approach which could be applied at a regional scale (see **Section 7.8**).

Further details on the potential opportunities which could exist for undertaking mammalian predator management or eradication are provided in **Section 7.6.5** below.

7.6.3 Timescales for response

Where effective predator management is implemented, the examples described above demonstrate that a population response can occur rapidly, and potentially within a year of implementing the management. Population increases have the potential to be sustained over a number of years until other factors (such as availability of suitable nest sites and food availability) become limiting. In the case of Lundy Island, for example, population increases of guillemot, razorbill and puffin were recorded in the first full count in 2008 following the 2004 rat eradication programme (St Pierre *et al.* 2023). In the case of gull species, Dalrymple (2023) detected an increase in the numbers of nesting birds and their breeding productivity in the breeding season after installation of the predator fence.

Whilst a response in population size may occur rapidly where mammalian predator management increases the availability of nesting habitat, response times will be longer where the effects are limited to increases in breeding productivity. Given the variation in age of first breeding amongst seabird species, between two to nine years may be required for adult population size to respond to increases in breeding productivity, noting that for the three 'target' species most likely to benefit from this management the average age of first breeding is five or six years (Horswill and Robinson 2015). It may also require several years to successfully implement a programme of mammalian predator eradication or management, with the challenges involved in such enterprises likely to vary according to a number of factors (see **Section 7.6.4**).
Based on the above, a four to 10 year period for obtaining a response in population size seem possible, although faster responses may occur at some colonies.

7.6.4 Practical feasibility

It has been demonstrated at a number of locations that predator management (both rat eradication and control of other mammalian predators through culling and / or fencing) is technically achievable.

The eradication of invasive mammalian predators (most notably, but not limited to, rats) would be restricted to islands and is most likely to be achieved where the island is small, the areas likely to be used by rats are accessible (by those undertaking the control measures) and there few (or no) human inhabitants. For example, based on previous eradication programmes (globally), Stanbury *et al.* (2017) consider that the eradication of rats is unlikely to be feasible on islands that exceed 12,873ha in area and which have more than 1000 human inhabitants. Where islands do not meet these criteria and for non-island colonies, management of mammalian predators is likely to be limited to control measures which reduce their occurrence within the colony and, as such, may have to be undertaken annually. In such situations, it may not always be practical to achieve sufficient reduction in predator occurrence within the colony to obtain a population-level response. For islands that are within likely swimming distances of potential mammalian predators, adequate monitoring (and potentially further eradication) is required to ensure they are not re-colonised even after a successful initial eradication programme (so the requirement for, and extent of, subsequent biosecurity measures and monitoring will increase with proximity to source populations of predators).

Therefore, whilst the required managements are likely to be practically feasible at many sites, the potential costs may be high, particularly given that the management would be required across multiple sites and could be annually recurring for a proportion of these sites. A further consideration in terms of practical feasibility is the risk of control measures (particularly for eradication) affecting non-target species.

It is considered unlikely that the management or eradication of mammalian predators will be an active, existing, element of SPA site management in many cases. As such, it should be available as compensation being 'additional'[26].

7.6.5 Estimation of the 'compensation return'

Estimating the potential compensation return from a strategic programme of management and / or eradication of mammalian predators at seabird colonies requires a considerable amount of detailed information and work, with much of the required information unavailable at the current time. However, it is possible to provide some preliminary indications on whether such a measure could have the potential to deliver sufficient levels of compensation.

Based on the evidence for efficacy, it seems highly unlikely that this measure would be effective in providing like-for-like compensation for either kittiwake or gannet because there is little evidence to suggest benefits to these species. Therefore, any compensation requirement associated with adverse effects on SPA populations of these species would require delivery via non-like-for-like compensation, most likely benefits to SPA populations of other seabird species (representing tiers 3 and 4 of the proposed compensation definition). For the other three 'target' species (guillemot, razorbill and puffin), there is moderate to strong evidence that the measure would benefit populations of these species but it seems unlikely that it would always (or even most often) be possible for the benefits to be directly applied to the impacted SPA populations, meaning that compensation would most likely align with tier 2 of the proposed compensation definition.

In terms of the potential range of sites at which such management could be undertaken, a review of the occurrence of invasive mammalian predators on breeding seabird islands in the UK identified 21 islands (including 17 in Scotland) from those considered in the review of Stanbury *et al.* (2017), which have breeding guillemots and razorbills present and on which either brown and / or black rats are confirmed or are considered likely to be present (ICEM 2023). This included 15 of the 25 islands prioritised by Stanbury *et al.* (2017) for invasive alien vertebrate eradication. A preliminary and qualitative assessment of the feasibility of eradication concluded that the criteria required to enable eradication were likely to be met for four of these 21 islands, whilst for the remainder it was also considered that these criteria were likely to be met but with greater uncertainty associated with the judgement in these cases (ICEM 2023). Nine of these 21 islands also held breeding puffins. A further 18 UK islands (including 12 in Scotland) which were not considered in the review of Stanbury *et al.* (2017) were also identified as having breeding guillemots and razorbills present and a likelihood of brown and / or black rat presence (ICEM 2023). The preliminary assessment of feasibility considered that the criteria to enable eradication were likely to be met but with uncertainty in this judgement in each of these cases. Six of these 18 islands also held breeding puffins.

---

[26] Note that Defra (2024) provides advice on additionality stating that 'Measures can be considered to be additional if they enhance or extend or complement either normal site management measures or the normal steps to avoid deterioration or disturbance'

This initial assessment suggests that there may be a considerable range of potential options available for undertaking rat eradication on islands where benefits to guillemot, razorbill and (to a lesser extent due to fewer available sites) puffin could result. However, caution is required in interpreting this initial information with, for example, several of the islands identified above being relatively large (e.g. six of the 21 islands from Stanbury *et al.* (2017) are over 4000ha in area) and having several hundred human inhabitants, which could make rat (and possibly other mammalian predator) eradication problematic (Stanbury *et al.* 2017). Furthermore, a substantial number of these same islands are already identified as targets for the RSPB Biosecurity for LIFE project[27] whilst a few have been identified as options for compensation for existing OWF projects (Skeate 2022). Consequently, the potential options that would be available for contributing to strategic compensation measures is likely to be reduced. At the same time, it is important to bear in mind that these numbers relate only to rat eradication on islands and extending consideration to feasible options for managing a greater range of mammalian predators across a greater range of sites (including headlands) could substantially increase the range of options for guillemot, razorbill and puffin.

Given the above, together with the scale of population response that has been associated with the management and / or eradication of mammalian predators at some colonies (e.g. increases of a few thousand guillemots and razorbills at Lundy and several hundred puffins at several colonies, as well as similar levels of increase in the numbers of Manx shearwater and European storm petrel at some sites), it seems possible that such management could have the potential to provide moderate to large compensation returns at a regional scale. This potential is likely to be increased if a strategic programme of mammalian predator management was undertaken in tandem with biosecurity measures to prevent invasive species from colonising, or re-colonising, islands which support breeding seabirds.

Further information on the levels of increase in annual breeding productivity which could result from a programme of mammalian predator management (bearing in mind the levels of *annual* mortality for which compensation could, potentially, be required – **Table 5**), and more detailed consideration of the ways in which the ‘compensation return’ of any associated biosecurity measures might be quantified, would be valuable in determining the extent to which this measure could meet the potential regional-scale compensation requirements for the NE and E ScotWind projects.

7.6.6 Duration

Once successfully implemented, rat eradication has potential to provide long-term (effectively unlimited duration) benefits to the colony, provided that biosecurity and monitoring measures are implemented to ensure that rat reinfestation does not occur. Evidence from sites where eradication has been successfully completed (such as Lundy and Canna) indicate that 1-2 years is typically required for the eradication to be completed, with a further two years of monitoring to confirm the absence of rats. If compensation is required for the lifetime of a windfarm (e.g. 30-35 years), it would be expected that biosecurity and monitoring measures would be required throughout this period. Similarly for the exclusion of predators by fencing, it would be expected that maintenance and monitoring would be required throughout the life of the project, whilst certain other managements (e.g. culling of predators) would likely need to be undertaken on an annual basis for the project duration.

7.6.7 Conclusion

The available evidence demonstrates that mammalian predator management or eradication can provide an effective compensation measure, although there are limitations in the extent to which it may provide like-for-like compensation (mainly due to the fact that mammalian predation appears unlikely to be important at kittiwake and gannet colonies in the UK). Therefore, if this measure was to be adopted in isolation of other

[27] *https://biosecurityforlife.org.uk/admin/resources/biosecurity-for-life-spa-list.pdf*

measures, there would need to be acceptance that in some circumstances compensation would have to be directed at benefiting different seabird species to those on which the impacts are predicted to occur.

The number and geographical range of sites at which such management could be undertaken appears sufficient to provide the potential for a strategic, regional-scale, approach to providing compensation, whilst the feasibility of successful implementation has been demonstrated at several UK seabird colonies. However, challenges remain in terms of feasibility, and several factors may limit this and make it challenging to achieve across the number and range of sites needed to provide a sufficient compensation requirement at a regional scale. In this respect, the extent to which predator management would be required at mainland colonies on headlands (where eradication is not feasible) and on larger islands with greater numbers of human inhabitants are likely to be important. Where successfully implemented, a response in seabird population sizes within four to 10 years may be a reasonable expectation, with more rapid responses possible where the management effectively acts to increase the availability of nesting habitat.

Based on the number of sites at which mammalian predator management or eradication may be undertaken, together with the documented responses of seabird populations to such management at some colonies, it is considered that it has the potential to provide moderate to large compensation returns at the regional-scale and, therefore, could make a substantive contribution to meeting the compensation requirements of the NE and E ScotWind projects. This potential would be increased if a programme of mammalian predator management was undertaken in tandem with biosecurity measures to prevent invasive species from colonising, or re-colonising, islands which support breeding seabirds.

7.7 Avian predator control

As detailed above (**Section 4**), avian predator control is not considered as a potential compensation measure in its own right but rather an optional add-on to mammalian predator management or eradication. This potential measure received little support from stakeholders as an option for regional-scale compensation, but it is considered that it should be available to enhance seabird populations at colonies where mammalian predator management or eradication is proposed and where avian predation may also be limiting or impacting seabird populations.

Based on the material reviewed in the long-list (**Appendix A**), there is weak evidence only that avian predator management could lead to population-level benefits for gannet, guillemot and razorbill but moderate evidence for this in relation to kittiwake, puffin and certain other seabird species. Thus, there may be situations in which greater population-level responses can be achieved for these latter species by combining management of avian predators with that undertaken on mammalian predators, as opposed to management focussed solely on mammalian predators.

Given that any measures involving avian predator management would represent an ‘optional’ add-on to enhance the potential benefits achieved via the management of mammalian predators, issues concerning the degree of scalability, timescales for response, practical feasibility, ‘compensation return’ and duration do not need to be considered in detail as they would be addressed on site- and situation-specific basis.

7.8 Biosecurity

The main element of any biosecurity compensation measure would be concerned with prevention of threats, mainly resulting from the occurrence of invasive species on breeding seabird islands. This would most frequently (but not exclusively – e.g. see **Section 7.9.1.1**) involve mammalian predators. As such, compensation measures based on biosecurity are likely to be integrally linked with measures involving the management and / or eradication of mammalian predators from seabird islands (**Section 7.6**).

7.8.1 Evidence for efficacy

Preventing new invasive species from arriving on seabird breeding islands is considered one of the most cost-effective strategies to prevent harmful impacts to nesting seabirds (Holmes *et al.* 2023), and rapid responses to potential biosecurity incursions close to seabird islands (e.g. from shipwrecks) can rapidly confirm the presence/absence of any rodents or other mammalian predators which may have come ashore.

Given the evidence considered in **Section 7.6.1** on the vulnerability of different seabird species to mammalian predation, such measures are likely to be most relevant to guillemot, razorbill, puffin and certain other 'non-target' seabird species (e.g. Manx shearwater). However, it is possible that incursion by mammalian predators could occur on islands where gannets or kittiwakes are nesting on habitat that is accessible to such predators, resulting in the potential for impacts on these two species as well.

In addition to the evidence that biosecurity measures would be effective in maintaining and restoring populations of breeding seabird species, it is considered that they would also provide wider ecosystem benefits through maintaining breeding range and the number of viable breeding colonies of UK populations of several seabird species.

7.8.2 Degree of scalability

Biosecurity measures could be applied widely across a range of seabird islands in Scotland and elsewhere in the UK (as evidenced by the existing RSPB Biosecurity of LIFE project[27]), and it is considered that they could be applied in such a way as to provide regional-scale compensation, although there is likely to be the same reliance on tiers 2 – 4 of the proposed compensation definition, as for mammalian predator management or eradication (see **Section 7.6.2**).

7.8.3 Timescales for response

Likely to immediate to short-term (a year or less), given that the measure involves rapid responses to neutralise potential threats.

7.8.4 Practical feasibility

Likely to be practically feasible (but further consideration of this should be based upon experience gained from existing work, notably the RSPB Biosecurity of LIFE project27).

This measure is unlikely to be an active, existing, element of site management at many SPAs and so should represent 'additionality'. However, it would be necessary to consider the extent to which it could complement and add to the work being undertaken on the RSPB Biosecurity of LIFE project, either in terms of expanding the spatial coverage, extending temporal coverage or improving efficacy.

As outlined in **Section 7.6**, consideration should be given to the potential for this measure to applied in tandem with a programme of mammalian predator management or eradication to provide strategic, regional-scale, compensation.

7.8.5 Estimation of the 'compensation return'

When considered in isolation it is unclear how the compensation return for this measure could be estimated (given the uncertainty associated with incursions of seabird islands by invasive species) and further consideration of the ways in which the 'compensation return' of any associated biosecurity measures might be quantified is required. However, if adopted in tandem with a programme of mammalian predator management or eradication it is considered that the measure could represent an important contribution to the provision of a regional-scale compensation strategy which may have the potential to meet (or go a substantial way towards meeting) the compensation requirements for the NE and E ScotWind projects.

7.8.6 Duration

This measure would have to be in pace for the lifetime of the relevant ScotWind projects, given it requires monitoring and response to potential incursions.

7.8.7 Conclusion

Biosecurity is likely to have greatest potential as a compensation measure if it is undertaken in tandem with a programme of mammalian predator management or eradication because it would act to complement (and secure the benefits from) eradication programmes on islands (as outlined in **Section 7.6**). The evidence for detrimental effects of invasive mammalian predators on breeding seabird populations demonstrates that biosecurity measures have the potential to provide effective compensation but, as for mammalian predator management or eradication, they would not provide like-for-like compensation in all circumstances and there is likely to be a reliance on tiers 2 – 4 of the proposed compensation definition.

It is considered that biosecurity measures could be applied across a sufficient number of sites to provide (or facilitate) a strategic, regional-scale, approach to compensation, whilst implementation is likely to be technically feasible (with the potential to benefit from the experience of existing programmes). Given the nature of the measure, the timescales for a response in seabird populations is likely to be short-term, whilst the measure would have to be in place for the lifetime of the relevant projects. As outlined above, estimation of the 'compensation return' is problematic, although this may be less critical if the measure is adopted in tandem with a programme of mammalian predator management or eradication.

7.9 Management of supporting habitats

7.9.1 Evidence for efficacy

Seabirds often appear to have very few requirements for selecting nest sites. Aside from the correct siting of the nest (e.g. the aspect or accessibility of the nest) they may also assess a range of oceanographic conditions surrounding the nesting sites when selecting a place to nest. These include temperature and salinity of water, bathymetry and productivity-related variables such as chlorophyll-a concentration, distance to food sources, prey availability and abundance. Water properties and zooplankton abundance have been shown as important factors in nesting location selection for boobies and auklets (Oppel *et al.* 2015; Sorensen *et al.* 2009). Tropical seas generally have lower and more stable productivity so expected that temperate species more likely to be influenced by marine conditions in their selection of nesting location. However, the nest site habitat may still have an influence and this can be manipulated to improve bird densities or even nest success.

7.9.1.1 Key seabirds

Amongst the five 'target' species, evidence for the efficacy of management of supporting habitats was limited to puffin, for which invasion of nesting habitat by tree mallow on some of the Forth Islands has affected colonies. Tree mallow has been linked with declining seabird numbers on Craigleith in the Forth Islands. An eradication program has been successful in reducing the growth of tree mallow but the seedbank is persistent (Anderson 2021). Numbers of breeding puffin increased as tree mallow cover decreased. Rabbits appear to be linked with the persistence of tree mallow as their activity reveals seeds at the surface. As this action is largely completed for this site, and this situation appears to be unique, the available compensation is small.

7.9.1.2 Other seabirds

Removal of vegetation from tern and gull islands.

Tern breeding sites can be improved by manipulation of the habitat, protecting nests from flooding by raising the substrate or reducing predation by providing vegetation cover, or conversely removing vegetation to provide open areas for species that preferentially select that type of nest site (Babcock and Booth 2020). Sandwich tern *Thalasseus sandvicensis* that prefer to nest in open areas and so suppression of vegetation (by physical removal or installing geotextile membranes) is used to encourage nesting. Tree mallow, introduced to provide cover for nesting roseate tern on Rockabill now needs regular removal as it will smother the nesting areas, although some if left in place to provide shelter for chicks.

It appears that efforts to encourage gulls to nest on islands are much rarer, with most effort made to exclude gulls although Mediterranean gull (*Icthyeatus melanocephalus*) has occasionally been deliberately attracted to sparsely vegetated islands (Burgess and Hirons 1992). Despite the lack of direct evidence, it can be imagined that the same principles would be important for gulls as with nesting islands for terns.

On Praia Island, Azores, driftwood was used to reduce soil erosion which had been caused by rabbits and native flora were reintroduced (Bried *et al.* 2009). While the increased availability of soil did not result in more natural burrows for petrels on the island (birds were provided with nest boxes) the increased native vegetation growth which resulted improved attractiveness for terns.

7.9.1.3 Wider ecological benefits

Removal of invasive vegetation can have greater benefit that just providing birds with access to nest sites as it allows native flora, and associated fauna to recover.

7.9.2 Degree of scalability

For ‘target’ species very few opportunities in the North and East Scotland area exist to manage seabird breeding habitat. Tree mallow removal is still ongoing at Craigleith although there is little cover in the puffin nesting areas now and the population of birds has largely recovered. Therefore, opportunity to provide this action for compensation is extremely limited.

7.9.3 Timescales for response

Most management actions envisaged would be very rapid (largely vegetation removal or soil/substrate addition) which could be accomplished in days or weeks and response from seabirds would be expected within one year.

7.9.4 Practical feasibility

Vegetation manipulation has been shown to be highly feasible at the scale of small islands. It would be difficult to scale to very large areas but for the species such as terns that respond most rapidly to this type of action that is not necessary.

7.9.5 Estimation of the ‘compensation return’

Compensation return for ‘target’ species through nest site management will provide very limited opportunity for compensation return. Possibly a few 10s of birds for puffin in the Forth Islands if other areas of tree mallow can be reached and the seed bank at Craigleith depleted sufficiently.

The opportunities for the other seabird species, such as terns or gulls, is much greater and will likely exceed any requirement. However, at existing tern sites it may be that much of the required vegetation manipulation management is already taking place (and for compensation further management would need to represent 'additionality'[28]).

7.9.6 Duration

These actions would be ongoing for the life of the project. To prolong effect continued management would probably be necessary for most interventions.

7.9.7 Conclusion

Cliff nesting species that do not make a nest and lay their eggs on virtually bare rock, such as common guillemot and razorbill, are unlikely to benefit from any management of the nesting habitat. Such exposed sea cliffs are only very slowly colonised by vegetation or infilled by soil which would render them unsuitable for these birds. If this was to occur making habitat manipulation necessary it would be on a very small scale. Gannet is able to build nests on bare rock or bare soil. The actions of 'clubs' of non-breeding birds, or nesting birds gathering vegetation for nest material, leads to creation of such areas from grassed stack tops and slopes. As nest area engineers themselves it does not appear that any management of gannet nest areas is required. The only intervention that may be considered beneficial would be removal of entangling rope and net material that birds have incorporated into their own nests. Accessing breeding sites out of season is not straightforward and the task of removing all such material would most likely remove or disrupt most of the nesting material at a colony. If it could be achieved then there would be some benefit in reducing deaths by entanglement that happen every year at any large colony. The feasibility is questionable and without reduction in material going into the sea (see Marine Litter) it will be constantly replenished at the colonies.

A similar situation does occur at kittiwake colonies, as these birds also build substantial nests and will incorporate fishing line and net into their nest matrix. This occasionally results in entanglement of young and adult birds which leads to their death. Removal of nests from colonies to remove this impact will only be effective if the supply of entangling material is reduced. Otherwise, kittiwake colonies do not usually require habitat maintenance. Outside of the UK, in the far north of the birds range, snow on cliffs in early season means that nests may be built on top of snow resulting in them slipping off the cliff when the snow melts. This does not occur in British colonies but potentially soil or debris accumulating on ledges could create an analogous situation. Again, as with the cliff nesting auks this is not expected to be widespread or particularly easy to deal with and so the compensation benefit from undertaking this action would be small.

Of the five 'target' species in our review, only puffin colonies have been found to definitely benefit from nest site management. This was to maintain access to nest sites by removal of invasive plants. The problem has not been found to be widespread and where it was known to occur the action required has already largely been completed. Ongoing management is currently supported by funding resources and so at present there appears to be little compensation gain available. Puffin colonies have been known to collapse following erosion, possibly by their own burrowing activity, removing soil that meant nest burrows could no longer be constructed. As far as we know, there have been no attempts to reinstate soil or turf on declining puffin colonies and so evidence that it may provide compensatory value and feasibility of the action is in doubt.

Of the 'non-target' species, terns and gulls are most likely to benefit from regular or semi-regular habitat management. Different species respond to different degrees of vegetation clearance and nesting in successional habitat, where vegetation is constantly trying to occupy ground, means that habitat manipulation is common, at least for terns. Most protected sites already undertake this management, so again opportunities to provide compensation action are limited. Like gannet and kittiwake, shag also accumulates potentially entangling waste in its nests, so removal of this would be an option but the benefit would be difficult to quantify. One final nest site management that was considered was drainage to prevent

---

[28] *Note that Defra (2024) provides a useful steer on what would be classed as additional*

flooding of underground nest sites for shearwaters, petrels and also puffin. Failure of nests has been reported but it is not a widespread problem. However, predictions of increased rainfall resulting from climate change could make this effective in some situations. At present however it does not appear to provide a valid scalable compensation pathway.

7.10 Marine litter

Two marine pollution measures were suggested to provide ornithology regional compensatory effects for offshore wind farms:

- Reduce anthropogenic pollution (agricultural runoff/waste treatment discharge); and
- Marine (plastic) litter removal.

The evidence basis for positive effects for both measures range from weak to moderate for seabird species and was considered as moderate for ecosystem benefits. It is expected that the timescale for populations to feel the benefit from, and respond to, the reduction of anthropogenic pollution to be relatively long, while for marine litter removal this is expected to occur over short to medium timescales. Therefore, marine (plastic) litter removal was chosen to be taken forward for assessment of compensatory effects.

7.10.1 Evidence for efficacy

Marine litter is classified as any persistent, manufactured or processed anthropogenic material in the marine environment, with the highest proportion attributed to plastics and discarded/lost commercial fishing gear (UNEP, 2021). In the Northern Hemisphere, European coastal waters have one of the largest proportions of marine litter (Barnes *et al.*, 2009; Høiberg *et al.*, 2022), with marine litter being highlighted as a major global issue by the United Nations Environment Assembly and G20 Leaders (Meyerjürgens *et al.*, 2023). Wilcox *et al.* (2015) estimated that by 2050, 99% of seabird species are likely to be negatively affected by marine plastics, with species such as fulmar, gannet and kittiwake currently thought to be some of the worst affected in the northeast Atlantic.

Marine litter can affect seabirds through ingestion and entanglement, and negative effects can occur both while at sea and when at colonies (Votier *et al.*, 2011; Roman *et al.*, 2020). Ingestion of marine litter can cause detrimental individual- and possibly population-level affects, preventing effective feeding/assimilation of nutrients, decreasing overall fitness through increased energy expenditure and affecting reproduction (Roman *et al.*, 2019; Senko *et al.*, 2020; Charlton-Howard *et al.*, 2023). Chemicals such as paraffin-like substances present in many anthropogenic objects may also leach out of items, causing additional physiological effects (Carey *et al.*, 2011; Tanaka *et al.*, 2013).

The composition of marine litter varies between the sea surface and seafloor (Gutow *et al.*, 2018), leading to potentially different effects on seabirds depending on their feeding strategies. For surface feeders such as fulmar or kittiwake, smaller items floating on or just below the sea surface are likely to pose the biggest risk through ingestion (Kühn *et al.*, 2022), while for gannet or guillemot there is a higher risk of ingestion or entanglement (such as with discarded/lost commercial fishing gear) within the water column and at the seabed (Donnelly-Greenan *et al.*, 2019). For gannet and kittiwake, entanglement risk at colonies should also be considered, as they often take litter back to colonies to use as nest material (Hartwig *et al.*, 2007; Votier *et al.*, 2011). See also **Section 7.9**.

Although the harmful effects of marine litter on seabirds have been widely studied, there is a paucity of information regarding how effective the removal of marine litter will be. Acknowledging this, we consider that although there are no data to directly support efficacy, it is logically assumed that reduction of this negative pressure will positively affect seabirds and the wider ecosystem.

Litter presence in Scotland's marine environment is currently being managed through the Marine Litter Strategy and National Litter Strategy by Marine Scotland (Scottish Government, 2022). One of the aims of the strategy aims to support the removal of litter from the marine environment, to provide '*biological diverse marine and coastal environment that meets the long term needs of people and nature*'. Implemented in response to the Marine Strategy Frameworks Directive (MSFD), litter presence is hoped to be reduced through infrastructure, enforcement, deterrence and education (Scottish Government, 2013).

The Fishing for Litter (FFL) scheme has been identified as the key method to address the removal of litter from the marine environment. It is a listed measure to achieve Good Environmental Status through the Marine Strategy Framework Directive and directly feeds into the Scottish Marine Litter Strategy. Managed by KIMO, the project has been supported by the commercial fishing industry throughout Europe, with the number of participating vessels increasing year on year (OSPAR, 2010). In the UK FFL operates in two areas: Scotland and southwest England (KIMO, 2022).

The efficacy of the scheme and others of a similar type have been demonstrated within European and international waters (Bergmann *et al.*, 2015). In a 2018 FFL report, it was estimated that around 1,800 tonnes of marine litter had been removed from UK waters through the FFL scheme since 2004/5 (Fishing For Litter, 2018). The 2018 report is the most recent official report, specific to litter removal in Scottish and wider UK waters, however, *pers comms* from KIMO (email dated 29/08/2023), states over 2,300 tonnes of marine litter had been removed from UK waters by mid-2023.

Collection of robust data which can be used to determine the efficacy of FFL is relatively difficult, especially when considering the project primarily relies on volunteers rather than dedicated staff. The time required to accurately quantify and sort through landed litter is not always available, therefore only basic assumptions can be made (Fishing For Litter, 2018). Figures within Fishing For Litter (2018) suggest monthly tonnage of collected litter increased slightly between 2014 and 2017. The number of participating ports has increased since 2017 which may have increased litter retrieval.

Anecdotal evidence from fishers also suggested that the incidence of large, heavy items present on the seabed within their commercial fishing grounds was lower (Fishing For Litter, 2018; Wyles *et al.,* 2019), although this is to be expected if the same areas are continuously fished and larger items are less likely to drift from areas further afield. If fishers are typically exploiting the same areas and the majority of heavy items are removed, then you would expect smaller items more easily transported due to metocean conditions will make up the majority of the litter collected, although as yet there is no evidence to support this.

7.10.2 Degree of scalability

Increasing the number of participating ports and vessels is the main way to increase scalability of the FFL scheme. Currently, the scheme is operating at 20 Scottish ports, although this may have changed slightly since Brexit, where funding changed from coming from the EU to be managed by the Scottish Government. Twenty ports are currently shown on the FFL website however it is unclear when the site was last updated. The degree of scalability is likely to be directly related to the amount of available funding, with the annual costs for the UK FFL scheme estimated at around £100k per annum (2020 figure; KIMO, 2020a); this figure is likely to have increased over the past six years. Currently, KIMO International estimates that around 300 vessels are participating in Scotland, although this figure may be higher in reality, due to the voluntary nature of collection and since any vessel can contribute if they want to.

Another crucial factor affecting scalability links to how litter will eventually be disposed of, post-collection. Essentially, the amount of litter which can be removed directly links to the availability of places to dispose of it. There will be costs associated with the upkeep and availability of skips and the bags provided to fishers which they use to hold litter. If collected litter is to be recycled, then there needs to be adequate funding available to allow for this.

Expansion of the FFL scheme to include additional ports is likely to increase the amount of litter collected, simply through increased effort. However, if the same commercial fishing grounds are targeted by boats from new ports as are already covered, then there may not be a measurable difference in the amount of bigger, heavy items recovered from the seabed. Anecdotal evidence from fishers suggests that after large items such as these are removed they typically are not replaced by those transported from outwith the area, as they are less likely to be transported by currents, tides etc (Fishing For Litter, 2018). Regardless, there is still likely to be increased removal of smaller items on the surface, water column and seabed which are more easily transported, even if the same commercial fishing grounds are targeted by boats from new ports.

Increasing direct benefits to fishers could increase uptake, for example such as provision of monetary rewards for collecting specific litter types, or through individual vessels reaching significant milestones in the amount/weight of litter which has been removed. However, the lack of any monetary incentives within FFL has been praised in the past, as renumeration could reduce positive changes to long-term attitudes and behavioural change within individuals (Wyles *et al.*, 2019). Other incentives such as collecting litter while transiting to/from fishing grounds could also be explored, although this may reduce the amount of time available to fish, which would not be advantageous.

7.10.3 Timescales for response

The timescale for response is likely to occur over a variety of scales, with any ecosystem level benefits likely to occur over a longer period of time. In terms of local or regional seabird populations, the response may occur over the short to medium term as FFL is already operational, so expansion may be possible almost immediately, although positive impacts to birds are unlikely to become apparent for a number of years. In terms of when compensatory benefits to seabirds are likely to start to be realised, this will probably be over a moderate timescale, likely at least five to ten years, to allow incorporation of litter into nest sites to reduce which will in turn reduce entanglement risk.

Change on all scales will depend on the level of expansion of FFL and the level of input of litter into the environment. Even with increased effort through FFL, if there is no change or an increase to the amount of litter entering the marine environment, then any benefits will be unable to be realised. Responses from fishers in Wyles *et al.* (2019) indicated that participation in FFL made individuals more aware of their actions while at sea and at home, which could help to reduce the amount of litter entering marine systems, although this is unlikely to make any measurable difference in terms of quantifying compensatory benefits.

To additionally limit the amount of marine litter present, other initiatives could be supported and/or done in conjunction with FFL, such as the annual Spring Clean Scotland campaign (https://www.keepscotlandbeautiful.org/springclean) or The Forth Estuary Forum (https://www.forthestuaryforum.co.uk/). The Colony Compensatory Measures Evidence Report submitted as part of the Berwick Bank Wind Farm application states that The Forth Estuary Forum would be willing to work with developers to tackle plastic pollution in the Forth Estuary (Skeate 2022). Monitoring and removal of anthropogenic material at seabird nest sites may also be beneficial.

7.10.4 Practical feasibility

Since the FFL scheme is already successfully operating nationally and internationally, there is little question around whether it will be a feasible option to contribute to seabird compensatory measures. The simplicity of the scheme and passive method of litter collection (occurs during normal fishing) means the scheme can be easily taken up by multiple users, making scaling up of the project more feasible. Removing litter from the marine environment will directly and indirectly affect seabird species, likely increasing resilience to other pressures acting on them.

The main issue surrounding the feasibility of FFL, especially when scaling up the scheme to operate with more ports or vessels, will be the effective disposal of collected litter. It is imperative that there is adequate funding for upkeep of the scheme through effective management and collection of skips, as well as provision of bags which fishers put litter into while onboard. To allow a more diverse range of vessels to participate, it has been suggested that supplying additional smaller collection bags would be useful, to allow them to be stored easily on small vessels (Wyles *et al.*, 2019). Landfill tax also has to be paid when disposing of unrecycled litter, which can be considered as counter-productive as the litter has been collected from somewhere it shouldn't have been, rather than it being newly produced.

To take full advantage of litter removal, litter will ideally be recycled, post-collection. A previous report from FFL states 'it is likely' that the majority of collected materials go straight to landfill, due to issues with biofouling which prevent effective recycling (Fishing For Litter, 2018). Their report also states that volunteers can be asked to sort through litter to enable recycling, although this was associated with a decrease in uptake of the scheme. Recycling of end-of-life commercial fishing nets has been achieved in conjunction with Danish company Plastix (KIMO, 2020b; Plastix, 2023) although there is a value gap between transport and processing and value of the end material; the final estimate for all processing was published at around £150 – £300/tonne (Fishing For Litter, 2018). As the initial testing phase was concentrated on end-of-life gear, rather than discarded or lost gear, is it unknown whether there would be additional costs or logistical elements associated with this.

As FFL is a voluntary scheme it should be kept in mind that there will be cases where litter is located but is not be removed, as catch will always be prioritised by fishers (Bergmann *et al.*, 2015). When also considering weight limits on vessels, situations where larger items have to be left may occur, which could lead to some disparity between the types of litter which are removed. To combat this, items which could not be landed could be marked for later removal or the location radioed to nearby vessels within the FFL scheme.

7.10.5 Estimation of the 'compensation return'

To make a significant impact in terms of the amount of litter removed, the scheme will have to operate at a relatively large scale, although the number of additional vessels/ports needed to achieve this is unknown. Payback in terms of numbers of seabirds is likely to be small to moderate, however the positive effects on the rest of the ecosystem must also be considered, such as ingestion and entanglement effects on other top predators like marine mammals or turtles, or through reduction of transmission of harmful pathogens, which are often transported on the surface of litter items, that can affect marine fauna and humans. Other benefits, such as decreased visual pollution to public both on beaches and at sea.

To quantify if litter removal is providing compensatory benefits, additional data collection or monitoring will be required, such as through analysis of stranded birds such as monitoring of dead puffins by CEH on the Isle of May or by Wageningen Marine Research through the Campaign to Save the North Sea (SNS) Fulmar Threshold Value (FTV). For entanglement with larger items, ancillary data collection by fishers could also be included. There will be cost associated with research and monitoring programmes, which would likely be funded by OWF developers and government. There will be high uncertainty in equating compensation benefit with predicted impacts from OWFs on seabird populations, and therefore may not be feasible to address this directly.

NatureScot advice on Berwick Bank derogation case colony compensatory measures evidence report stated they 'did not consider that [removal of marine plastic] could be classified as a compensatory measure because the benefit is impossible to quantify' (Skeate 2022). While this may be true, removing litter from the marine environment is likely to allow seabirds to become more resilient to other negative pressures, such as changes to suitable habitat and prey availability.

7.10.6 Duration

For positive effects to be realised, the FFL scheme should continue for at least as long as the life of the windfarm schemes, at a scale larger than is currently in operation (following information presented in the rest of the section). Since FFL has already been operating for nearly two decades, and it generally relies on volunteers, this should not be an issue. As stated previously, the main limiting factors will be the availability of infrastructure to store and process litter once it has been collected.

7.10.7 Conclusion

Reduction of marine litter is seen as an action that has wide ecosystem benefits. However, for many seabird species the direct impacts are poorly quantified and may even be described as unknown. It is however well established that procellariiformes (shearwaters and petrels) tend to amass plastic fragments in their stomach, and whilst the negative consequences are not disputed it is unclear how many actually die from direct effects of plastic ingestion. This is even more the case for other species, including the 'target' species in this project. Plastic ingestion is widespread but direct evidence of mortality due to plastic ingestion is harder to acquire.

Entanglement in discarded plastic waste, including waste originating in the fishing industry, is known in many species including all five 'target' species considered in this review. The number of birds killed by entanglement and ingestion would be difficult to estimate and we have not attempted to do so with any degree of accuracy in this current work. To make a significant impact on the levels of mortality that arise, then the constant supply of plastic material entering the ocean has to be reduced and eventually eliminated. A number of beach-cleaning and local schemes are in operation, but the FFL scheme provides a scalable and region-wide operation capable of removing hundreds of tonnes of litter from the sea annually. There is also considerable potential to expand the scheme, which is voluntary but has considerable backing from the fishing community. Barriers to participation in the scheme appear to be higher for small vessels where deck space for handling and storing litter during the voyage is limited. Recycling of the recovered litter also requires improvement. Currently, funding for the scheme in Scotland comes from the Scottish government with the secretariat based at KIMO in Shetland but additional funding would help the scheme expand and provide facilities for collection and transportation of recovered litter to recycling or disposal locations.

While litter removal from the ocean is likely to benefit not only birds but a whole range of other marine life, as well as have amenity benefits (such as less litter on beaches) it is challenging to obtain quantitative measures of these benefits. OSPAR, MSFD and UNESCO targets would all be addressed by increased participation and increased effectiveness of the fishing for litter scheme although timescales for any response from seabirds, in terms of increased productivity or survival, are likely to be long and may in fact be difficult to measure because of confounding effects resulting from other changes in the marine environment.

8 Synthesis and conclusions

8.1 Overview of the potential suitability of different measures

The work described in this report seeks to identify measures which are suitable for delivering regional-scale compensation in relation to SPA seabird populations for which an adverse effect is determined as a consequence of the NE and E ScotWind projects. This is undertaken within the context of a compensation definition that is not constrained to the delivery of like-for-like measures, but which allows for varying levels of non-like-for-like compensation. Through a process heavily focussed on stakeholder consultation, an initial long-list of potential measures was refined down to nine[29] measures considered to have the most potential to deliver regional-scale compensation. The bulk of this report is concerned with assessing this potential for each of these nine measures, with the key benefits and limitations of each being summarised in Table 6.

Amongst the nine measures that were taken forward for more detailed investigation, none were considered to have the potential to provide like-for-like compensation for all five of the 'target' species (i.e. those species considered most likely to be associated with AEoI as a consequence of the NE and E ScotWind projects) in the event that they would be the only measure adopted by a strategic, regional-scale, compensation programme. However, biosecurity may have potential to provide compensation for all five 'target' species, albeit that this would be unlikely to target the specific SPA populations of relevance (so meeting criterion 2 of the proposed compensation definition – **Section 2.2.1.2.3**). In addition, four other measures would have potential to meet this criterion (and in some circumstances also criterion 1 – i.e. compensating the impacted SPA population) for one or more of these 'target' species. These four other measures are:

- Establishment of new colonies at natural sites
- Provision of artificial nests
- Mammalian predator management and eradication
- Management of supporting habitats

Four of the five measures identified above were also considered to have at least some (and in some cases substantive) potential to provide benefits to a range of other seabird species that are often qualifying features of SPAs (relevant to meeting criteria 3 and 4 of the proposed compensation definition), but this potential was more limited for the management of supporting habitats measure. Furthermore, management of supporting habitats was considered to have little potential to be applied at multiple sites and would be unlikely to provide (or contribute in any substantive way) to regional-scale compensation. Similarly, there are likely to be considerable constraints to identifying suitable sites for establishing new colonies at natural sites (which will limit scalability and, hence, regional-scale application), whilst for several seabird species (including all five 'target' species) there would be major challenges in the feasibility of achieving colonisation at any such sites.

For biosecurity, mammalian predator management and eradication, and provision of artificial nests, there is considered to be potential for sufficient scalability, as well as a sufficient basis to feasibility, for these measures to be regarded as possible options for regional-scale compensation. In terms of the potential 'compensation returns' that could be achieved from each of these measures, the material considered in this report points (provisionally) to mammalian predator management and eradication as being the measure most likely to go furthest in meeting the possible compensation requirements of the NE and E ScotWind projects (but noting that it is unlikely to be effective for two of the five 'target' species - kittiwake and gannet). By contrast, it is recognised that there is substantial uncertainty over any estimation or quantification of the potential 'compensation returns' associated with biosecurity measures, but it is considered that this measure would be most appropriately adopted in tandem with a programme of mammalian predator management or eradication. As such, biosecurity measures would act to secure benefits obtained from eradication of mammalian predators on seabird breeding islands (as well as having some potential to extend compensation benefits to all five 'target' species). Inclusion of artificial nest provision in a strategic compensation programme could also provide complementary benefits, particularly because amongst the five 'target' species this measure appears most likely to be of benefit to kittiwake (for which mammalian predator management or eradication is unlikely to provide benefits).

The remaining four measures that have been considered in this report are not suited to estimating the potential 'compensation returns' in terms of the possible levels of increase in seabird populations that could

[29] *This excludes avian predator management which, although encompassed within this report, is only included as an optional add-on to mammalian predator management or eradication, and would be for consideration on a site- and situation-specific basis.*

be achieved by implementation of these measures. Three of these measures are concerned with the creation or restoration of marine habitats (i.e. seagrass, oyster reefs and kelp beds), whilst the fourth concerns removal of marine litter. For each, there is insufficient evidence to enable direct linkage between implementation and a response in seabird populations. However, the available evidence suggests these measures are likely to benefit seabird populations and will add resilience to the marine environment on which seabird populations depend (e.g. via increases in fish populations and reductions in plastics). Thus, for these four measures, implementation would be on the basis of providing wider benefits to the SPA site network, and seabird populations generally, as opposed to any direct linkage to a specific SPA qualifying feature (so meeting criterion 5 of the proposed compensation definition). It is considered that there is potential for such measures to be implemented widely and across a range of sites, so enabling the provision of regional-scale compensation, with this potential increased when these measures are regarded as a combined, generic, ‘marine habitat restoration and improvement’ measure. It is also the case that greater understanding of the determinants of likely success of initiatives to create or restore marine habitats would be required to ensure technical feasibility.

Table 6 Summary of key benefits and limitations of ornithological regional compensation measures

Ornithological regional compensation measure	Potential as compensation measure		Potential compensation return	Timescale
	Key benefits	**Key limitations**		
Establish new colonies at natural sites	• Use of social attraction techniques proven to be successful for puffin recolonisation of natural sites • Relatively straightforward for certain other seabird species such as terns (and possibly gulls) • Translocating seabirds may positively impact marine environment e.g. nutrient cycling • Rapid response may be seen to social attraction in some species	• Very limited evidence of success for other ‘target’ seabird species • Requires understanding and overcoming issues that previously prevented birds from colonising naturally • Uncertainty over the efficacy of social attraction techniques • Potential difficulties in acquiring a source population for translocation	• Generally moderate to large • Potentially colonies of 100s for most of the ‘target’ species (possibly larger for gannet) • For non-target species, 10s to 100s of pairs of gulls and terns could result from successful colony establishment	• Species and location-dependent • Rapid response observed for kittiwake and guillemot (within one year) but longer for puffin (8-12 years) • Sites further from source population may take longer to be colonised than those close to existing populations
Artificial nest sites	• Colonisation of artificial structures by kittiwakes is well known and may increase productivity • Structures can be designed to provide optimal nesting conditions and sited in advantageous locations • Easy to monitor if designed to provide access for research purposes • Existing structures may provide ready made infrastructure • Translocating seabirds may positively impact marine environment e.g. nutrient cycling • Potentially deliverable at large scale	• Limited evidence of success in attracting gannet and auks to artificial nest sites • Benefits of artificial nest sites seem limited in east Scotland given natural nest sites are abundant and populations have declined • Costs of producing and siting artificial sites at sufficient scale could be prohibitive • Uncertainty over the efficacy of social attraction techniques • Potential difficulties in acquiring a source population for translocation	• Generally moderate to large • Potentially colonies of 100s for most of the ‘target’ species (possibly larger for gannet) • For non-target species, 10s to 100s of pairs of gulls and terns could result from successful colony establishment	• Species and location-dependent • Rapid response observed for kittiwake and guillemot (within one year) but longer for puffin (8-12 years) • Sites further from source population may take longer to be colonised than those close to existing populations
Seagrass restoration	• Seagrass provides nursery habitat for fish which are prey for seabirds (including ‘target’ species) • Range of ecosystem services provided including carbon storage, nutrient cycling and increased biodiversity	• Lack of direct evidence linking ‘target’ species and other seabirds with seagrass habitats in the UK • High uncertainty in equating compensation benefits of seagrass with predicted impacts from OWFs on seabird populations	• Extremely difficult to quantify in terms of numbers of birds and may require consideration of alternative measures of return (e.g. in terms of abundance of fish populations as prey resource for seabirds)	• Long-term (>10 years) • Dependent on timeframe for habitat restoration and associated fish population response

Ornithological regional compensation measure	Potential as compensation measure: Key benefits	Potential as compensation measure: Key limitations	Potential compensation return	Timescale
	• Potential opportunities for seagrass restoration at a range of sites and geographical scales • Novel technologies and methods potentially making large scale restoration more feasible • Requirement to compensate for lifetime of OWF project would provide mechanism for monitoring and adaptive management	• Traditional methods of seed collection and distribution considered time-consuming, expensive and difficult • Potential conflict with other industries e.g. fishing, aquaculture • Costs of monitoring and adaptive management • Long-term response timescale		
Oyster reef restoration	• Oyster reefs provide nursery habitat for fish which are prey for seabirds • Range of ecosystem services provided including water quality improvement, sediment stabilisation, increased biodiversity and excess nutrient removal • Potential opportunities for oyster reef restoration at a range of sites and geographical scales • Requirement to compensate for lifetime of OWF project would provide mechanism for monitoring and adaptive management	• Lack of direct evidence linking 'target' species and other seabirds with seagrass habitats in the UK • High uncertainty in equating compensation benefits of oyster reefs with predicted impacts from OWFs on seabird populations • Provision of sufficient number of oysters to keep pace with restoration • Biosecurity considerations • Costs of monitoring and adaptive management • Long-term response timescale	• Extremely difficult to quantify in terms of numbers of birds and may require consideration of alternative measures of return (e.g. in terms of abundance of fish populations as prey resource for seabirds)	• Long-term (>10 years) • Dependent on timeframe for habitat restoration and associated fish population response
Kelp bed extension	• Kelp provides nursery habitat for fish which are prey for seabirds • Range of ecosystem services provided including nutrient cycling, carbon sequestration and increased biodiversity • Extending protection of kelp beyond MPAs and/or kelp restoration theoretically possible widely along Scottish coastline • Novel tools potentially making large scale restoration more feasible	• Lack of direct evidence linking 'target' species and other seabirds with kelp habitats in the UK • High uncertainty in equating compensation benefits of kelp habitats with predicted impacts from OWFs on seabird populations • Potential conflict with commercial kelp harvesting	• Extremely difficult to quantify in terms of numbers of birds and may require consideration of alternative measures of return (e.g. in terms of abundance of fish populations as prey resource for seabirds)	• Long-term (>10 years) • Dependent on timeframe for habitat restoration and associated fish population response

Ornithological regional compensation measure	Potential as compensation measure		Potential compensation return	Timescale
	Key benefits	Key limitations		
	• Requirement to compensate for lifetime of OWF project would provide mechanism for monitoring and adaptive management	• Difficulty of sourcing kelp material and practicalities of active restoration • Sensitivity to environmental conditions and climate change-related stressors • Long-term response timescale for restoration (potentially shorter for MPA extension)		
Mammalian predator management and eradication	• Evidence demonstrates mammalian predator management can provide an effective compensation measure for seabird species, particularly auks, shearwaters, petrels and terns • Population responses in seabirds can occur rapidly following eradication of mammalian predators and increased breeding productivity likely to occur at colonies where the management is successful • Potentially deliverable at regional scale (particularly if undertaken in tandem with biosecurity measures)	• Little/no evidence of benefit to kittiwake and gannet • Potential difficulty of maintaining predator free colonies after initial eradication • Eradication unlikely to be feasible on headlands or large islands (where management likely to be limited to reducing predator densities / occurrence and likely to require a level of ongoing effort) • Risk of control measures affecting non-target species	• Generally moderate to large - potentially initial increases of several hundred breeding pairs for auks at some colonies, with additional increases in levels of breeding productivity likely. Similar, or potentially, larger responses in certain non-target species • Potentially greater if combined with avian predator control and biosecurity	• Potentially rapid initial response in breeding productivity (within one year of implementation) • Likely medium-term (4-10 years) for obtaining a response in seabird population size
Avian predator control	• Potential 'add-on' to mammalian predator control / eradication which could be available for consideration on a site- and situation-specific basis • Could act to increase population-level responses from mammalian predator management or eradication at some sites	• Not considered to have potential as a viable regional-scale compensation measure in its own right	• Small to moderate – perhaps 10s to 100s of birds depending on species and predator pressure • Potentially greater if combined with mammalian predator control	• Potentially rapid initial response in breeding productivity (within one year of implementation) • Likely medium-term (4-10 years) for obtaining a response in seabird population size
Biosecurity	• Could be proposed in tandem with a programme of mammalian predator management or eradication, and therefore	• Potential logistical difficulties in providing rapid response to biosecurity incursions at remote sites	• Difficult to quantify in terms of numbers of birds when considered in isolation of mammalian predator management or eradication	• Immediate to short-term in response to neutralise potential threats

Ornithological regional compensation measure	Potential as compensation measure		Potential compensation return	Timescale
	Key benefits	Key limitations		
	likely to be of greatest benefit to auks and certain other non-target species • Preventing arrival of introduced species more cost-effective compared with management of established invasive species • Potentially applicable widely across a range of breeding seabird islands	• Biosecurity measures may already be in place across a range of the potential sites at which this has greatest potential e.g. via Biosecurity for LIFE project	• If operated in tandem with mammalian predator management or eradication, could contribute to moderate to large compensation return - potentially colonies of 100s for auks and certain non-target species	
Management of supporting habitats	• Clearance of tree mallow on the Forth Islands has been shown to lead to an increase in breeding puffin numbers • Management of vegetation can improve nesting conditions at tern and gull colonies • Removal of invasive vegetation can allow native flora to recover • Re-colonisation by nesting birds can be rapid following vegetation clearance • Potentially highly feasible at the scale of small islands	• Among 'target' species, management of supporting habitats only found to obviously benefit puffin on the Forth Islands • Few opportunities to manage supporting habitats exist elsewhere in North and East Scotland • Unclear how management of supporting habitats at the colony could be undertaken to benefit nesting guillemots, razorbill and kittiwake given that the vast majority are cliff nesting • Potentially labour intensive as management is often required annually • Habitat management at many sites is already ongoing therefore limited opportunities for compensation gain	• Small - possibly a few 10s of birds for puffin in the Forth Islands if other areas of tree mallow can be reached and the seed bank at Craigleith depleted sufficiently • Potentially larger for terns and gulls and likely to exceed any compensation requirement, but management already taking place at many locations	• Potentially rapid response (within one year) following vegetation removal or soil/substrate addition
Marine litter	• All five 'target' species and a range of other seabirds known to be affected in some way by marine litter • Negative effects well studied e.g. entanglement, ingestion to physiological and psychological effects on seabirds • Fishing for Litter scheme represents a successful regional operation supported by	• Direct evidence of mortality due to plastic ingestion is insufficient to make quantitative estimates • Current limits to storage and recycling of recovered litter • Potential long-term response time in seabirds • To make a significant impact on the levels of seabird mortality, the constant supply of	• Very difficult to quantify in terms of seabird numbers but likely to be small to moderate	• Likely medium-term (5-10 years) to allow time for reduction of litter in nest sites and associated entanglement risk to reduce • Dependent on reduction in litter entering the marine environment

Ornithological regional compensation measure	Potential as compensation measure		Potential compensation return	Timescale
	Key benefits	Key limitations		
	the fishing industry with considerable room for expansion • Wider ecosystem and amenity benefits from litter removal	plastic material entering the ocean has to be reduced and eventually eliminated		

8.2 Next steps

This work has identified several measures that have potential to provide, or contribute to, regional-scale compensation for the NE and E ScotWind projects. These measures differ substantially in approach but should not be regarded as mutually exclusive and could be combined in a strategic programme to address the compensation requirements.

To progress the development of such a programme, there is a need to refine the details around the likely compensation requirement and the extent to which the potential measures that have been identified can address this (e.g. by exploring potential ‘compensation returns’ for a range of scenarios for mammalian predator management and eradication), as well as understanding the costs involved in the implementation. Uncertainty remains over the extent to which the wider ‘marine habitat’ measures will be regarded as an acceptable approach to providing compensation, necessitating further dialogue on this element of any proposed package of measures. Finally, greater clarity is required on whether, and exactly how, the closure of the sandeel fishery in Scotland could contribute to the provision of regional-scale compensation and the implications this would have for the development of a strategic compensation programme for the NE and E ScotWind projects.

9 References

ABPmer (2019). Sectoral Marine Plan for Offshore Wind Energy. Strategic Habitat Regulations Appraisal (HRA): Screening and Appropriate Assessment Information Report – Final. At: Sectoral Marine Plan for Offshore Wind Energy: Strategic Habitat Regulations Appraisal: Screening and Appropriate Assessment Information Report - Final (www.gov.scot)

Acker, P., Besnard, A., Monnat, J-Y and Cam E. (2017). Breeding habitat selection across spatial scales: is grass always greener on the other side? Ecology 98 2648-2697

Anderson, H. (2021). Status of the Tree Mallow seedbank on Craigleith in 2021. Report prepared for the Scottish Seabird Centre. Aberdeen University.

Anderson, T. W. (1994). Role of macroalgal structure in the distribution and abundance of a temperate reef fish. Marine Ecology Progress Series, 113, 279–290.

Anderson, H.B., Evans, P.G., Potts, J.M., Harris, M.P. and Wanless, S. (2014). The diet of Common Guillemot *Uria aalge* chicks provides evidence of changing prey communities in the North Sea. Ibis, 156(1), 23-34.

Babcock, M. and Booth V. (2020). Tern Conservation Best Practice Habitat: Vegetation management. Report in Roseate Tern Life Project.

Bell, E., Bell, M., Morgan, G., & Morgan, L. (2019). The recovery of seabird populations on Ramsey Island, Pembrokeshire, Wales, following the 1999/2000 rat eradication. Island invasives: scaling up to meet the challenge, (62), 539.

Bergmann, M., Klages, M. and Gutow, L. (eds) (2015). Marine Anthropogenic Litter. [E-book]. Available at: https://link.springer.com/book/10.1007/978-3-319-16510-3. Accessed 03 January 2024.

Bertelli, C.M. and Unsworth, R.K.F. (2014). Protecting the hand that feeds us: Seagrass (*Zostera marina*) serves as commercial juvenile fish habitat. Marine Pollution Bulletin, 83, 425-429.

Bertocci, I., Araújo, R., Oliveira, P., and Sousa-Pinto, I. (2015). Review: Potential effects of kelp species on local fisheries. J. Appl. Ecol. 52, 1216–1226.

Boertmann, D. (2023). Re-establishment of an extinct breeding colony of Brunnich’s Guillemot Uria lomvia in West Greenland. Seabird 35

Bosman, A.L. and Hockey, P.A.R. (1986). Seabird guano as a determinant of rocky intertidal community structure. Mar Ecol Prog Ser 32 247-257

Breid, J., Magalhaes, C., Bolton, M., Neves, V.C., Bell, E., Pereira, J.C., Aguiar, L., Monteiro, L.R. and Santos, R.S. (2009). Seabird Habitat Restoration on Praia Islet, Azores Archipelago. Ecological Restoration 27 27-36

Bunce, A. (2001). Prey consumption of Australasian gannets (Morus serrator) breeding in Port Philip Bay, southeast Australia, and potential overlap with commercial fisheries.

Burgess, N.D. and Hirons, G.J.M. (1992). Creation and management of artificial nesting sites for wetland birds. Journal of Environmental management 34 285-295

Burnell, D., Perkins, A.J., Newton, S.F., Bolton, M., Tierney, T.D. & Dunn, T.E. (2023). Seabirds Count: a census of breeding seabirds in Britain and Ireland (2015–2021). Lynx

Burrows (2014). Assessment of carbon budgets and potential blue carbon stores in Scotland’s coastal and marine environment. Scottish Natural Heritage Commissioned Report No. 761.

Bustnes, J. O. & Systad, G. H. (2001b). Habitat use by wintering Steller’s Eiders Polysticta stelleri in Northern Norway. Ardea, 89, 267-274.

Bustnes, J. O. & Lønne, O. J. (1997). Habitat partitioning among sympatric wintering Common Eiders Somateria mollissima and King Eiders Somateria spectabilis. Ibis, 139: 549-554.

Camphuysen, K. (2011). Northern Gannets in the North Sea: foraging distribution and feeding techniques around the Bass Rock. British Birds 104, 60-76.

Calado, J.G., Ramos, J.A, Almeida, A., Oliveira, N. and Paiva V.H. (2021). Seabird-fishery interactions and bycatch at multiple gears in the Atlantic Iberian coast. Ocean and Coastal Management 200

Carey, M.J. (2011). Intergenerational transfer of plastic debris by Short-tailed Shearwaters (*Ardenna tenuirostris*). Emu, 111, 229-234.

Carr, M. H. (1989). Effects of macroalgal assemblages on the recruitment of temperate zone reef fishes. Journal of Experimental Marine Biology and Ecology, 126, 59–76.

Carr, M. (1983). Spatial and temporal patterns of recruitment of young of the year rockfishes (genus Sebastes) into a central Californian kelp forest. MSc. Thesis: San Francisco State University, San Francisco, California. 104pp.

Casey, D. and Hooton, S. (1991). A register of county wildlife sites in Suffolk. Waveney District Council.

Charlton-Howard, H., Bond, A.L., Rivers-Auty, J. and Lavers, J.L. (2023). ‘Plasticosis’: Characterising macro- and microplastic-associated fibrosis in seabird tissues. Journal of Hazardous Materials, 450, 131090.

Christensen-Dalsgaard, S., Langset, M. and Anker-Nilssen, T. (2019). Offshore oil rigs – a breeding refuge for Norwegian Black-legged Kittiwakes *Rissa tridactyla*? Seabird 32 20-32

Christensen-Dalsgaard, S., Mattisson, J., Norderhaug, K.M. *et al.* (2020). Sharing the neighbourhood: assessing the impact of kelp harvest on foraging behaviour of the European shag. Mar Biol 167, 136.

Christie, H., N. M. Jorgensen, K. M. Norderhaug, and E. Waage-Nielsen. (2003). Species distribution and habitat exploitation of fauna associated with kelp (Laminaria hyperborean) along the Norwegian coast. J. Mar. Biol. Assoc. U.K. 83: 687–699.

Cope, C. (2022). ‘No brainer’ marine litter scheme goes from strength to strength, Shetland News, 8 September. Available at https://www.shetnews.co.uk/2022/09/08/no-brainer-marine-litter-scheme-goes-from-strength-to-strength/ (Accessed 04 September 2023).

Cornell University (2019). 'All About Birds: Northern Gannet'. Available at: https://www.allaboutbirds.org/guide/Northern_Gannet/lifehistory#
Ciotti, B. and Persson, A. 2023. Identifying juvenile fish habitats for sustainable fisheries. https://www.plymouth.ac.uk/research/marine-conservation-research-group/identifying-juvenile-fish-habitats-for-sustainable-fisheries

Coulson, J.C. (2009). Ecology and Colonial structure of Large Gulls in an Urban Colony: Investigations and Management at Dumfires, SW Scotland. Waterbirds 32 1-15.

Coulson, J.C. (2011). The Kittiwake. Poyser.

Coulson, J.C. and Coulson, B.A (2007). Measuring immigration and philopatry in seabirds; recruitment to Black-legged Kittiwake colonies. Ibis 150 288-299.

Cramp, S. and Simmons, K.E.L. (1977). Handbook of the birds of Europe, the Middle East, and North Africa: The birds of the Western Palearctic. Vol 1 Ostrich to Ducks. Oxford University Press.

Cramp, S. and Simmons, K.E.L. (1983). Handbook of the birds of Europe, the Middle East and North Africa: The birds of the Western Palearctic, vol 3 Waders to Gulls. Oxford University Press.

Dalrymple, S. A. (2023). Predator exclusion fencing improves productivity at a mixed colony of Herring Gulls *Larus argentatus*, Lesser Black-backed Gulls *L. fuscus* and Great Black-backed Gulls *L. marinus*. Seabird 35.

Danchin, E., Boulier, T. and Massot, M. (1998). Conspecific Reproductive Success and Breeding Habitat Selection: Implications for Study of Coloniality. Ecology 79 2415-2428.

Defra (2012). Habitats and Wild Birds Directives: guidance on the application of article 6(4) Alternative solutions, imperative reasons of overriding public interest (IROPI) and compensatory measures.

Defra (2021). Best practice guidance for developing compensatory measures in relation to Marine Protected Areas Date: 22 July 2021 Version: For consultation

Defra (2024). Consultation on policies to inform updated guidance for Marine Protected Area (MPA) assessments

DESNZ (2023a). Habitats Regulations Assessment for an Application Under the Planning Act 2008. Hornsea Project Four Offshore Windfarm. Desnz HRA – Hornsea Project 4 (planninginspectorate.gov.uk)

Donnelly-Greenan, E.L., Nevins, H.M. and Harvey, J.T. (2019). Entangled seabird and marine mammal reports from citizen science surveys from coastal California (1997–2017). Marine Pollution Bulletin, 149, 110557.

DTA Ecology (2020). Habitats Regulations Derogations Workshop Report. Final Version. Advice to the Crown Estate. At: 1094_dta_derogations_worksho.pdf (ymaws.com).

Dunlop, C.L., Blokpoel, H. and Jarvie, S. (1991). Nesting rafts as a management tool for a declining common tern (Sterna hirundo) colony. Colonial Waterbirds 14 116-120

Eger, A.M., Marzinelli, E.M., Beas-Luna, R. *et al.* (2023). The value of ecosystem services in global marine kelp forests. Nat Commun 14, 1894.

Eger, A. M., Layton, C., McHugh, T. A, Gleason, M., and Eddy, N. (2022a). Kelp Restoration Guidebook: Lessons Learned from Kelp Projects Around the World. The Nature Conservancy, Arlington, VA, USA

Eger, A.M.; Marzinelli, E.M.; Christie, H.; Fagerli, C.W.; Fujita, D.; Gonzalez, A.P.; Hong, S.W.; Kim, J.H.; Lee, L.C. and McHugh, T.A. (2022). Global kelp forest restoration: Past lessons, present status, and future directions. Biol. Rev. 97, 1449–1475

Engelhard, G.H., Peck, M.A., Rindorf, A., Smout, S.C., van Deurs, M., Raab, K., Andersen, K.H., Garthe, S., Lauerburg, R.A., Scott, F. and Brunel, T. (2014). Forage fish, their fisheries, and their predators: who drives whom? ICES Journal of Marine Science, 71(1), 90-104.

European Commission (1992). The Habitats Directive https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31992L0043

EC (2012). Guidance document on Article 6(4) of the 'Habitats Directive' 92/43/EEC. Clarification of the Concepts of: Alternative Solutions, Imperative Reasons of Overriding Public Interest, Compensatory Measures, Overall Coherence, Opinion of the Commission.

European Commission (2019). Managing Natura 2000 sites – The provisions of Article 6 of the 'Habitats' Directive 92/43/EEC https://ec.europa.eu/environment/nature/natura2000/management/docs/art6/EN_art_6_guide_jun_2019.pdf

Fosså, J. H, Christie, H., Sjøtun, K. (1998). Laminaria hyperborea beds as feeding chamber for fish. Abs. 16th International Seaweed Symposium, Philippines.

Furness R. (2015). Non-breeding season populations of seabirds in UK waters. Population sizes for biologically defined minimum population scales (BDMPS). Natural England Commissioned Report NECR164

Furness, R.W. (2021). HRA Derogation Scope B – Review of Seabird Strategic Compensation Options. Report to Crown Estate Scotland and SOWEC.

Furness, R.W., MacArthur, D., Trinder, M. and MacArthur, K. (2013). Evidence Review to Support the Identification of Potential Conservation Measures for Selected Species of Seabirds. Report to Defra.

Fredriksen, S., Filbee-Dexter, K., Norderhaug, K. M., Steen, H., Bodvin, T., Coleman, M. A., *et al.* (2020). Green gravel: a novel restoration tool to combat kelp forest decline. Sci. Rep. 10, 1–7.

Gamble C., Debney, A., Glover, A., Bertelli, C., Green, B., Hendy, I., Lilley, R., Nuuttila, H., Potouroglou, M., Ragazzola, F., Unsworth, R. and Preston, J, (eds) (2021). Seagrass Restoration Handbook. Zoological Society of London, UK., London, UK.

Garcia-Cegarra A.M., Ramirez, R. and Orrego, R. (2020). Red-legged cormorant uses plastic as nest material in an artificial breeding colony of Atacmama desert coast. Mar Poll Bull 160.

Garcia-Quintas, A., Roy, A., Barbraud, C., Demarcq, H., Denis, D., and Bertrand, S.L. (2023). Machine and deep learning approaches to understand and predict habitat suitability for seabird breeding. Ecology and Evolution 13.

Gibson R.N. (1994). Impact of habitat quality and quantity on the recruitment of juvenile flatfishes. Neth J Sea Res 32: 191−206

Gobe Consultants Ltd. (2021). Hornsea Project Four: Derogation Information. Volume B2, Annex 8.3: Compensation measures for FFC SPA: Predator Eradication: Ecological Evidence. Test (planninginspectorate.gov.uk)

Gobe Consultants and Niras (2023). Hornsea Three: Kittiwake Implementation and Monitoring Plan (KIMP). At:EN010080-003661-FINAL_Hornsea_Three_Kittiwake_Implementation_and_Monitoring_Plan_Redacted.pdf (planninginspectorate.gov.uk)

Gotceitas *et al.* (1995). Habitat use by juvenile Atlantic cod (Gadus morhua) in the presence of an actively foraging and non-foraging predator. Marine Biology, 123, 421–430

Green, A.J. and Elmberg, J. (2014). Ecosystem services provided by waterbirds. Biological reviews, 89(1), 105-122.

Grémillet, D., Péron, C., Lescroel, A., Fort, J., Patrick, S.C. *et al.* (2020). No way home: Collapse in northern gannet survival rates point to critical marine ecosystem perturbation. Marine Biology, 167, 189. ff10.1007/s00227-020-03801-yff. ffhal-03022345f

Grose, A.V., Schulze, B. and Cremer, M.J. (2011). Registro de reproducao do atoba-pardo Sula leucogaster (Suliformes: Sulidae) em estrutura artificial no estuario da baia da Babitonga, Santa Catarina, Brasil. Revista Brasileira de Ornitologia, 19 541-544.

Gundersen, H., Christie, H., de Wit, H., Norderhaug, K., Bekkby, T., & Walday, M. (2011). Utredning om CO2-opptak i marine naturtyper. NIVA, Report, L.NR. 6070, 2010.

Gutow, L., Ricker, M., Holstein, J.M., Dannheim, J., Stanev, E.V. and Wolff, J.O. (2018). Distribution and trajectories of floating and benthic marine macrolitter in the south-eastern North Sea. Marine Pollution Bulletin, 131, 763-772.

Harding, J.M. and Mann, R.L. (2001). Oyster reefs as fish habitat: Opportunistic use of restored reefs by transient fishes. Journal of Shellfish Research, 20(3), 951-959.

Harris, M.P. and Wanless, S. (1997). Breeding success, diet, and brood neglect in the kittiwake (Rissa tridactyla) over an 11-year period. ICES Journal of Marine Science, 54, 615–623.

Hartman C.A., Ackerman, J.T., Herzog, M.P., Strong, C. and Trachtenberg, D. (2019). Social attraction used to establish Caspian tern nesting colonies in San Francisco Bay. Global Ecology and Conservation 20.

Hartman, C.A., Ackerman, J.T., Herzog, M.P., Wang, Y. and String , C. (2020). Establishing Forster's Tern (Sterna forsteri) nesting sites at pond A16 using social attraction for the South Bay Slat Pond restoration project. USGS report.

Hartwig, E., Clemens, T. and Heckroth, M. (2007). Plastic debris as nesting material in a Kittiwake (Rissa tridactyla) colony at the Jammerbugt, Northwest Denmark. Marine Pollution Bulletin, 54(5), 595–597

Heck Jr, K.L., Hays, G. and Orth, R. (2003). Critical evaluation of the nursery role hypothesis for seagrass meadows. Marine Ecology Progress Series, 253, 123-136.

Helmer, L., Farrell, P., Hendy, I., Harding, S., Robertson, M. and Preston, J. (2019). Active management is required to turn the tide for depleted Ostrea edulis stocks from the effects of overfishing, disease and invasive species. PeerJ. 2019 Feb 28;7:e6431.

Hentati-Sundberg, J., Osterblom, H., Kadin, M. , Jansson, A. and Olsson, O. (2012). The Karlso Murre lab methodology can stimulate innovative seabird research. Marine Ornithology 40 11-16.

Hentati-Sundberg, J., Raymond, C., Skold, M., Svensson, O., Gustafsson, B. and Bonaglia, S. (2020). Fueling of a marine-terrestral ecosystem by a major seabird colony. Sceintific Reports 10

Hentati-Sundberg, J., Oiln, A.B., Reddy, S., Berglund, P-A., Svensson, E., Reddy, M., Kasarareni, S., Carlsen, A.A., Hanes, M., Kad, S. and Olsson, O. (2023). Seabird surveillance: combining CCTV and artificial intelligence for monitoring and research. Remote Sensing in Ecology and Conservation 9 568-581

Høiberg, M.A., Woods, J.S. and Verones, F. (2022). Global Distribution of Potential Impact Hotspots for Marine Plastic Debris Entanglement. Ecological Indicators, 135, 108509.

Hoeisaeter, T. and Fosså, J.H. (1993). The kelp forest and its resident fish fauna. Institutt for Fiskeri og Marinbiologi, University of Bergen, Bergen.

Holmes, N.D., Buxton, R.T., Jones, H.P., Sànchez, F.M., Oppel, S., Russell, J.C., Spatz, D.R. and Samaniego, A. (2023). Conservation of marine birds: Biosecurity, control, and eradication of invasive species threats. In Young, L. and VanderWerf, E. (eds) Conservation of Marine Birds. Elsevier.

Horswill, C. and Robinson, R.A. (2015). Review of seabird demographic rates and density dependence. JNCC Report No. 552. JNCC, Peterborough.

Huang, L. (2021). Subtidal Seagrass Bed Habitat Suitability in Scotland. University of Edinburgh MSc thesis.

ICEM (2023). Review of predator eradication options for offshore wind compensation. Unpublished report to Royal HaskoningDHV.

ICES (2015). Working Group on the Value of Coastal Habitats for Exploited Species: Making shore of coastal habitat value. https://www.ices.dk/news-and-events/news-archive/news/Pages/Making-shore-of-coastal-habitat-value-.aspx

ICES (2021). Working Group on the value of Coastal Habitats for Exploited Species (WGVHES). ICES Scientific Reports. 3:78. 11 pp. https://doi.org/10.17895/ices.pub.8245

Infantes, E., Eriander, L. and Moksnes, P.O. (2016). Eelgrass (Zostera marina) restoration on the west coast of Sweden using seeds. Marine Ecology Progress Series 546.

Johnston, A., Cook, A.S.C.P., Wright, L.J., Humphreys, E.M. and Burton, E.H.K. (2014a). Modelling flight heights of marine birds to more accurately assess collision risk with offshore wind turbines. Journal of Applied Ecology, 51, 31-41.

Johnston, A., Cook, A.S.C.P., Wright, L.J., Humphreys, E.M. and Burton, N.H.K. (2014b). Corrigendum. Journal of Applied Ecology, 51, 1126 – 1130.

JNCC (2023). SMP Report 1986–2019 | JNCC - Adviser to Government on Nature Conservation [accessed 29/12/2023]

Jones, H.P. and Kress, S.W. (2012). A Review of the World's Active Seabird Restoration Projects. Journ Wild Man 76 2-9

Kent, F., Lilley, R., Unsworth, R., Cunningham, S., Begg, T., Boulcott, P., Jeorrett, C., Horsburgh, R. and Michelotti, M. (2021). Seagrass restoration in Scotland - handbook and guidance. NatureScot Research Report 1286.

Kildaw S.D., Irons, D.B., Nysewander, D.R. and Buck, C.L. (2005). Formation and growth of new seabird colonies: the significance of habitat quality. Marine Ornithology 33 49-58

KIMO (2020a). https://www.kimointernational.org/news/brexit-threat-to-uks-fishing-for-litter-as-eu-funding-ends/ - Kimo 2020a

KIMO (2020b). https://www.kimointernational.org/news/net-recycling-in-scotland/ - KIMO, 2020b

KIMO (2022). https://www.kimointernational.org/networks/uk/ - 2022

Kingston, A., Northridge, S., Paxton, C.G.M. and Buratti, J.P.F. (2023). Improving understanding of Seabird bycatch in Scottish longline fisheries and exploring potential solutions. Report to Scottish Government.

Krause-Jensen, D. and Duarte, C.M. (2016). Substantial role of macroalgae in marine carbon sequestration. Nature Geoscience, 9, 737–742.

Kress, S. W. (1997). Using animal behaviour for Conservation: Case Studies in Seabird Restoration from the Maine Coast, USA. Jor Yamashina Inst. Ornithology, 29, 1-26

Kress, S.W. (1983). The use of decoys, sound recording and gull control for re-establishing a tern colony in Maine. Colonial Waterbird, 6, 185-196

Kress, S. W. and Nettleship, D.N. (1988). Re-establishment of Atlantic puffins (Fratercula arctica) at a former breeding site in the Gulf of Maine. Journal of Field Ornithology, 59, 161-170.

Krumhansl, K.A. and Scheibling, R.E. (2012). Production and fate of kelp detritus. Marine Ecology Progress Series, 467, 281-302.

Kühn S., Meijboom A., Bittner O. and Van Franeker J.A. (2022). Fulmar Litter Monitoring in the Netherlands – Update 2021. Wageningen Marine Research Report C043/22 / RWS Centrale Informatievoorziening BM 22.17.

Lazzari M. A., Stone B. Z. (2006). Use of Submerged Aquatic Vegetation as Habitat by Young-of-the-Year Epibenthic Fishes in Shallow Maine Nearshore Waters. Estuar. Coast. Shelf. Sci. 69, 591–606.

Lilley, R.J. and Unsworth, R.K.F. (2014). Atlantic Cod (*Gadus morhua*) benefits from the availability of seagrass (Zostera marina) nursery habitat. Global Ecology and Conservation, 2, 367-377.

Lefcheck, J.S., Hughes, B.B., Johnson, A.J., Pfirrmann, B.W., Rasher, D.B., Smyth, A.R., Williams, B.L., Beck, M.W. and Orth, R.J. (2019). Are coastal habitats important nurseries? A meta-analysis. Conservation Letters, 12, e12645.

Lorentsen, S-H., Sjøtun, K., and Grémillet, D. (2010). Multi-trophic consequences of kelp harvest. Biological Conservation 143 (9) 2054-2062.

Lovas, S. M. and Torum, A. (2001). Effect of the kelp Laminaria hyperborea upon sand dune erosion and water particle velocities. Coast. Eng. 44: 37–63.

Luxmoore, R., Swann, R., & Bell, E. (2019). Canna seabird recovery project: 10 years on. Island invasives: scaling up to meet the challenge, (62), 576.

MacArthur Green and Royal HaskoningDHV (2021). Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects: Appendix 3 – Kittiwake Compensation Document. EN010109-000441-5.5.3 Appendix 3 Kittiwake Compensation Document.pdf (planninginspectorate.gov.uk)

MacArthur Green and Royal Haskoning DHV (2022a). Norfolk Projects Offshore Wind Farms: Lesser Black-Backed Gull Implementation and Monitoring Plan. Norfolk Boreas Limited and Norfolk Vanguard Limited. At: EN010087-002993-The Norfolk Projects Lesser Black-Backed Gull Implementation and Monitoring Plan .pdf (planninginspectorate.gov.uk)

MacArthur Green and Royal Haskoning DHV (2022b). Norfolk Projects Offshore Wind Farms: Kittiwake Implementation and Monitoring Plan. Norfolk Boreas Limited and Norfolk Vanguard Limited. EN010087-003002-The-Norfolk-Projects-Kittiwake-Implementation-and-Monitoring-Plan.pdf (planninginspectorate.gov.uk)

Manikowska-Slepowronska, B., Slepowronski, K. and Jakubas D. (2021). The use of artificial floating nest platforms as conservation measure for the common tern Sterna hirundo: a case study in the RAMSAR site Druzno Lake in Northern Poland. The European Zoologial Journal, 89 229-240

McChesney G. J., Eigner, L.E., Kappes, P.J., Pointras T.B., Lontoh, D.N., Rhoades, S.J., Metheny, N.J., Golightly, R.T., Capitolo, P.J., Carter, H.R., Kress, S.W. and Parker, M.W. (2008). Restoration of Common Murre colonies in central California – Annual Report 2007. Report to the Apex Houston Trustee council and Command Trustee Council. USFWS.

McDevitt-Irwin, J.M., Iacarella, J.C. and Baum, J.K. (2016). Reassessing the nursery role of seagrass habitats from temperate to tropical regions: a meta-analysis. Marine Ecology Progress Series, 557, 133-143.

McGregor, R., Trinder, M. and Goodship, N. (2022). *Assessment of compensatory measures for impacts of offshore windfarms on seabirds*. A report for Natural England. Natural England Commissioned Reports. Report number NECR431.

Meier T.I. (1980). Artificial nesting structures for the double-crested cormorant. MSc Thesis. University of Wisconsin.

Menard, Y. (2011). Murre seabird chicks hatch for the first time in 100 years on the channel islands < Murre Seabird Chicks Hatch for the First Time in 100 Years on the Channel Islands – Channel Islands National Park (U.S. National Park Service) (nps.gov)> [accessed 29/12/2023]

Meyerjürgens, J., Ricker, M., Aden, C., Albinus, M., Barrelet, J., Freund, H., Hahner, F. *et al.* (2023). Sources, pathways, and abatement strategies of microplastic pollution: an interdisciplinary approach for the southern North Sea. Frontiers in Marine Science, 10, 1148714.

Miller, R. J., Lafferty, K. D., Lamy, T., Kui, L., Rassweiler, A., and Reed, D. C. (2018). Giant kelp, Macrocystis pyrifera, increases faunal diversity through physical engineering. Proc. R. Soc. B Biol. Sci. 285, 20172571

Mitchell, I., Newton, S.F., Ratcliffe, N. and Dunn, T.E. (2004). Seabird populations of Britain and Ireland: results of the Seabird 2000 census (1998-2002). T&A.D. Poyser. London

Moksnes P.O., Gipperth L., Eriander L., Laas K., Cole S. and Infantes E. (2021). Handbook for restoration of eelgrass in Sweden - National guideline. Swedish Agency for Marine and Water Management, Report number 2021:5,

Moray West Offshore Windfarm (2019). Information to inform HRA. Refinement to the assessment of in-combination effects on great black-backed gull feature of East Caithness Cliffs SPA.

Morris, R.L., Graham, T.D.J., JKelvin, J., Ghisalberti, M., and Swearer, S.E. (2020). Kelp beds as coastal protection: wave attenuation of Ecklonia radiata in a shallow coastal bay, Annals of Botany, Volume 125, Issue 2, Pages 235–246.

Murphy, M. L., Johnson, S. W. and Csepp, D. J. (2000). A comparison of fish assemblages in eelgrass and adjacent subtidal habitats near Craig, Alaska. Alaska Fishery Research Bulletin, 7: 11-21.

Natural England (2023). Sheringham Shoal Extension and Dudgeon Extension Offshore Wind Farms. Appendix L to the Natural England's Deadline 1 Submission: Natural England's Response to Examining Authority's First Written Questions. EN010109-000908-Natural England – Responses to the Examining Authority's First Written Questions (WQ1).pdf (planninginspectorate.gov.uk) [accessed 18/042024].

NatureScot (2023a). Berwick Bank Offshore Wind Farm. Advice on Ornithology Impact Assessment. 03._consultation_representations_and_advice.pdf (marine.gov.scot) [accessed 25/01/2024]

NatureScot (2023b). Berwick Bank Offshore Wind Farm. Derogation Under Article 6(4) of the Habitats Directive. 03._consultation_representations_and_advice.pdf (marine.gov.scot) [accessed 25/01/2024]

NatureScot (2023c). Berwick Bank Offshore Wind Farm – Additional Environmental Information. Addendum to the Derogation Case (AEI02). Supplementary Information to the Derogation Case (AEI03). representations_-_additional_information.pdf (marine.gov.scot) [accessed 17/04/2024].

Niras (2021). Hornsea Project Four: Derogation Information. Volume B2, Annex 7.3: Compensation measures for FFC SPA: Onshore Artificial Nesting: Ecological Evidence. Report for Orsted.

Nordström, M., Högmander, J., Laine, J., Nummelin, J., Laanetu, N. and Korpimäki, E. (2003). Effects of feral mink removal on seabirds, waders and passerines on small islands in the Baltic Sea. Biological Conservation, 109, 359-368.

Northridge, S.P., Kingston, A.R. & Coram, A.J. (2023). Regional seabird bycatch hotspot analysis. JNCC Report No. 726. JNCC, Peterborough. [https://hub.jncc.gov.uk/assets/a00403c7-6f56-4f38-8b57-b2ab1859c564].

O'Hanlon, N. J., James, N., Masden, E., and Bond, A. (2017). Seabirds and marine plastic debris in the northeastern Atlantic: A synthesis and recommendations for monitoring and research. Environmental Pollution, 231, 1291-1301.

Oppel, S., Beard, A., Fox, D., Mackley, E., Leat, E., Henry, L., Clingham, E., Fowler, N., Sim, J., Sommerfield, J., Weber, N., Weber, S., and Bolton, M. (2015). Foraging distribution of a tropical seabird supports Ashmole's hypothesis of population regulation. Behavioural Ecology and Sociobiology 69 915-926.

Oreska, M.P.J., McGlathery, K.J., Aoki, L.R., Berger, A.C., Berg, P. and Mullins, L. (2020). The greenhouse gas offset potential from seagrass restoration. Scientific Reports 10(1).

Orth, R.J., Lefcheck, J.S., McGlathery, K.S., Aoki, L., Luckenbach, M.W., Moore, K.A. *et al.* (2020). Restoration of seagrass habitat leads to rapid recovery of coastal ecosystem services. Science Advances 6(41).

Ørsted (2021a). Hornsea Project Four: Derogation Information. Volume B2, Annex 7.1: Compensation measures for FFC SPA offshore artificial nesting ecological evidence. Test (planninginspectorate.gov.uk)

Ørsted (2021b). Hornsea Project Four: Derogation Information. Volume B2, Annex 8.5: Compensation measures for FFC SPA: Fish Habitat Enhancement: Ecological Evidence.

Ørsted (2022). Hornsea Project Four: Derogation Information. FFC SPA: Guillemot and razorbill compensation plan EN010098-002038-Hornsea Project Four – Other- B2.8 FFC SPA Guillemot and Razorbill Compensation Plan.pdf (planninginspectorate.gov.uk)

Orwin, K.H., Warbel, D.A., Towns, D.R., St John, M.G., Bellingham, P.J., Jone, C., Fitzgerlad, B.M., Parrish, R.G. and Lyver, P. O'B. (2016). Burrowing seabird effects on invertebrate communities in soil and litter are dominated by ecosystem engineering rather than nutrient addition. Oecologica 180 217-230.

OSPAR. (2010). Quality status report 2010. London: OSPAR Commission.

Ozsanlav-Harris, L., Inger, R. and Sherley, R. (2023). Review of data used to calculate avoidance rates for collision risk modelling of seabirds. JNCC Report No. 732. JNCC, Peterborough.

Pavat, D., Harker, A.J., Humphries, G., Keogan, K., Webb, A. and Macleod, K. (2023). Consideration of avoidance behaviour of northern gannet (*Morus bassanus*) in collision risk modelling for offshore wind farm impact assessments. NECR490. Natural England.

Parker, M.W., Kress, S.W., Golightly, R.T., Carter, H.R., Parsons, E.B., Schubel, S.E., Boyce, J.A., McChesney, G.J. and Wisely, S.M. (2007). Assessment of Social attraction techniques used to restore a common murre colony in Central Calfiornia. Waterbirds 30 17-28

Peterson, C.H., Grabowski, J.H., and Powers, S.P. (2003). Estimated enhancement of fish production resulting from restoring oyster reef habitat: Quantitative valuation. Marine Ecology Progress Series, 264, 249–64.

Pierson, K.J., and Eggleston, D.B. (2014). Response of estuarine fish to large-scale oyster reef restoration. Transactions of the American Fisheries Society 143:273-288

Pinsent Masons, SSE Renewables and Gobe Consultants (2022). Berwick Bank Wind Farm Derogation Case. At: eor0766_berwick_bank_wind_farm_application_-_1._derogation_case.pdf (marine.gov.scot)

Plastix (2023). https://plastixglobal.com/

Potouroglou, M., Whitlock, D., Milatovic, L., MacKinnon, G., Kennedy, H., Diele, K. and Huxham, M. (2021). The sediment carbon stocks of intertidal seagrass meadows in Scotland. Estuarine, Coastal and Shelf Science, 258, 107442.

Preston J., Gamble, C., Debney, A., Helmer, L., Hancock, B. and zu Ermgassen, P.S.E. (eds) (2020). European Native Oyster Habitat Restoration Handbook. The Zoological Society of London, UK.

Raybaud V, Beaugrand G, Goberville E, Delebecq G, Destombe C, Valero M, *et al.* (2013). Decline in Kelp in West Europe and Climate. PLoS ONE 8(6): e66044.

Raya Rey, A. and Schiavini, A.C.M. (2000). Distribution, abundance and associations of seabirds in the Beagle Channel, Tierra del Fuego, Argentina. Polar Biology 23, 338-345.

Ricart, A., Ward, M., Hill, T., Sanford, E., Kroeker, K., Takeshita, Y. *et al.* (2021). Coast-wide evidence of low pH amelioration by seagrass ecosystems. Global Change Biology 27(11) 2580-2591.

Roman, L., Hardesty, B.D., Hindell, M.A. and Wilcox, C. (2019). A quantitative analysis linking seabird mortality and marine debris ingestion. Scientific Reports, 9(1), 1-7.

Roman, L., Kastury, F., Petit, S., Aleman, R., Wilcox, C., Hardesty, B.D., and Hindell, M.A. (2020). Plastic, nutrition and pollution; relationships between ingested plastic and metal concentrations in the livers of two Pachyptila seabirds. Nature Scientific Reports, 10, 10823.

Royal HaskoningDHV (2022). Berwick Bank Wind Farm Report to Inform Appropriate Assessment. Part Three: Special Protection Areas. At: 221220_-_eor0766_berwick_bank_wind_farm_-_riaa_part_3_spa_assessment_-_signed.pdf (marine.gov.scot)

RSPB (2023). Berwick Bank Offshore Wind Farm Application Response by the RSPB.

Sas H, Deden B, Kamermans P, zu Ermgassen PSE, Pogoda B, Preston J, Helmer L, Holbrook Z, Arzul I, van der Have T, Villalba A, Colsoul B, Merk V, Lown A, Zwerschke N, Reuchlin E. (2020). Bonamia infection in flat oysters (Ostrea edulis) in relation to European restoration projects. Aquatic Conserv 30: 2150–2162.

Scottish Government. (2013). Marine litter strategy, national litter strategy: Strategic environmental assessment environmental report. Retrieved September 5, 2014 from http://www.scotland.gov.uk/Publications/2013/07/9297/5.

Scottish Government. (2022). Marine litter strategy. Environment and climate change, Marine and fisheries, Marine Directorate. ISBN: 9781804359808.

Senko, J.F., Nelms, S.E., Reavis, J.L., Witherington, B., Godley, B.J. and Wallace, B.P. (2020). Understanding individual and population-level effects of plastic pollution on marine megafauna. Endangered Species Research, 43, 234-252.

Shaffer, S. (2003). Preferential use of nearshore kelp habitats by juvenile salmon and forage fish. Proceedings of the Georgia Basin/Puget Sound Research Conference. 11pp.

Signe, G., Mazzola, A., and Vizzini, S. (2021). Seabird influence of ecological processes in coastal marine ecosystems: An overlooked role? A critical review. Estuarine, Coastala dn Shelf Science 250

Sjøtun, K. and Lorentsen, S-H. (2003). Kelp forest (Laminaria hyperborea) as habitat for juvenile gadoids. Poster presented at the 3rd European Phycological Congress, Belfast, North-Ireland, 21-26 July, 2003.

Skeate (2022). Berwick Bank Derogation Case. Colony Compensatory Measures Evidence Report.

Smith, R.S. and Castorani, M.C.N. (2023). Meta-analysis reveals drivers of restoration success for oysters and reef community. Ecological Applications, 10, e2865.

Smith, R.S., Cheng, S.L., and Castorani, M.C.N. (2023). Meta-analysis of ecosystem services associated with oyster restoration. Conserv Biol. 2023 Feb;37(1):e13966.

Sorensen, M., Hipfner, J.M., Kyser, T.K. and Norris, R.D. (2009). Carry-over effects in a Pacific seabird: stable isotope evidence that pre-breeding diet quality influences reproductive success. Journal of Animal Ecology 78 460-467

Sjøtun, K. and Lorentsen, S-H. (2003). Kelp forest (Laminaria hyperborea) as habitat for juvenile gadoids. Poster presented at the 3rd European Phycological Congress, Belfast, North-Ireland, 21-26 July, 2003.

St Pierre, P., Booker, H., Price D., Slader, P., Bellamy, A.J., Pearson, J. (2023). Lundy now internationally important for seabirds: Cliff nesting seabird survey 2021. Journal of the Lundy Field Society 8, 7-20.

Stanbury, A., Thomas, S., Aegerter, J., Brown, A., Bullock, D., Eaton, M., Lock, L., Luxmoore, R., Roy, S., Whitaker, S. and Oppel, S. (2017). Prioritising islands in the United Kingdom and crown dependencies for the eradication of invasive alien vertebrates and rodent biosecurity. European Journal of Wildlife Research, 63. https://doi.org/10.1007/s10344-017-1084-7.

Stanbury, A.J., Eaton, M.A., Aebischer, N.J., Balmer, D., Brown, A.F., Douse, A., Lindley, P., McCulloch, N., Noble, D.G. and Win, I. (2021). The status of our bird populations: the fifth Bird of Conservation Concern in the United Kingdon, Channel Islands and the Isle of Man and second IUCN Red List assessment of extinction risk for Great Britain. British Birds 114.

Strand, Å., Bakker, N., Bird, A., Blanco, A., Bonačić, K., Brundu, G., Colsoul, B., Connellan, I., da Costa, F., Fabra, M., Hannan, M., Hugh-Jones, T., Humm, G., Nielsen, P., Stechle, B., & zu Ermgassen, P. (2021). What restoration practitioners need to know about the oyster production industry. NORA, Berlin.

Suffolk Wildlife Trust (2007). County Wildlife Site Audit.

Sustainable Inshore Fisheries Trust (SIFT) (2018). Protection for Scotland's kelp forests.

Tanaka, K., Takada, H., Yamashita, R., Mizukawa, K., Fukuwaka, M.A. and Watanuki, Y. (2013). Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics. Marine Pollution Bulletin, 69(1-2), 219- 222.

Teagle, H., Hawkins, S. J., Moore, P. J., and Smale, D. A. (2017). The role of kelp species as biogenic habitat formers in coastal marine ecosystems. J. Exp. Mar. Bio. Ecol. 492, 81–98.

Thomas, S., Collins, K., Hauton C. and Jensen, A. (2022). A Review of the Ecosystem Services Provided by the Native Oyster (Ostrea edulis): Implications for Restoration. IOP Conference Series: Materials Science and Engineering, 1245, 012010.

Trinder, M. (2016). Population viability analysis of the Sula Sgeir gannet population. Scottish Natural Heritage Commissioned Report No. 897.

Trinder, M. (2023). Beatrice Offshore Wind Farm: Year 2 Post-construction Ornithological Monitoring Report. MacArthur Green report.

UNEP. (2021). From Pollution to Solution: a global assessment of marine litter and plastic pollution. United Nations Environment Programme, Nairobi. Available at: https://www.unep.org/resources/pollution-solution-global-assessment-marine-litter-and-plastic-pollution. Accessed 18 October 2023.

Unsworth, R.K., Bertelli, C.M., Cullen-Unsworth, L.C., Esteban, N., Jones, B.L., Lilley, R., Lowe, C., Nuuttila, H.K. and Rees, S.C. (2019). Sowing the seeds of seagrass recovery using hessian bags. Frontiers in Ecology and Evolution, 7, 311.

van de Wolfshaar, K. E., Tulp, I., Wennhage, H., & Støttrup, J. G. (2015). Modelling population effects of juvenile offshore fish displacement towards adult habitat. *Marine Ecology Progress Series*, *540*, 193-201. https://doi.org/10.3354/meps11519

Verbeek, J., Louro, I., Christie, H., Carlsson, P. M., Matsson, S., Renaud, P. E. (2021). Restoring Norway's underwater forests. A strategy to recover kelp ecosystems from urchin barrens. SeaForester, NIVA & Akvaplan-niva, Report, 2021.

Vihtakari, M., Welcker, J., Moe, B. *et al.* (2018). Black-legged kittiwakes as messengers of Atlantification in the Arctic. Sci Rep 8, 1178.

Votier, S.C., Archibald, K., Morgan, G. and Morgan, L. (2011). The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. Marine Pollution Bulletin, 62, 168–172.

Wakefield, E.D., Bodey, T.W., Bearhop, S., Blackburn, J., Colhoun, K., Davies, R., Dwyer, R.G., Green J.A., Gremllet, D., Jackson, A.L., Jessop, M.J., Kane, A., Langston, R.H.W., Lescroel, A., Murray, S., Le Nuz, M., Patrick, S.C., Peron, C., Soanes, L.M., Wanless, S., Votier, S.C. and Hamer, K.C. (2013). Space Partitioning without territoriality in gannets. Science. 341 68-70.

Wakefield, E. D., Owen, E., Baer, J., Carroll, M. J., Daunt, F., Dodd, S. G., Green, J. A., Guilford, T., Mavor, R. A., Miller, P. I., Newell, M. A., Newton, S. F., Robertson, G. S., Shoji, A., Soanes, L. M., Votier, S. C., Wanless, S. and Bolton, M. (2017). Breeding density, fine-scale tracking, and large-scale modelling reveal the regional distribution of four seabird species. Ecological Applications, 27, 2074–2091.

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. Report for The Crown Estate.

Wells , M.R., Angel, L.P. and Arnould, J.P.Y. (2016). Habitat-specific foraging strategies in Australasian gannets Biology Open 5, 921-927.

Wernberg, T., Krumhansl, K., Filbee-Dexter, K., & Pedersen, M. F. (2019). Status and trends for the world's kelp forests. In World seas: An environmental evaluation (pp. 57-78). Academic Press.

Zonfrillo, B. (2007). Ailsa Craig – rat eradication – history and effects. In: Tackling the problem of invasive alien mammals on seabird colonies – strategic approaches and practical experience. Proceedings of a conference held on 18-19 September 2007, Education Centre, Edinburgh Zoo. National Trust for Scotland, Royal Zoological Society of Scotland and Central Science Laboratory.

zu Ermgassen, P., Thurstan, R., Corrales, J., Alleway, H., Carranza, A., Dankers, N., *et al.* (2020). The benefits of bivalve reef restoration: a global synthesis of underrepresented species. Aquatic Conservation: Marine and freshwater ecosystems.

Appendix A

Original long-list of potential regional compensation measures

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
Sandeel fishery closure	**Kittiwake**	**Strong** • Evidence of negative effect of sandeel fishery on breeding productivity at regional level from Before-After-Control-Impact (BACI) study. The scale of the positive response of the treatment colonies in the 'after closure' period was relatively small but contrasted the continued negative trend in breeding productivity in the control colonies during this period (Searle *et al.* 2023). • Evidence breeding productivity on Isle of May increases with the proportion of sandeel in the chick diet (and diet composition is linked to some measures of sandeel abundance (positive) and fishing effort (negative)) (Searle *et al.* 2023). • Evidence for positive effects of sandeel abundance and negative effects of fishing effort on breeding productivity at a regional scale in east Scotland and at the Flamborough and Filey Coast SPA population (Carroll *et al.* 2017, Searle *et al.* 2023). • Annual return rates of adult kittiwake (a possible surrogate of survival rate) and colony population size on the Isle of May positively correlated with sandeel total stock biomass (McGregor 2022). Adult survival rates also linked to sandeel abundance in Shetland (Oro & Furness 2002). • Correlative evidence from three North Sea regions for effects of sandeel abundance on breeding productivity (Carroll *et al*. 2017, Furness 2021a). • Evidence for effects of fishing effort on sandeel stock biomass (Frederiksen *et al.* 2008, Carroll *et*	Yes	High (Tiers 1 or 2 of compensation definition met)	• Largely outwith developers' control • Implementation by government may negate it as compensation • Uncertainty in equating compensation benefit with predicted impacts (from OWFs) on seabird populations	Medium / long term (5 – 10 years) • Time required for response and recovery in sandeel populations • If main effects on seabird species are via increased productivity, time required for response in adult breeding numbers at SPA colonies (likely 4 – 6 years depending on species although less for some 'other' seabird species not identified as key species for strategic compensation)

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		al. 2017, Lindegren *et al.* 2018, Furness 2021a) albeit that there is risk that sandeel stock recovery may be limited by other environmental factors (e.g. climate change effects or predation pressure on the populations that have been reduced by heavy fishing pressure). • Logical biological basis, given evidence of dependence on sandeel as prey and apparent difficulty in switching to other prey (in some populations at least), together with evidence that limiting fishing effort on forage fish stocks is the most effective measure for increasing those stocks (Lindegren *et al*. 2018).				
	Gannet	**Weak** • Gannets take wide range of fish taxa and size classes from sandeel to adult mackerel. • No direct evidence of linkage between sandeel availability and gannet demography / population trends. • Not identified as a potential measure in previous reviews of options for compensation (Furness 2013, Furness 2021a, McGregor *et al.* 2022).	Yes	High (Tiers 1 or 2 of compensation definition is met)		
	Guillemot	**Moderate** • No evidence of positive effects of closure of a part of the East Scotland sandeel fishery on breeding productivity at Isle of May (Searle *et al.* 2023). • Evidence breeding productivity on the Isle of May increases with the proportion of sandeel in the chick diet (and diet composition is linked to some measures of sandeel abundance) (Searle *et al*. 2023).	Yes	High (Tiers 1 or 2 of compensation definition is met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		• Evidence for positive effects of sandeel abundance on breeding productivity at a regional scale (Searle *et al.* 2023). • Annual return rates of adult guillemot (a possible surrogate of survival rate) and colony population size on the Isle of May positively correlated with sandeel total stock biomass (McGregor 2022). • Low breeding productivity at the FFC SPA in recent years has coincided with a period of particularly low sandeel stock biomass (McGregor *et al*. 2022). • Forage fish are considered a key determinant of guillemot breeding productivity although evidence suggests they are more capable of switching to non-sandeel prey (e.g. sprats) than some other seabird species (Furness 2021a). • Logical biological basis, given importance of sandeel in diet and dependence on forage fish as prey, together with evidence that limiting fishing effort on forage fish stocks is the most effective measure for increasing those stocks (Lindegren *et al.* 2018).				
	Razorbill	**Moderate** • No evidence that razorbill breeding success on Isle of May benefited from 20-year closure of sandeel fishery and was in fact lower post-closure (Searle *et al.* 2023). • Evidence breeding productivity on the Isle of May increases with the proportion of sandeel in the chick diet (and composition of chick diet on the Isle of May linked to some measures of sandeel abundance (i.e. proportion of sandeel increased under conditions of higher 0-group sandeel	Yes	High (Tiers 1 or 2 of compensation definition is met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		abundance, or higher ratio of sandeel to sprat abundance; and sandeel proportion decreased with higher fishing effort - Searle *et al.* 2023)). • No evidence for effects of sandeel abundance or fishing effort on breeding productivity at a regional scale (Searle *et al.* 2023). • Annual return rates of adult razorbill (a possible surrogate of survival rate) and colony population size on the Isle of May positively correlated with sandeel total stock biomass (McGregor 2022). • Logical biological basis, given importance of sandeel in diet and dependence on forage fish as prey, together with evidence that limiting fishing effort on forage fish stocks is the most effective measure for increasing those stocks (Lindegren *et al.* 2018).				
	Puffin	**Moderate** • No evidence of positive effects of closure of a part of the East Scotland sandeel fishery on breeding productivity at Isle of May (Searle *et al*. 2023). • Little evidence (weak and statistically non-significant relationship) that breeding productivity on the Isle of May increases with the proportion of sandeel in the chick diet (although composition of chick diet is linked to measures of sandeel abundance) (Searle *et al*. 2023). • Limited evidence (weak and statistically non-significant relationship) for positive effects of sandeel abundance (and no evidence for effects of fishing effort) on breeding productivity at a regional scale (Searle *et al*. 2023).	Yes	High (Tiers 1 or 2 of compensation definition is met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		• Annual return rates of adult puffin (a possible surrogate of survival rate) on the Isle of May positively correlated with sandeel total stock biomass (McGregor 2022). • Marked declines in breeding puffin populations in Shetland associated with the collapse of the sandeel stock in Shetland – e.g. as on Fair Isle, where studies demonstrate that the decline was associated with substantive (and coincident) decreases in breeding productivity and in the quantities of fish prey brought ashore by breeding adults (Furness 2021a, Miles *et al*. 2015). • Evidence that overwinter survival in puffins may be linked to availability of forage fish (with sandeels identified as an important winter prey in some populations at least) (Harris *et al*. 2015, Glew *et al*. 2019). • Logical biological basis, given evidence of dependence on sandeel as prey and apparent difficulty in switching to other prey (in some populations at least), together with evidence that limiting fishing effort on forage fish stocks is the most effective measure for increasing those stocks (Lindegren *et al*. 2018).				
	Other seabird species	**Moderate** • Evidence that several other UK SPA seabird species may benefit from sandeel fishery closures, with potential benefits in terms of both breeding and wintering populations (e.g. red-throated diver (both SPA breeding and non-breeding populations), fulmar, Arctic and great skua and tern species) (Furness 2013, Furness 2021a).	Yes	Moderate (Tiers 3 or 4 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		• Evidence for such effects is strongest in relation to populations of such species breeding in Shetland and Orkney, most notably Arctic tern and Arctic skua (Furness 2021a). Given the substantive declines that have occurred in such SPA populations, the potential extent of the compensation is also large (should the measure be successful).				
	Ecosystem resilience / wider ecosystem benefits	**Strong** • Importance of sandeel (and more generally forage fish) as key prey for seabirds and other taxa. • Evidence for effects of fishing effort on sandeel stock biomass (Frederiksen *et al.* 2008, Carroll *et al.* 2017, Lindegren *et al*. 2018, Furness 2021a), albeit that there is risk that sandeel stock recovery may be limited by other environmental factors following release from fishing pressures (e.g. climate change effects or predation pressure on the populations that have been reduced by heavy fishing pressure).	Yes	Low (Tier 5 of compensation definition met)		
Other fisheries – closures / no-take zones / sustainable management	**Kittiwake**	**Weak** • No direct evidence for effects. • Sprat can be an important breeding season prey item at some UK east coast colonies (including small colonies in the upper Firth of Forth), so benefits at such colonies may arise by establishing sprat no-take zones (Furness 2021a). • Clupeids may also be important prey in the breeding season (Wanless *et al.*. 2018).	No (unlikely to have sufficiently widescale effects if limited to sprat fisheries)	High (Tiers 1 or 2 of compensation definition is met)	• Largely outwith developers' control • Implementation by government may negate it as compensation • Greater potential for direct effect on Scottish fishing	Medium / long term (5 – 10 years) • Time required for response and recovery in fish populations • If main effects on seabird species are via increased productivity,
	Gannet	**Weak** • Gannets take a wide range of fish taxa and size classes from sandeel to adult mackerel	Yes	High (Tiers 1 or 2 of compensation		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		• Gannets are competitive in obtaining discards from fisheries vessels and are likely to be a beneficiary of fisheries. • Rates of increase in gannet breeding numbers showed no apparent decline during period when herring and mackerel stocks in UK waters were depleted (1960s – 1980s) (Furness 2013).		definition is met)	industry than for sandeel closure. • Uncertainty in equating compensation benefit with predicted impacts (from OWFs) on seabird populations.	time required for response in adult breeding number at SPA colonies (likely 4 – 6 years depending on species although less for some 'other' seabird species not identified as key species for strategic compensation).
	Guillemot	**Weak** • No direct evidence for effects. • Sprat is the main other fishery previously identified as potentially important to guillemot, with such fisheries considered to be currently limited to localised activity off west coast of Scotland and English Channel (Furness 2013). • Clupeids may also be important prey in the breeding season (Wanless *et al*. 2018).	No (unlikely to have sufficiently widescale effects if limited to sprat fisheries)	High (Tiers 1 or 2 of compensation definition is met)		
	Razorbill	**Weak** • No direct evidence for effects. • Sprat is the main other fishery previously identified as potentially important to guillemot, with such fisheries considered to be currently limited to localised activity off west coast of Scotland and English Channel (Furness 2013). • Clupeids may also be important prey in the breeding season (Wanless *et al.* 2018).	No (unlikely to have sufficiently widescale effects if limited to sprat fisheries)	High (Tiers 1 or 2 of compensation definition is met)		
	Puffin	**Weak** • No direct evidence for effects. • Clupeids may also be important prey in the breeding season (Wanless *et al.* 2018). • In some regions at least (e.g. Shetland), puffin appear to be a sandeel specialist to a greater degree than guillemot and razorbill (Furness 2021a). This may mean that there is less potential	No	High (Tiers 1 or 2 of compensation definition is met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		benefits from management of other fisheries than for these other species.				
	Other seabird species	**Weak** • Closures, no-take zones or other forms of sustainable management of other fisheries seem likely to produce benefits for at least some other UK SPA seabird species (Furness 2021a). • Direct evidence for effects is scarce although declines and subsequent recovery of the common tern population in the Firth of Forth was associated with the operation and subsequent collapse of the herring fishery (Jennings *et al.* 2012).	Unlikely	Moderate (Tiers 3 or 4 of compensation definition met)		
	Ecosystem resilience / wider ecosystem benefits	**Moderate** • Likely that recovery of fish stocks following fisheries closures or introduction of no-take zones / forms of sustainable management suggest such action would result in wider ecosystem benefits.	Yes	Low (Tier 5 of compensation definition met)		
Mammalian predator control / management	**Kittiwake**	**Weak** • Few recorded instances of mammalian predation affecting nesting kittiwakes although breeding productivity (in some years at least) was considered to be reduced due predation by brown rats and cats at colonies on the Isles of Scilly, by mink at St Abb's Head and by foxes at Lowestoft (Furness 2013). • Little evidence of benefits from rat eradication programmes at seabird colonies. • Considered likely that many colonies are inaccessible to many mammalian predators (Furness 2021a).	No	High (Tiers 1 or 2 of compensation definition met)	• Difficulty of demonstrating predators are having detrimental effects on colony populations • Difficulty of maintaining predator free colonies after initial eradication (particularly if	Short / long term (2 – 10 years) • Time required to instigate effective predator control / management • If main effects are via increased breeding productivity in terms of numbers of
	Gannet	**Weak**	No	High (Tiers 1 or 2 of		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		• Existing reviews of potential compensation measures provide no evidence that mammalian predation is a problem at UK gannet colonies (Furness 2013, Furness 2021a, McGregor *et al.* 2021).		compensation definition met)	not small island colonies and / or with human habitation) • Applying control measures without effects on non-target species. • In some situations, it is possible that mammalian predator control may be considered part of the SPA site management, so not available as compensation (at any such sites) because it will not represent 'additionality'.	chicks fledged per pair, time required for response in adult breeding numbers at SPA colonies following effective management likely to be 4 – 6 years depending on species (although less for some 'other' seabird species not identified as key species for strategic compensation). • Shorter timescales for response are possible if the management enables colonisation of additional nesting habitat.
	Guillemot	**Moderate** • Evidence that rat eradication resulted in increased breeding numbers on Lundy but not on Canna (with effects on Lundy apparently due to colonisation of previously unoccupied habitat where nests would have been vulnerable to predation) (Furness 2021a). • Rat eradication on islands in the Channel Islands considered a viable compensatory measure for Hornsea Four (DESNZ 2023a). Also proposed on Handa but doubts over evidence to support likely efficacy (Skeate 2022, NatureScot 2023). • Rats present on several offshore islands with breeding guillemots, whilst other mammalian predators may also have effects at some colonies (Stanbury *et al.* 2017, Ørsted 2022).	No (Likely too few islands on which predator eradication would benefit breeding populations)	High (Tiers 1 or 2 of compensation definition met)		
	Razorbill	**Moderate** • Evidence that rat eradication resulted in increased breeding numbers on Lundy (apparently due to colonisation of previously unoccupied habitat where nests would have been vulnerable to predation) (Furness 2021a). Comparison to nearby colonies' smaller population increases, indicates rat eradication has benefited Lundy population (DESNZ 2023a). • Breeding abundance on Canna increased in the short-term (2006 and 2007) following eradication of brown rats (and has more recently increased	No (Likely too few islands on which predator eradication would benefit breeding populations)	High (Tiers 1 or 2 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		again after approximately 10 years of stability), but breeding success remained low, attributed to role of low food supply (DESNZ 2023a). • Rat eradication on islands in the Channel Islands considered as a "without prejudice" compensatory measure for Hornsea Four (DESNZ 2023a). • NatureScot (2023) acknowledge evidence of potential benefits to razorbill of a previous rat eradication on Handa (due to enabling birds to occupy boulder fields accessible to rats, as opposed to being restricted to cliffs), and of potential for benefits of black rat eradication on Inchcolm if applied alongside biosecurity and management of habitat (e.g. tree mallow removal). • Furness (2013) notes that islands with rats present represent a very small proportion of UK razorbill colonies, although other mammalian predators may also have effects at some colonies (Ørsted 2022).				
	Puffin	**Strong** • Clear evidence that rat eradication from offshore islands can benefit breeding puffin populations, with eradication from Lundy, Handa and Canna resulting in increases in breeding puffin populations (Booker *et al.* 2019, Luxmoore *et al.* 2019). • Puffins recolonised Ailsa Craig following rat eradication (Zonfrillo 2002, 2007). • Rats and other mammalian predators (e.g. ferret) still present on several offshore islands with breeding puffins e.g. Rathlin Island.	No (Likely too few islands on which predator eradication would benefit breeding populations)	High (Tiers 1 or 2 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
	Other seabird species	**Strong** • Substantial evidence of negative effects of mammalian predators on the breeding populations of a range of other SPA seabird species including Manx shearwater, European storm petrel, fulmar, shag, and several gull and tern species (e.g. as reviewed in Furness 2021a). • Rat eradication programmes on various islands have been associated with positive responses in several such species (e.g. Manx shearwater, European storm petrel), whilst measures to control (or exclude from colonies) predators such as foxes and mink are often associated with beneficial effects on breeding gull and / or tern populations (e.g. Furness 2021a). • Considered that such management could allow recolonisation of some islands by Leach's storm petrel (Furness 2021a). • Likely to be considerable potential for benefits to SPA seabird species (e.g. Furness 2021a).	Yes	Moderate (Tiers 3 or 4 of compensation definition met)		
	Ecosystem resilience / wider ecosystem benefits	**Strong** • Likely high potential to increase ecosystem resilience via increases in breeding productivity of a range of seabird species at several colonies, potential increases in the number of breeding colonies for several species and potentially some expansion of UK breeding range for some species.	Yes	Moderate – High (on basis that the benefits to ecosystem resilience are are via effects on SPA seabird populations, Tiers 3 or 4 of compensation definition met,		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
				and potentially also Tiers 1 or 2)		
Avian predator control / management (e.g. diversionary feeding, deterrents)	**Kittiwake**	**Moderate** • Few instances of recorded avian predation on adult kittiwakes (with exception of predation by great skuas) although raptors (notably peregrine falcons) are known predators of seabirds, including of other gull species and terns (e.g. Sutton and Loram 2021, Dixon and Drewitt 2018). • Evidence of great skua predation affecting adult survival rates and being associated with colony declines. Any such effects limited to Northern Isles and possibly other parts of N and NW Scotland. • Larger gull species may also predate kittiwake eggs and chicks (as recorded at the Farne Islands and Ailsa Craig) and great skuas and peregrine falcons have been recorded predating large chicks or fledglings at a small number of colonies (Furness 2103). In some instances at least, such predation by avian predators may be associated with poor nest attendance by adults due to low food availability. • Logical biological basis	No	High (Tier 2 of compensation definition met)	• Difficulty of demonstrating such effects and identifying affected colonies • Identifying effective methods of control given the predators may be protected species and (for great skuas and large gulls) the predation is often by specific individuals from large colonies. • In some situations, it is possible that such management may be considered part of the SPA site management, so not available as	Short / long term (2 – 10 years) • Time required to instigate effective predator control / management • If main effects via increased breeding productivity, time required for response in adult breeding numbers at SPA colonies following effective management likely to be 4 – 6 years depending on species (although less for some 'other' seabird species not identified as key species for
	Gannet	**Weak** • Evidence from Norway that harassment (and presumably at least the potential for predation on the breeding adults and large chicks) by white-tailed eagles has negatively affected some colonies. Given the increasing white-tailed eagle population, it is possible such effects may also occur in Scotland in the future.	No	High (Tier 2 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
	Guillemot	**Weak** • Not identified as a potential compensation approach in previous reviews of potential compensatory measures (e.g. Furness 2013, Furness 2021a, McGregor *et al*. 2022). • However, predation of eggs by ravens, crows, gulls and skuas is considered to be widespread, whilst fledglings and some nestlings are taken by large gulls and skuas (Furness 2021a). • Logical biological basis	No	High (Tier 2 of compensation definition met)	compensation (at any such sites) because it will not represent 'additionality'	strategic compensation). • If main effects via increased adult survival rates, response in adult breeding numbers at SPA likely to be faster.
	Razorbill	**Weak** • Not identified as a potential compensation approach in previous reviews of potential compensatory measures (e.g. Furness 2013, Furness 2021a, McGregor *et al.* 2022). • However, predation of eggs by ravens, crows, gulls and skuas is considered to be widespread, whilst fledglings and some nestlings are taken by large gulls and skuas (Furness 2021a). • Nests on more open ledges had lower success, most likely due to avian predation (Furness 2013). • Logical biological basis	No	High (Tier 2 of compensation definition met)		
	Puffin	**Moderate** • On the Isle of May, increases in great black-backed gull numbers are associated with increased predation of puffins (Langlois Lopez *et al.* 2023), whilst reducing the density of breeding herring and lesser black-backed gulls nests has been linked to an increase in recruitment rate of puffins to the breeding colony (Finney *et al.* 2003). • Puffins breeding in gull-free habitat on the Isle of May provisioned their chicks at a higher rate and	No	High (Tiers 1 or 2 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		had a lower risk of kleptoparasitism than puffins breeding in gull-occupied habitat, although there was no associated significant difference chick growth or survival (Finney *et al.* 2001). • Puffins are also subject to kleptoparasitism from Arctic skuas (Jones 2002) and predation by great skuas (Votier *et al.* 2004).				
	Other seabird species	**Strong** • Exclusion of large gulls highly likely to improve the conservation status of common tern (and may also do so for Sandwich tern although there is a lack of clear evidence for widescale benefits) (Furness 2013). • Great skuas appeared to have a negative impact on a range of seabird populations at Hermaness (Votier *et al*. 2004). Also, exclusion of great skuas from around Arctic skua colonies may benefit Arctic skua breeding productivity (although this in itself may not be sufficient to enable population recovery, given that Arctic skua populations are also strongly affected by declines in sandeel populations). • Evidence for diversionary feeding of kestrels reducing predation of little tern chicks (Smart and Amar 2018). • Avian predation has been implicated in declines of Leach's storm petrels at some colonies (Furness 2021a).	No	Moderate (Tiers 3 or 4 of compensation definition met)		
	Ecosystem resilience / wider ecosystem benefits	**Moderate** • Possible potential to increase ecosystem resilience via increases in breeding productivity of a range of seabird species at several colonies.	No	Moderate – High (On basis that the benefits to ecosystem		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
				resilience are via effects on SPA seabird populations, Tiers 3 or 4 of compensation definition met, and potentially also Tiers 1 or 2)		
Establish new colonies at suitable <u>natural</u> sites	**Kittiwake**	**None** • No known evidence for this (which is consistent with the fact that kittiwake populations are declining across much of their UK range, and particularly in northeast Scotland.	No	N/A	• N/A – as no indication of importance.	N/A
	Gannet	**Weak** • No published records of northern gannet being attracted to colonise a specific location but Australasian gannet has been attracted to a new natural site using social attractants (Sawyer *et al.* 2013). Some other previous attempts to establish new colonies (both for Australasian and northern gannet) have failed (Furness 2013). • Would only provide compensation if nest-site availability is limiting breeding numbers at existing colonies and / or if breeding productivity is higher at new colonies. The former is not considered likely at most UK colonies (with the Bass Rock being a possible exception) whilst no evidence is known to be available to support the latter (although it is feasible due to density dependent effects).	Yes (dependent on extent (if at all) to which (i) nest-sites are limiting at existing colonies and (ii) breeding productivity at newly established colonies is increased relative to that at SPA colonies)	High (Tier 2 of compensation definition met)	• Ensuring occupation and colonisation of new site, noting that uncertainty over the efficacy of social attractants including decoys and sound lures has previously been highlighted (Furness 2013) • Potential negative effects on other seabird species as	Medium / long term (4 – 10 years), given that colonisation is unlikely to be immediate and a number of years following initial colonisation may be required for colony growth.

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
					gannets may displace them from their nest-sites.	
	Guillemot	**Weak** • No known evidence for this in UK. Examples of being attracted to colonise natural nest sites through acoustic/decoy social attractants limited to Pacific, where nesting preferences can differ - e.g. clifftop nesting under trees (Parker *et al.* 2007).	No	N/A	• N/A – as no indication of importance.	N/A
	Razorbill	**Weak** • No known evidence for this. A relatively small number of birds were recorded alongside nesting kittiwakes on an offshore oil platform in UK waters in the southern North Sea but these were not confirmed as nesting (Ørsted 2021a).	No	N/A		
	Puffin	**Weak** • Evidence of limited, early, success in using decoys along with sound recordings to attract breeding puffins to recolonise the Calf of Man following rat eradication, and to achieve first known colonisation of the Copeland Islands in Northern Ireland (https://manxnationalheritage.im/news/puffins-return-to-the-calf-of-man/, https://www.belfasttelegraph.co.uk/news/northern-ireland/experts-sell-the-perfect-dummy-and-lure-puffins-to-copelands/31529811.html). • Similar methods, combined with translocation and hand-rearing of chicks, used to achieve recolonisation of the Maine Islands, USA, from which breeding puffins eradicated by hunting in	No	High (Tier 2 of compensation definition met)	• Ensuring colonisation of new colony, noting that uncertainty over the efficacy of social attractants including decoys and sound lures. • Potentially resource intensive if use of decoys and sound lures is	Medium / long term (4 – 10 years), given that colonisation is unlikely to be immediate and a number of years following initial colonisation may be required for colony growth.

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		the late 1800s (https://ocean.si.edu/ocean-life/seabirds/how-puffin-returned-eastern-egg-rock).			not sufficient, and translocation of chicks is required (as for the Maine Islands puffin example).	
	Other seabird species	**Moderate** • Habitat management at suitable sites (eg. lagoons and islands) in suitable locations can provide the potential for establishment of new gull and tern colonies, as can management to restore suitable conditions (e.g. in terms of predation, human disturbance, habitat and flood prevention) at historical sites that have been deserted (e.g. Burgess and Hirons 1992, Furness 2013, 2021).	Unlikely	Moderate (Tiers 3 or 4 of compensation definition met)		
	Ecosystem resilience / wider ecosystem benefits	**Weak** • Potential to increase ecosystem resilience via increases in the number of breeding colonies, and potentially UK breeding range, for those species for which the measure is feasible.	No	Moderate – High (on basis that the benefits to ecosystem resilience are via effects on SPA seabird populations, Tiers 3 or 4 of compensation definition met, and potentially also Tier 2).		
Provision of artificial nest sites	**Kittiwake**	**Moderate** • Some basis from known biology that breeding productivity can be higher at artificial sites, from which a proportion of the resulting fledglings are likely to recruit into SPA populations. • Benefits of additional coastal / onshore nest sites seem unlikely in east Scotland given natural nest	Unlikely but some potential for this dependent on efficacy of	High (Tiers 1 or 2 of compensation definition met)	• Uncertainty in ensuring colonisation of artificial nest sites, particularly if not	Medium term (4 – 6 years) • Time required for sufficient colonisation to occur.

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		sites are abundant and populations have declined (although see Furness 2021a). • Kittiwakes are known to use artificial nesting structures and have been documented as colonising structures at various locations away from existing colonies, including offshore oil platforms (Furness 2021a, Ørsted 2021a). No evidence appears to be available on colonisation of offshore structures in waters off the east coast of Scotland, where kittiwake populations have undergone marked declines and where nesting sites will not be limiting. • Kittiwakes nesting on offshore artificial nesting structures in Norway had higher breeding productivity than those using natural coastal nest sites (Furness 2021a), which may be due to benefits of greater proximity to foraging areas. Any such benefits may potentially be offset by greater risks of collision mortality.	offshore nest sites		adjacent to existing colonies • High costs and logistical difficulties of constructing / maintaining structures if in offshore locations • If offshore, undertaking the monitoring that is required to demonstrate delivery of compensation	• If main effects are via increased productivity (in terms of either numbers of chicks fledged per pair and / or number of pairs producing fledged chicks), then time required for response in adult breeding numbers at SPA colonies (likely 4 – 6 years depending on species).
	Gannet	**Weak** • No published records of northern gannet nesting on artificial structures although Australasian gannet has naturally colonised and bred on (non-purpose built) artificial structures (e.g. National Trust (Au) (2023)). However, it seems likely that suitable artificial nest sites would be colonised if provided at any existing colonies where natural sites are limiting. • Would only provide compensation if nest-site availability is limiting breeding numbers at existing colonies and / or if use of artificial nest-sites increased breeding productivity. The former is not considered likely at most UK colonies (with the	Yes (dependent on extent (if at all) to which (i) nest-sites are limiting at existing colonies and (ii) breeding productivity at artificial nest-sites is increased relative to	High (Tiers 1 or 2 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		Bass Rock being a possible exception) whilst there is no evidence to support the latter. • If located offshore, could be potential benefits of greater proximity to foraging areas (which could potentially lead to higher breeding productivity) but this may be offset by greater risks of collision mortality.	natural nest-sites)			
	Guillemot	**Weak** • Limited evidence of using artificial nest sites (Hentati-Sundberg *et al.* 2012, Ørsted 2021a), with limited examples of being attracted to colonise natural nest sites through acoustic/decoy social attractants (Parker *et al.* 2007), or benefitting from artificial additions to colony sites (Parrish & Paine 1996) (with these examples in Pacific where nesting preferences can differ - e.g. clifftop nesting under trees). • Evidence (from UK waters at least) for nesting on offshore oil platforms appears to be limited to the occurrence of c.100 birds on a single platform, with some of these birds showing behaviour indicative of possible breeding (Ørsted 2021a). • No evidence that use of artificial structures would be associated with higher breeding productivity but, if located offshore, could be potential benefits of greater proximity to foraging areas (which could potentially lead to higher breeding productivity).	Yes (dependent on extent (if at all) to which (i) nest-sites are limiting at existing colonies and (ii) breeding productivity at artificial nest-sites is increased relative to natural nest-sites)	High (Tiers 1 or 2 of compensation definition met)		
	Razorbill	**Weak** • Known evidence of using artificial nest sites limited to use of nest boxes within an existing colony in the Gulf of St Lawrence (Petalas *et al.* 2021), whilst relatively small numbers of birds have been recorded alongside nesting kittiwakes	Yes (dependent on extent (if at all) to which (i) nest-sites are limiting at	High (Tiers 1 or 2 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		on an offshore oil platform in UK waters but these were not confirmed as nesting (Ørsted 2021a). • No evidence that use of artificial structures would be associated with higher breeding productivity but, if located offshore, could be potential benefits of greater proximity to foraging areas (which could potentially lead to higher breeding productivity).	existing colonies and (ii) breeding productivity at artificial nest-sites is increased relative to natural nest-sites)			
	Puffin	**Weak** • Very limited evidence of use, with artificial burrows currently being trialled on Jersey (http://www.birdsontheedge.org/2020/03/16/a-shire-for-jerseys-puffins/). • No evidence that use of artificial structures would be associated with higher breeding productivity and probably difficult to create suitable structures in offshore location where there could be potential benefits of greater proximity to foraging areas (which could potentially lead to higher breeding productivity).	No	High (Tiers 1 or 2 of compensation definition met)		
	Other seabird species	**Strong** • Creation of 'islands' and use of rafts and artificial structures to create tern nesting habitat is a long-established management technique, particularly for common terns (Burgess & Hirons, 1992) which have been recorded nesting on artificial rafts at several sites (e.g. Langstone Harbour, Blashford Lakes, Blithfield Reservoir and Rutland Water). • Artificial breeding platforms may be an effective conservation measure for common terns where access to breeding habitat is limited but good	Yes (dependent on extent (if at all) to which (i) nest-sites are limiting at existing colonies and (ii) breeding productivity at artificial nest-	Moderate (Tiers 3 or 4 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		foraging habitat exists close by (Manikowska-Ślepowrońska *et al.* 2022). • Likely that flat-roofed structures could be used to provide nest sites for large gull species. • Diver species may also benefit from provision of nesting rafts, with use of rafts at black-throated diver territories in Scotland improving breeding productivity by a factor of 2.7, although this level of improvement declined over the longer-term, possibly as a result of maintenance requirements of the rafts (Hancock 2000, ap Rheinallt *et al*. 2007). Artificial nest sites also found to increase the breeding success of red-throated diver in Scotland and Finland (Merrie 1986, ap Rheinallt *et al*. 2007, Nummi *et al.* 2013).	sites is increased relative to natural nest			
	Ecosystem resilience / wider ecosystem benefits	**Moderate** • Potential to increase ecosystem resilience via increases in the size of breeding colonies, and potentially breeding productivity, for those species for which the measure is feasible.	Yes (but see caveats as identified for species above)	Moderate – High (On basis that the benefits to ecosystem resilience are via effects on SPA seabird populations, Tiers 3 or 4 of compensation definition met, and potentially also Tier 2).		
Reduce anthropogenic	**Kittiwake**	**Moderate** • Evidence for negative effects of visitor pressure on nesting success of the colony at the St Abb's Head NNR (Beale and Monaghan 2004). Given	No (limited to colonies where visitor access	High (Tiers 1 or 2 of compensation definition met)	• May be difficult / complicated to demonstrate	Medium term (4 – 6 years) with main effects likely to be via increased

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
disturbance at colonies		most kittiwake colonies have little, or no, visitor access and are likely to be subject to little human disturbance, such effects are likely to be restricted to a small number of colonies. • Recreational use of Unmanned Aerial Vehicles (UAVs) shown to disturb birds from cliffs (but noting that UAVs can be used effectively, with little or no (apparent) disturbance, for monitoring purposes at seabird colonies (Spaans *et al.* 2018, S. Zisman, pers. comm.)	frequent and (likely) relatively heavy)		occurrence of such effects • Required management solutions may conflict with basic requirements of public access and value obtained by showing birds to people. • Where associated with visitor access, likely to be considered as part of the SPA site management, so not available as compensation because it will not represent 'additionality'.	productivity, so requiring time for response in adult breeding numbers at SPA colonies (likely 4 – 6 years depending on species although less for some 'other' seabird species not identified as key species for strategic compensation).
	Gannet	**Moderate** • Evidence that visitor disturbance may cause increased chick mortality at the Bass Rock colony (with this suggested to result in the deaths of approximately 40 chick per year – DTA Ecology 2020). • Effects local and limited to situations where visitor access occurs in close proximity to nesting birds, which is rare at gannet colonies (and within the UK may be limited to the Bass Rock).	No	High (Tiers 1 or 2 of compensation definition met)		
	Guillemot	**Moderate** • Evidence for negative effects of visitor pressure on nesting success of the colony at the St Abb's Head NNR (Beale and Monaghan 2004). Given most kittiwake colonies have little, or no, visitor access and are likely to be subject to little human disturbance, such effects are likely to be restricted to a small number of colonies.	No (limited to colonies where visitor access frequent and (likely) relatively heavy)	High (Tiers 1 or 2 of compensation definition met)		
	Razorbill	**Weak** • No known evidence for this but feasible there could be situations analogous to those described above for kittiwake and guillemot.	No	High (Tiers 1 or 2 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
	Puffin	**Weak** • No known evidence for this but feasible there could be situations analogous to those described above for kittiwake and guillemot.	No	High (Tiers 1 or 2 of compensation definition met)		
	Other seabird species	**Moderate** • Nesting terns and divers are amongst the seabird species often considered most susceptible to the effects of human disturbance close to the nesting colonies / sites, with evidence that this can lead to breeding failure / reduce breeding productivity (e.g. Mitchell *et al.* 2004, Furness 2021a,b).	No	Moderate (Tiers 3 or 4 of compensation definition met)		
	Ecosystem resilience / wider ecosystem benefits	**Weak** • Benefits likely to be highly localised for most species, with limited potential to increase ecosystem resilience.	No	Moderate – High (on basis that the benefits to ecosystem resilience are via effects on SPA seabird populations, Tiers 3 or 4 of compensation definition met, and potentially also Tiers 1 and 2).		
Reduce anthropogenic disturbance at sea	**Kittiwake**	**Weak** • Little evidence that kittiwakes are particularly susceptible to vessel traffic or other sources of anthropogenic disturbance at sea (Furness *et al*. 2013).	No	High (Tier 2 of compensation definition met)	• May be difficult / complicated to demonstrate occurrence of any such effects	Unknown given lack of evidence for / understanding of potential mechanisms via

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		• No evidence that any such disturbance leads to potential population-level effects (e.g. via reduced annual survival or breeding productivity rates).			and challenging to identify how compensation benefit equates to predicted impacts (from OWFs) on seabird populations • Solutions to any such effects may be difficult / expensive to deploy (e.g. changes to shipping routes) and disproportionate to likely value gained.	which effects may manifest.
	Gannet	**Weak** • Little evidence that gannets are particularly susceptible to vessel traffic or other sources of anthropogenic disturbance at sea (Furness *et al*. 2013). • No evidence that any such disturbance leads to potential population-level effects (e.g. via reduced annual survival or breeding productivity rates).	No	High (Tier 2 of compensation definition met)		
	Guillemot	**Weak** • Regarded as moderately sensitive to vessel traffic or other sources of anthropogenic disturbance at sea (Furness *et al*. 2013) and may be particularly so when with flightless young or during moult periods. • No evidence that any such disturbance leads to potential population-level effects (e.g. via reduced annual survival or breeding productivity rates).	No	High (Tier 2 of compensation definition met)		
	Razorbill	**Weak** • Regarded as moderately sensitive to vessel traffic or other sources of anthropogenic disturbance at sea (Furness *et al*. 2013) and may be particularly so when with flightless young or during moult periods. • No evidence that any such disturbance leads to potential population-level effects (e.g. via reduced annual survival or breeding productivity rates).	No	High (Tier 2 of compensation definition met)		
	Puffin	**Weak** • Little evidence that gannet are particularly susceptible to vessel traffic or other sources of	No	High (Tier 2 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	‘Proximity’ to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		anthropogenic disturbance at sea (Furness *et al.* 2013). • No evidence that any such disturbance leads to potential population-level effects (e.g. via reduced annual survival or breeding productivity rates).				
	Other seabird species	**Weak** • A small number of other SPA seabird species are considered to be particularly sensitive vessel traffic or other sources of anthropogenic disturbance at sea, most notably diver species in their wintering areas (Furness *et al.* 2013, Mendel *et al.* 2019). • No evidence that any such disturbance is likely to lead to potential population-level effects - e.g. via reduced annual survival or breeding productivity rates (Thompson *et al.* 2023).	No	Moderate (Tier 4 of compensation definition met)		
	Ecosystem resilience / wider ecosystem benefits	**Weak** • Little basis for proposing wider ecosystem benefits.	No	Low (Tier 5 of compensation definition met)		
Bycatch mitigation	**Kittiwake**	**Weak** • No evidence apparent for bycatch being important for this species, at least in UK waters (Furness 2013, Furness 2021a, Heath *et al.* 2017).	No	N/A	N/A – as no indication of importance	N/A
	Gannet	**Strong** • Gannet known to be subject to bycatch from fisheries in UK waters, as well as in EU and West African waters and so is an established source of direct mortality. • Annual bycatch for UK registered vessels estimated to be 25 – 764 birds, with bycatch in UK waters modelled to be higher in summer and in	Yes (at least if extended outside UK waters)	High (Tier 2 of compensation definition met)	• Bycatch in UK waters could potentially be addressed by fisheries mitigation, negating availability as a	Short / medium term (2 – 5 years)

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	‘Proximity’ to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		inshore Scottish waters (Bradbury *et al.* 2017, Miles *et al*. 2020). • Larger bycatch mortality seems likely to occur in the Bay of Biscay, the Atlantic Iberian waters and West African waters (McGregor *et al.* 2022). Bycatch in these waters may occur year-round (with immatures more likely to be taken in summer) and coincides with the main wintering areas for the UK breeding population.			compensation measure (although this has not happened yet). • Identification of methods that are proven to mitigate bycatch. • For bycatch outside UK waters need to confirm / demonstrate connectivity with UK breeding populations • Challenges of applying mitigation likely to be greater outside the UK, where there will be less regulation and monitoring (in some cases at least). • In relation to West Africa, bycatch mitigation may	

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
					potentially affect a subsistence resource.	
	Guillemot	**Moderate** • Guillemot ranked in top 10 species for rate and risk of bycatch in pelagic and benthic (gill-nets or trawl nets) and surface (long-line) fisheries (Bradbury *et al*. 2017), and represent majority of seabird bycatch in static net and midwater trawls with no observations in longline bycatch (Northridge *et al.* 2020). • Bycatch mortality estimated as 1600-2500 individuals/year (Northridge *et al*. 2020), with cessation of this impact predicted to lead to 1% increase in population size over 25 year period (Miles *et al*. 2020). • Relevant fisheries may be largely restricted to southern England with limited potential in terms of the compensation levels that can be delivered, and bycatch modelled to be concentrated in English Channel / Celtic Sea (noting that the static net fisheries operating off northeast Scotland use larger vessels which are not associated with guillemot bycatch – Northridge *et al.* 2020). • Considered a viable compensatory measure for Hornsea Four (DESNZ 2023a,b).	No	High (Tier 2 of compensation definition is met)	• Bycatch in UK waters could potentially be addressed by fisheries mitigation, negating availability as a compensation measure (although this has not happened yet). • Identification of methods that are proven to mitigate bycatch.	Short / medium term (2 – 5 years)
	Razorbill	**Weak** • Razorbill ranked in top 10 species for rate and risk of bycatch in pelagic and benthic (gill-nets or trawl nets) and surface (long-line) fisheries (Bradbury *et al.* 2017). • Observed bycatch mortality in static net and (lesser extent) midwater trawls, estimated as 100-	No	High (Tier 2 of compensation definition is met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		200 individuals/year, with cessation of this impact associated with a lower potential population effect that for guillemot (Miles *et al*. 2020, DESNZ 2023b). • Relevant fisheries may be largely restricted to southern England with limited potential in terms of the compensation levels that can be delivered, and bycatch modelled to be concentrated in English Channel / Celtic Sea (noting that the static net fisheries operating off northeast Scotland use larger vessels which are not associated with razorbill bycatch – Northridge *et al.* 2020). • Considered a viable without-prejudice compensatory measure for Hornsea Four (DESNZ 2023a,b).				
	Puffin	**None** • Not identified as a potential measure in previous reviews of options for compensation, and little indication that puffin may be at risk of bycatch mortality (Furness 2013, Furness 2021a, McGregor *et al*. 2022, Heath *et al.* 2017).	No	N/A		
	Other seabird species	**Moderate** • Long-line fishing in UK waters known to be a cause of bycatch mortality for fulmar and great skua, whilst great northern diver is also at risk particularly from set nets (Furness 2013, Furness 2021a). • Measures to reduce bycatch of fulmar and great northern diver could increase populations of these species, with the cessation of this impact in UK waters predicted to lead to a 7% increase in fulmar population size over 25 years and a >1% increase in the great northern diver population	Unlikely	Moderate (Tier 4 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		size over 25 years (Miles *et al.* 2020). Also, bycatch mortality of fulmars is likely to be considerably greater outside UK waters (Furness 2021a). • Great skua populations could also benefit from bycatch reduction, however more evidence is required if this is to be considered as a compensation measure for this species (Furness 2021a).				
	Ecosystem resilience / wider ecosystem benefits	**Weak** • Little basis for proposing wider ecosystem benefits.	No	Low (Tier 5 of compensation definition met)		
Reduction / cessation of illegal harvesting of birds	**Kittiwake**	**None** • Not identified as a potential measure in previous reviews of options for compensation, and no indication that UK kittiwake populations affected by this (Furness 2013, Furness 2021a, McGregor *et al.* 2022).	No	N/A	• N/A – as no indication of importance	N/A
	Gannet	**Moderate** • Illegal harvest of birds in west African waters considered likely to represent the highest level of anthropogenic additional mortality to gannets and may have increased in recent years (Furness 2021a).	Yes	High (Tier 2 of compensation definition met)	• Need to confirm / demonstrate connectivity with UK breeding populations. • Problems of applying required regulation and enforcement in West Africa. • Harvest appears to be associated	Short / medium term (2 – 5 years)

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
					with shipping large numbers of birds (of many species) to Asia for human consumption, so economic incentives may make control difficult to achieve in practice (irrespective of regulation).	
	Guillemot	**None** • Not identified as a potential measure in previous reviews of options for compensation, and no indication that UK guillemot populations affected by this (Furness 2013, Furness 2021a, McGregor *et al*. 2022).	No	N/A	• N/A – as no indication of importance	N/A
	Razorbill	**None** • Not identified as a potential measure in previous reviews of options for compensation, and no indication that UK razorbill populations affected by this (Furness 2013, Furness 2021a, McGregor *et al.* 2022).	No	N/A		
	Puffin	**None** • Not identified as a potential measure in previous reviews of options for compensation, and no indication that UK puffin populations affected by this (Furness 2013, Furness 2021a, McGregor *et al*. 2022).	No	N/A		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	‘Proximity’ to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
	Other seabird species	**Weak** • Furness (2021a) state that great skuas may still be subject to some illegal persecution although the extent of such activity has almost certainly declined. Action to reduce this activity is not identified as a potential compensation measure (reflecting the likely low levels that now occur). • Large gull species are also presumably also likely to be subject to some illegal persecution at some colonies.	No	Moderate (Tiers 3 or 4 of compensation definition met)	• The likely low levels of such activity may make it difficult to identify where it occurs.	Short / medium term (2 – 5 years)
	Ecosystem resilience / wider ecosystem benefits	**Weak** • Little basis for proposing wider ecosystem benefits.	No	Low (Tier 5 of compensation definition met)	N/A	N/A
Reduction / cessation of legal harvesting of eggs, chicks and / or adult birds	**Kittiwake**	**None** • Not considered relevant to UK populations	No	N/A	N/A – as no indication of importance	N/A
	Gannet	**Strong** • The harvest at the Sula Sgeir colony removes close to 2000 fully grown chicks annually, whilst further chick mortality may result from the associated disturbance at the colony. • Population modelling suggests that the harvest has reduced the population growth rate at Sula Sgeir, which has the lowest growth rate of any UK SPA colony (Trinder 2016, Furness 2021a). • Possible (small) reduction in growth rates of other colonies in region due to effects on natal emigration, resulting in Sula Sgeir potentially being a sink for these emigrants from other colonies (Trinder 2016).	No (although the likelihood of natal dispersal between colonies within a northeast Atlantic metapopulation means that other colonies within the North Sea region may	High (Tiers 1 or 2 of compensation definition met)	• Cultural and ‘political’ issues associated with the Sula Sgeir harvest which has not led to cessation on any previous review or grounds • For Faroese and Icelandic colonies, need to confirm / demonstrate	Medium term (5 – 6 years) given time required for response in adult breeding numbers at the Sula Sgeir colony (and potentially at other colonies).

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		• Harvests of chicks at colonies in the Faroes Islands and Iceland may also have effects on UK SPA colonies due to the likelihood of some natal dispersal between colonies within a northeast Atlantic meta-population.	benefit to some extent)		extent of connectivity with UK breeding populations. • Challenges involved in agreeing and implementing cessation or reduction in harvests at non-UK colonies	
	Guillemot	**None** • Not considered relevant to UK populations	No	N/A	N/A – as no indication of importance	N/A
	Razorbill	**None** • Not considered relevant to UK populations	No	N/A	N/A – as no indication of importance	N/A
	Puffin	**Weak** • Harvests of adult puffins at colonies in the Faroes Islands and Iceland may have effects on UK SPA colonies due to the likelihood of some natal dispersal between colonies within a northeast Atlantic meta-population. • Declines in puffin numbers in Iceland attributed to factors other than hunting (e.g. climate change, prey availability – Fayet *et al.* 2021) suggesting hunting may not be of major importance in limiting these populations and any benefits from cessation or reduction in hunting may be minor.	No	High (Tier 2 of compensation definition met)	• Need to confirm / demonstrate extent of connectivity with UK breeding populations. • Challenges involved in agreeing and implementing cessation or reduction in harvests at non-UK colonies	Short / medium term (2 – 5 years).

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
	Other seabird species	**Moderate** • Reduction or cessation in culling of herring and / or lesser black-backed gulls is highly likely to improve the conservation status of these species (Furness 2013)	Yes (depending on the number of locations at which culling occurs)	Moderate (Tiers 3 or 4 of compensation definition met)	• Increases in large gull populations may negatively impact other SPA seabird species (e.g. common tern).	Short / medium term (1 – 5 years).
	Ecosystem resilience / wider ecosystem benefits	**Weak** • Unlikely to be strong basis for proposing wider ecosystem benefits.	No	Low (Tier 5 of compensation definition met)	• N/A	N/A
Supplementary feeding / 'head-starting' chicks	**Kittiwake**	**Moderate** • Supplementary feeding of chicks is possible, at least at artificial nest sites designed to enable this. • Studies testing provision of food to breeding adults and chicks at Middleton Island, Alaska, demonstrated positive effects on breeding productivity (Gill *et al.* 2002). • 'Head-starting' would involve removal of the 2nd (and if present) 3rd laid eggs from nests and raising them artificially for release (noting that it is frequently only the 1st laid eggs in two and three eg clutches – Coulson 2011). Such methods can be used to boost recruitment into small and vulnerable populations and have been used on some wader species in the UK but not previously on seabird populations.	No	High (Tiers 1 or 2 of compensation definition met)	• For supplementary feeding, requirement for accessible colonies and development of a method for successfully delivering supplementary food to the nests or the construction of sufficient extent of artificial nest sites designed to facilitate this management.	Medium term (4 years) with effects on population size via increased breeding productivity, so requiring time for response in adult numbers at SPA colonies (likely 4 years for kittiwakes).

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
					• Risk of attracting competitor and potential predatory species (e.g. large gulls) to the colony if providing supplementary food. • For 'head-starting', it is likely that considerable resources would be required to produce sufficient numbers of additional young, whilst there may be complicating issues in releasing reared young into the wild.	
	Gannet	**None** • No known evidence for effects. Likely that supplementary feeding would benefit breeding performance in conditions of low prey availability but unlikely to be practical.	No	N/A	• N/A – as no indication of importance	N/A

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
	Guillemot	**None** • No known evidence for effects. Likely that supplementary feeding would benefit breeding performance in conditions of low prey availability but unlikely to be practical.	No	N/A	• N/A – as no indication of importance	N/A
	Razorbill	**None** • No known evidence for effects. Likely that supplementary feeding would benefit breeding performance in conditions of low prey availability but unlikely to be practical.	No	N/A	• N/A – as no indication of importance	N/A
	Puffin	**Moderate** • Studies to assess the effects of supplementary feeding of puffin chicks have found contrasting results but in several cases (e.g. in eastern Canada and on St Kilda) demonstrate that fed chicks have faster growth rates and / or heavier fledging weights than unfed controls (Fitzsimmons *et al.* 2017, Harris 1978). In other cases, provisioning of the chicks by the parent birds has declined in response to supplementary feeding, resulting in little difference in growth rates / fledging weights of fed and unfed groups (Cook and Hamer 1997). Such differences appear to reflect stronger effects of supplementary feeding in conditions of low forage fish abundance.	No	High (Tiers 1 or 2 of compensation definition met)	• Difficulty in demonstrating beneficial effects on breeding success and population growth rate • Supplementary feeding unlikely to be practical since puffin burrows are often inaccessible and disturbance when feeding is likely to detrimentally affect breeding success. • Effective supplementary	Medium term (5 years) with effects on population size via increased breeding productivity, so requiring time for response in adult numbers at SPA colonies (likely 5 years for puffin).

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
					feeding would likely be resource intensive due to the large numbers of birds that would have to be provisioned to obtain any population-level effect.	
	Other seabird species	**Strong** • Supplementary feeding has previously been identified as a possible compensation measure for both Arctic and great skua (Furness 2013, Furness 2021a). Large gulls will also take supplementary food that is provided at nesting colonies (Hiom *et al*. 1991). • Studies have demonstrated that supplementary feeding of Arctic skuas increases breeding productivity and annual return rates to the breeding grounds in declining populations in Shetland (Davis *et al.* 2005, Furness 2021a). • Supplementary feeding of Arctic skuas considered a potentially viable compensation measure due to the relatively small numbers breeding at SPA colonies (Furness 2021a). • Supplementary feeding of great skuas as an option for compensation considered to be impractical due to the large numbers of birds that would need to be involved and associated prohibitively high costs (Furness 2013).	Yes (if this was implemented across several SPAs)	Moderate (Tier 4 of compensation definition met)	• Labour-intensive if undertaken across multiple SPAs • Requirement for 'training period' for Arctic skuas to accept supplementary food • Risk of attracting non-target species which may be predators of Arctic skua eggs and chicks (or in the case of great skuas	Short / medium term (1 – 4 years), dependent on relative importance of responses in terms of breeding productivity and adult return / survival rates (noting that Arctic skuas generally start to breed at 4 years of age).

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		• Evidence that supplementary feeding of lesser black-backed gulls can benefit breeding success (with fed birds laying large eggs and clutches at some colonies) but such effects likely dependent on extent to which the birds are food limited (Hiom *et al*. 1991). Also, may be impractical option for compensation for same reasons as great skua.			possibly also of adult birds) • In the case of great skuas and large gulls, risk that increases in their populations would lead to detrimental effects on other seabird species.	
	Ecosystem resilience / wider ecosystem benefits	**Weak** • Unlikely to be strong basis for proposing wider ecosystem benefits.	No	Low (Tier 5 of compensation definition met)	• N/A	N/A
Management of supporting habitats at colony	**Kittiwake**	**None** • Other than via provision or maintenance of artificial nest sites (see above) it is unclear how management of supporting habitats at the colony could be undertaken to benefit nesting kittiwakes (given that the vast majority are cliff nesting)	No	N/A	N/A	N/A
	Gannet	**None** • No examples identified where specific habitat management required at UK gannet colonies UK.				
	Guillemot	**None** • Unclear how management of supporting habitats at the colony could be undertaken to benefit nesting guillemots, given that the vast majority are cliff nesting.				
	Razorbill	**None**				

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		• Unclear how management of supporting habitats at the colony could be undertaken to benefit nesting guillemots, given that the vast majority are cliff nesting.				
	Puffin	**Strong** • Access to nesting burrows can be affected by growth of tall, dense, vegetation. Notably, invasive tree mallow has colonised several islands in the Forth Islands SPA (e.g. Craigleith, Fidra, The Lamb), resulting in substantive declines in numbers of breeding puffin (particularly on Craigleith). Clearance of tree mallow on Craigleith has been associated with recovery in the puffin population (Van der Wal 2008, Anderson 2021).	No (problems associated with tree mallow spread at colonies appear largely limited to the islands on the Firth of Forth)	High (Tiers 1 or 2 of compensation definition met)	• Potentially labour intensive as management often required annually at colonies. • Such habitat management is likely to be considered as required site management at protected sites and therefore may not be available as compensation because it will not represent 'additionality'.	Short / medium term (1 – 5 years). Re-colonisation by nesting birds can be rapid following vegetation clearance.
	Other seabird species	**Strong** • Seabird species which nest on the ground (notably gulls and terns) can be affected by changes in vegetation, with some colonies dependent on active management to prevent succession and maintain suitable vegetation structure (Burgess and Hirons 1992, Mitchell *et al.* 2004, Forrester *et al.* 2007). Invasive tree mallow may have caused declines in a number of seabird species (other than puffin) nesting on the affected islands in the Forth Islands SPA (including herring gull, lesser black-backed gull and eider duck) (Van der Wal 2008). • Tern nest boxes have been used on the Isle of May to reduce predation by large gulls on the eggs and chicks of tern species on the Isle of May (Steel and Outram 2020).	likely	Moderate (Tiers 3 or 4 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
	Ecosystem resilience / wider ecosystem benefits	**Moderate** • Benefits likely to be relatively localised for those species that are affected, with limited potential to increase ecosystem resilience.		Low (Tier 5 of compensation definition met)		
Seagrass restoration and recovery	**Kittiwake Gannet Guillemot Razorbill Puffin Other seabird species**	**Weak** • Expansion of seagrass habitat likely to increase availability of nursery habitat for (at least) some seabird prey species and, more generally, the habitat would support productive fisheries (Ørsted 2021b). • However, no evidence relating to linkage between occurrence of seagrass habitats and foraging sites of seabirds and no direct evidence that expansion of seagrass habitat benefits populations.	Yes	High (Tiers 1 or 2 of compensation definition met) Moderate (Tiers 3 or 4 of compensation definition met)	• Removal of areas of sea previously used by other industries (e.g. fishing), so proposals and management initiatives may be contested. • Costs of monitoring success of the restoration and potential requirement for maintenance management or further intervention. • Ensure non-native seagrass species don't outcompete native species • High uncertainty in equating compensation	Long term (> 10 years). Time required to establish sufficiently large areas of habitat at sufficient number of locations, together with time required for response in seabird populations (which may arise via effects on breeding productivity, so involving time for this to manifest in breeding populations).
	Ecosystem resilience / wider ecosystem benefits	**Moderate** • Likely increase in ecosystem resilience via improved habitats for fish, invertebrates and algal epiphytes (Ørsted 2021b). Habitat is known to support juvenile fish of commercially important species, such as plaice, pollock, herring and sprat (Bertelli and Unsworth, 2014) • Carbon sequestration by seagrass. Concentration of organic carbon has been shown to be significantly higher in areas with higher seagrass coverage (Potouroglou *et al.* 2021). Increased sequestration has the potential to reduce impacts from climate change on a range of marine species (including seabirds). In turn, this may make species more resilient to other pressures, including negative impacts of OWFs.		Low (Tier 5 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		• Sediment stabilisation and reduced turbidity due to the presence of seagrass (Moksnes *et al*. 2021) will provide habitat conditions that are potentially suitable for a more diverse range of species, as opposed to a more limited range of species suited to highly turbid environments. Such increased diversity at these lower trophic levels may potentially benefit marine megafauna (including seabirds) via reduced competition for prey resources.			benefit with predicted impacts (from OWFs) on seabird populations, and may not be feasible to address this directly.	
Oyster restoration	**Kittiwake** **Gannet** **Guillemot** **Razorbill** **Puffin**	**Weak** • No direct evidence found to suggest that restoring oyster reefs benefits seabird populations in the UK. • Oysters are reef builders, creating habitat complexity that provides refugia, nesting habitat, and nursery grounds for juvenile fish (Preston *et al*. 2020), which in turn should increase the prey resource for seabirds. • Oyster reefs provide a food source and habitat for fish and crustaceans, which should also act to increase prey for seabirds. For example, 10m^2 of restored eastern oyster reef in the southeast US produces approximately 2.6 kg of fish and large crustaceans per year (Peterson *et al.* 2003).	Potentially expandable to sea lochs throughout much of Scotland but native oyster restoration projects currently limited to a small number of locations (e.g. Loch Craignish, Firth of Forth Dornoch Firth - Native Oyster Network). Therefore, requirement	High (Tiers 1 or 2 of compensation definition met)	• Costs of expanding scale of management • Provision of sufficient numbers of oysters to keep pace with restoration • Ensuring biosecurity e.g. preventing spread of disease caused by *Bonamia ostreae* which is a major driver of decline in remnant populations	Long term (> 10 years). Time required to establish sufficiently large areas of habitat at sufficient number of locations, together with time required for response in seabird populations (which may arise via effects on breeding productivity, so require time for this to manifest in breeding populations).
	Other seabird species			Moderate (Tiers 3 or 4 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
	Ecosystem resilience / wider ecosystem benefits	**Moderate to Strong** • Oyster restoration has potential to provide a range of ecosystem services through their bioengineering and reef building capabilities, which provide habitat for a range of taxa and increase biodiversity (left undisturbed they will form complex reef structures, which provide habitat and refuge for a diversity of organisms, such as juvenile fish, crabs, sea snails and sponges - Native Oyster Network). Additionally, they may act to reduce flood risk and coastal erosion potential (Thomas *et al.* 2022). • A single oyster can filter as much as 200 litres of water per day, meaning they are important regulators of water quality (Preston *et al.* 2020)	for considerable expansion of the scale and distribution of the management.	Low (Tier 5 of compensation definition met)	• Licencing/ permitting requirements • Costs of monitoring success of the restoration and potential requirement for maintenance management or further intervention. • High uncertainty in equating compensation benefit with predicted impacts (from OWFs) on seabird populations, and may not be feasible to address this directly.	
Extend protection of kelp beds beyond 17 MPAs where currently protected in Scottish waters	**Kittiwake Gannet Guillemot Razorbill Puffin**	**Weak** • Kelp beds support productive fisheries, including maintenance of nursery habitat for some seabird prey species (e.g. gadoids such as cod, pollock and saithe). Also provide habitat in which	Yes	High (Tiers 1 or 2 of compensation definition met)	• Many kelp beds threatened by large-scale harvesting for commercial	Potentially long term (> 10 years). Time required for protection to result in substantive increases in

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
	Other seabird species	predation on juvenile fish may be reduced (Gotceitas *et al*. 1995). • Provide habitat for molluscs and crustaceans which can be prey for some seabird species, including on occasion kittiwake (e.g. Cramp and Simmons 1983). • In Argentina, kelp beds were associated with higher seabird abundance, attributed to high prey species diversity (Raya Rey and Schiavini, 2000). In Norway, the higher prey abundance associated with kelp beds increased was linked to increased foraging efficiency of cormorants (Lorentsen *et al*. 2010).		Moderate (Tiers 3 or 4 of compensation definition met)	interests, so requirement to prevent harvesting which could lead to conflict with other industries. • Mechanism to enable protection against harvesting is unclear • Establishing or re-establishing kelp beds does not appear to be difficult and could be scaled up effectively (see Fredriksen *et al*. 2020) • High uncertainty in equating compensation benefit with predicted impacts (from OWFs) on seabird populations, and may not be	habitat, together with time required for response in seabird populations (which may arise via effects on breeding productivity, so require time for this to manifest in breeding populations).
	Ecosystem resilience / wider ecosystem benefits	**Moderate** • Likely increased coastal protection during periods of adverse weather • Provision of habitat for lower trophic level species and likely to lead to increased species diversity, which should increase ecosystem resilience in relation to effects such as rising sea temperature or disease. • Enhance nutrient cycling and carbon assimilation, storage and transfer. Kelp is the main pathway for long-term carbon storage in sediments and has the highest rate of carbon sequestration in Scottish marine habitats (Burrows *et al.* 2014). The kelp beds themselves do not store the carbon but dislodged/eroded plants are broken down and the carbon in detritus is sequestered in sediments or drift to deep sea environments where atmospheric exchange is no longer possible (Krumhansl and Scheibling 2012, Krause-Jensen and Duart 2016). Increased sequestration has the		Low (Tier 5 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		potential to reduce impacts from climate change on a range of marine species (including seabirds). In turn, this may make species more resilient to other pressures, including negative impacts of OWFs. • Should act to increase sediment stabilisation and reduce turbidity (Krause-Jensen and Duarte 2016), providing habitat conditions that are potentially suitable for a more diverse range of species, as opposed to a more limited range of species suited to highly turbid environments. Such increased diversity at these lower trophic levels may potentially benefit marine megafauna (including seabirds) via reduced competition for prey resources.			feasible to address this directly.	
Reduce anthropogenic pollution from agricultural runoff or discharge from waste treatment facilities	**Kittiwake** **Gannet** **Guillemot** **Razorbill** **Puffin**	**Weak** • Reduce potential for harmful algal toxins to bioaccumulate in lower trophic level species such as fish, which are preyed on by seabirds (Gibble and Hoover 2018). Increased contaminant concentrations from harmful algal toxins within seabirds is likely to affect overall fitness and may lead to reduction in reproductive success or increase mortality rates (Smith *et al*. 1999). • Increased primary productivity and algal blooms can limit capacity of feathers to be waterproof, negatively effecting foraging efficiency and increasing potential for mortality (Phillips *et al*. 2011).	Yes	High (Tiers 1 or 2 of compensation definition met)	• Practical challenges (and potentially high costs) in achieving reductions in runoff or discharges whether via collaboration with relevant industries (to achieve direct intervention) or habitat management approaches (due to likely	Potentially long term (> 10 years). Time required for implementation (e.g. if via creation of wetland environments), together with time required for response in seabird populations (which may arise via effects on breeding productivity, so require time for this to manifest in
	Other seabird species			Moderate (Tiers 3 or 4 of compensation definition met)		
	Ecosystem resilience / wider	**Moderate** • Temporary, high primary production due to agricultural run-off or discharge from waste treatment facilities affects local ecosystems		Low (Tier 5 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
	ecosystem benefits	through changes to function and stability (Gibble and Hoover 2018). • Implementation of methods to reduce the potential for agricultural run-off, such as creating wetland environments to facilitate sedimentation prior to polluted water entering the marine environment (Ockenden *et al*. 2014), is likely to have positive ecosystem-level effects.			large scale of requirement). • High uncertainty in equating compensation benefit with predicted impacts (from OWFs) on seabird populations, and may not be feasible to address this directly.	breeding populations).
Marine (plastic) Litter Removal – supporting Fishing for Litter project (https://fishingforlitter.org).	**Kittiwake**	**Weak** • Baak *et al.* (2020) found that 15% of Kittiwake had ingested plastic. Mortality from ingested plastic is unlikely to be high. • Entanglement deaths are recorded at colonies and in beached bird surveys (www.birdsanddebris.com)	Yes	High (Tiers 1 or 2 of compensation definition met)	• Requires equipment to extract waste material at sea (boats and nets) • Would require substantial expansion of operation to enable it to be undertaken on sufficient scale to make any significant impact. • Funding for current Fishing for Litter project	Short / medium term (3 – 5 years). Fishing for litter scheme already operational, expansion possible almost immediately but impacts on birds unlikely to be apparent for a number of years, although social / wider environmental impacts potentially rapid.
	Gannet	**Moderate** • Votier *et al.* (2011) quantify nest entanglement risk for gannet, with a mortality of 62 birds per year at one colony (Grassholm) but majority were chicks and so population level impacts were not expected. • Gannet also feature strongly in entangled beached bird records (e.g. SOTEAG data) and this frequently includes adult birds. These are likely to be additional to deaths at the colony from nest material entanglement.		High (Tiers 1 or 2 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		• Gannet appears to be one of the most frequently recorded species in the 'citizen science' reports of birds entangled in marine debris (see www.birdsanddebris.com). • Ingestion would be a risk for these birds but ingestion of plastic fragments probably only a minor risk. Sulids do feature in lists of fauna recorded as ingesting plastic (Kuhn *et al.* 2015).			from Marine Directorate • Open-ended • High uncertainty in equating compensation benefit with predicted impacts (from OWFs) on seabird populations, and may not be feasible to address this directly.	
	Guillemot Razorbill Puffin	**Weak** • Entanglement in discarded materials appears to be relatively rare in auks although entanglement in active fishing gear especially drift nets is more often reported. • Bond *et al.* (2013) found plastic ingestion in both common guillemots (*Uria aalge*) and thick-billed murres (*U. lomvia*) but Baak *et al.* (2020) found none in auks.		High (Tiers 1 or 2 of compensation definition met)		
	Other seabird species	**Moderate** • Entanglement risk is known in fulmar and is probably responsible for some deaths of this species. They are regularly recorded, in small numbers, as entanglement deaths in SOTEAG surveys for example. • Entanglement risk in some other species (e.g. Manx shearwater) does not appear to be high. • In terms of ingestion of plastic fragments, direct mortality can result and is likely to be under-recorded. Other fitness impacts may be expected to occur. It is mainly considered an issue for Procellariformes (due to their digestive system) but many species can be affected including gulls and terns (e.g. Laist 1997, Kuhn *et al.* 2015).		Moderate (Tiers 3 or 4 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		• Fulmar is known to be vulnerable to plastic ingestion and is used as a monitoring species for marine pollution impacts. • ME5209 – Using Northern fulmars as an ecological monitor of marine litter. The EcoQ% gives the percentage of fulmars having more than 0.1 g in the stomach. Target for this is 10%. Over 45% of fulmar from the UK North Sea coast over the 2017- 21 period had more than 0.1 g of plastic in the stomach (Kunh and van Franeker 2023). • Less detail is available on ingestion in most other seabird species but for Manx shearwater ingestion of plastic is likely to be widespread (Alley *et al.* 2022) due to the species biology and feeding ecology.				
	Ecosystem resilience / wider ecosystem benefits	**Moderate** • This compensation measure would address two main sources of negative impact of marine litter on seabirds – i.e. entanglement and ingestion. Entanglement especially of nylon monofilament, nylon netting and ropes and ingestion mainly of plastic bags, small hard plastics and plastic fragments and pellets. These along with impacts of microplastics (not addressed directly here but some of which comes from marine litter), are considered to have wider, general, negative impacts on the marine environment (e.g. Gola *et al.* 2021). • In terms of effects on marine species overall, Kuhn *et al*. 2015, building on work from Laist 1997, show that 557 marine species are affected by marine litter either through entanglement or ingestion. This includes all world species of turtle		Low (Tier 5 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
		and 81 or the 123 species of marine mammals. Since Laist 1997, strong increases in records were also listed for fish and invertebrates, groups that were previously not considered in detail. • In general, definitive proof of population-level effects is lacking even for those species thought to be most affected by entanglement due to considerable sampling constraints. However, it has been stated that, for marine mammals at least, conclusions suggesting low or insignificant population impacts should be treated with caution. Indeed, indirect analyses for some species offer convincing evidence that effects of entanglement are sufficient to have effects on populations (Kuhn *et al*. 2015). • In terms of wider environmental objectives, United Nations Sustainable Development goal 14 'Life below water' and MSFD descriptor 10 relate to marine litter.				

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
Biosecurity (prevention of threats via incursion response)	**Kittiwake Gannet Guillemot Razorbill Puffin**	**Strong** • Preventing a new invasive species from arriving on seabird breeding islands is considered one of the most cost-effective strategies to prevent harmful impacts to nesting seabirds (Holmes *et al.* 2023). • Fast response to a potential biosecurity incursion close to seabird islands (e.g. a shipwreck) can rapidly confirm the presence/absence of any rodents or other mammalian predators which may have come ashore. • The recent Biosecurity for LIFE project aimed to protect seabirds from invasive predators by producing biosecurity plans for all islands in the UK with SPAs that are designated for breeding seabirds, with plans involving surveillance mechanisms and Rapid Incursion Response Hubs (which are at now seven locations across the country (Biosecurity for LIFE website). • Given evidence for effects of mammalian predators (as well as other invasive species) on a range of seabird species (see above), effective biosecurity on seabird islands is likely to have major benefits to these populations.	Yes (e.g. Biodiversity for LIFE project covers all UK islands with SPAs designated for breeding seabirds)	High (Tiers 1 or 2 of compensation definition met)	• Potential logistical difficulties and high costs in providing rapid response to remote sites. • Given the recent Biodiversity for LIFE project, it is necessary to identify biosecurity measures and strategies that are additional to what has been implemented already.	Short term as Rapid response to biosecurity incursion would neutralise potential threat posed by invasive species to breeding seabird colonies
	Other seabird species			Moderate (Tiers 3 or 4 of compensation definition met)		
	Ecosystem resilience / wider	**Moderate**		Low (Tier 5 of compensation definition met)		

Measure	Attribute	Evidence-basis for positive effects	Strategic and regional scale	'Proximity' to like-for-like compensation (on basis the measure has a population-level effect)	Main issues affecting feasibility of implementing	Timescales from implementation to response (in terms population sizes at breeding colonies)
	ecosystem benefits	• Prevention of invasive species (whether plant or animal) likely to provide wider ecosystem benefits to affected islands. • Likely high potential to increase resilience by playing key role in maintaining extent of breeding range and numbers of breeding colonies of UK populations of several seabird species.				

Appendix A references

Alley *et al.* (2022) *Seabird* **34.**

Anderson (2021) Status of the Tree Mallow Seedbank on Craigleith in 2021.

Baak *et al.* (2020) Plastic ingestion by four seabird species in the Canadian Arctic: Comparisons across species and time. *Mar Pollut Bull*. **158**:111386. Doi: 10.1016/j.marpolbul.2020.111386. Epub 2020 Jun 18. PMID: 32568085

Bertelli and Unsworth (2014) Protecting the hand that feeds us: Seagrass (*Zostera marina*) serves as commercial juvenile fish habitat. *Marine Pollution Bulletin*, **83**, 425-429.

Bond *et al.* (2013) Ingestion of plastic marine debris by common and thick-billed murres in the northwestern Atlantci from 1985 to 2012. *Marine Poluution Bulletin*, **77**, 192-195.

Booker *et al.* (2019) Seabird recovery on Lundy: Population change in Manx shearwaters and other seabirds in response to the eradication of rats. *British Birds*, **112**, 217-230.

Bradbury *et al*. (2017) Risk assessment of seabird bycatch in UK waters. WWT Consulting report to Defra.

Burgess and Hirons (1992) Creation and management of artificial nesting sites for wetland birds. *Journal of Environmental Management*, **34**, 285-295.

Burrows (2014) *Assessment of carbon budgets and potential blue carbon stores in Scotland's coastal and marine environment*. Scottish Natural Heritage Commissioned Report No. **761.**

Carroll *et al.* (2017) Kittiwake breeding success in the southern North Sea correlates with prior sandeel fishing mortality. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **27**, 1164-1175.

Cook and Hamer (1997) Effects of supplementary feeding on provisioning and growth rates of nestling puffins *Fratercula arctica*: Evidence for regulation of growth. *Journal of Avian Biology*, **28**, 56-62.

Coulson (2011) The Kittiwake. T & AD Poyser, London.

Cramp and Simmons (1983) Handbook of the birds of Europe, the Middle East and North Africa: The birds of the Western Palearctic, vol 3 Waders to Gulls. Oxford University Press.

Davis *et al.* (2005) Food availability affects adult survival as well as breeding success in parasitic jaegers. *Ecology*, **86**, 1047 – 1056.

DESNZ (2023a) Habitats Regulations Assessment for an Application Under the Planning Act 2008. Hornsea Project Four Offshore Windfarm. Desnz HRA – Hornsea Project 4 (planninginspectorate.gov.uk)

DESNZ (2023b) Hornsea Project Four: Derogation Information PINS Document Reference: B2.8.1 APFP Regulation: 5(2)(q) Volume B2, Annex 8.1: Compensation measures for FFC SPA: Bycatch Reduction: Ecological Evidence. Test (planninginspectorate.gov.uk)

DTA Ecology (2020) Habitats Regulations Derogations Workshop Report. Advice to the Crown Estate.

Fayet *et al.* (2021) Local prey shortages drive foraging costs and breeding success in a declining seabird, the Atlantic puffin. *Journal of Animal Ecology*,

Finney *et al.* (2001) The impact of gulls on puffin reproductive performance: an experimental test of two management strategies. *Biological Conservation*, **98**, 159-165

Finney *et al.* (2003) Reducing the density of breeding gulls influences the pattern of recruitment of immature Atlantic puffins *Fratercula arctica* to a breeding colony. *Journal of Applied Ecology*, **40**, 545-552

Fitzsimmons *et al.* (2017) High growth and low corticosterone in food-supplemented Atlantic puffin *Fratercula arctica* chicks under poor foraging conditions. *Marine Ecology Progress Series*, **565**, 217-226.

Forrester *et al*. (2007) *The Birds of Scotland*. Scottish Ornithologists' Club, Aberlady.

Frederiksen *et al.* (2008) Differential effects of a local industrial sand lance fishery on seabird breeding performance. *Ecological Applications*, **18**, 701-710.

Fredriksen *et al.* (2020) Green gravel: a novel restoration tool to combat kelp forest decline. *Nature Scientific Reports*, **10**, 3983

Furness (2013) Evidence review to support the identification of potential conservation measures for selected species of seabirds. Report to Defra

Furness *et al.* (2013) Assessing vulnerability of marine bird populations to offshore wind farms. *Journal of Environmental Management*, **119**, 56-66.

Furness (2021a) Report to the Crown Estate Scotland and SOWEC: HRA Derogation Scope B – Review of Seabird Strategic Compensation Options. MacArthur Green.

Furness (2021b) Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects. Annex 1B – Sandwich tern and kittiwake ecological evidence. EN010109-000449-5.5.1.2 Annex 1B Sandwich Tern and Kittiwake Ecological Evidence.pdf (planninginspectorate.gov.uk)

Gibble and Hoover (2018) *Interactions between seabirds and harmful algal blooms*. Harmful algal blooms: A compendium desk reference, 223-242

Gill *et al.* (2002) Sensitivity of breeding parameters to food supply in black-legged kittiwakes *Rissa tridactyla*. *Ibis*, **144**, 268-283.

Glew *et al.* (2019) Sympatric Atlantic puffins and razorbills show contrasting responses to adverse marine conditions during winter foraging within the North Sea. *Movement Ecology*, **7**, 33.

Gola *et al.* (2021) The impact of microplastics on marine environment: A review. *Environmental Nanotechnology, Monitoring & Management* **16**. https://doi.org/10.1016/j.enmm.2021.100552

Gotceitas *et al.* (1995) Habitat use by juvenile Atlantic cod (*Gadus morhua*) in the presence of an actively foraging and non-foraging predator. *Marine Biology*, **123**, 421–430

Hancock (2000) Artificial floating islands for nesting Black-throated Divers *Gavia arctica* in Scotland: construction, use and effect on breeding success. *Bird Study,* **47**, 165 – 175

Harris (1978) Supplementary feeding of young puffins *Fratercula arctica*. *Journal of Animal Ecology*, **47**, 15-23.

Harris *et al.* (2015) The winter diet of the Atlantic puffin *Fratercula arctica* around the Faeroe Islands. *Ibis*, **157**, 468-479.

Heath *et al.* (2017) Scoping the background information for an ecosystem approach to fisheries in Scottish waters: Review of predator-prey interactions with fisheries, and balanced harvesting: A Report Commissioned by Fisheries Innovation Scotland (FIS) http://www. Fiscot. Org

Hentati-Sundberg *et al.* (2012) The Karlsö murre lab methodology can stimulate innovative seabird research. *Marine Ornithology*, **40**, 11-16.

Hiom *et al*. (1991) Experimental evidence for food limitation of egg production in gulls. *Ornis Scandinavica*, **22**, 94-97.

Holmes *et al.* (2023) Conservation of marine birds: Biosecurity, control, and eradication of invasive species threats, pp 403-438. In Young and VanderWerf (eds.) *Conservation of Marine Birds*. Elsevier, Jennings *et al.* (2012) Responses to changes in sprat abundance of common tern breeding numbers at 12 colonies in the Firth of Forth, east Scotland. *ICES journal of Marine Science*, **69**, 572-577

Jones (2002) Plumage polymorphism and kleptoparasitism in the Arctic skua *Sterocorarius parasiticus*. *Atlantic Seabirds*, **4**, 41-52.

Krause-Jensen and Duarte (2016) Substantial role of macroalgae in marine carbon sequestration. *Nature Geoscience*, **9**, 737–742

Krumhans and Scheibling (2012) Production and fate of kelp detritus. *Marine Ecology Progress Series*, **467**, 281-302.

Kuhn *et al.* (2015) Deleterious effects of marine litter. In M. Bergmann *et al.*. (eds.), Marine Anthropogenic Litter, DOI 10.1007/978-3-319-16510-3_4

Kunh and van Franeker (2023) Using Northern Fulmars as an ecological monitor of marine litter in line with indicators set for UK Marine Strategy Descriptor 10. DEFRA Project code ME5227. Illustrated results with the: Annual/Interim Project Report for Period 2021. 14pp doi: https://doi.org/10.18174/585706

Laist (1997) Impacts of marine debris: Entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In Coe JM, Rogers DB (eds) Marine Debris Sources, Impacts and Solutions. Springer Series on Environmental Management, New York, pp 99-132

Langlois Lopez *et al.* (2023) Quantifying the impacts of predation by Great Black-backed Gulls *Larus marinus* on an Atlantic Puffin *Fratercula* arctica population: Implications for conservation management and impact assessments. *Marine Environmental Research*, **188**.

Lindegren *et al.* (2018) Productivity and recovery of forage fish under climate change and fishing: North Sea sandeel as a case study. *Fisheries Oceanography*, **27**, 212-221.

Lorentsen *et al.* (2010) Multi-trophic consequences of kelp harvest. Biological Conservation, **143**, 2054-2062.

Luxmoore *et al.* (2019) Canna seabird recovery project 10 years on. In Veitch *et al.* (Eds.) Island invasives: Scaling up to Meet the Challenge, Occasional Paper SSC no. 62, Gland, Switzerland: IUCN, pp. 576-579

Manikowska-Ślepowrońska *et al.* (2022) The use of artificial floating nest platforms as conservation measure for the common tern *Sterna hirundo*: a case study in the RAMSAR site Druzno Lake in Northern Poland

McGregor (2022) Berwick Bank Derogation Case. Fisheries Compensatory Measures Evidence Report.

McGregor *et al.* (2022) Assessment of Compensatory Measures for Impacts of Offshore Windfarms on Seabirds. Rept for Natural England. MacArthur Green.

Mendel *et al.* (2019) Operational offshore wind farms and associated ship traffic cause profound changes in distribution patterns of loons (*Gavia* spp.). *Journal of Environmental Management*, **231**, 429-438.

Merrie (1996) Breeding success of raft-nesting divers in Scotland. British Birds **89**: 306 – 309.

Miles *et al.* (2015) Decline in an Atlantic puffin population: Evaluation of magnitude and mechanisms. *PloS ONE*, **10**, e0131527

Miles *et al*. (2020) Preliminary assessment of seabird population response to potential bycatch mitigation in the UK-registered fishing fleet. Prepared for Defra Project Code ME6024. JNCC. Science Search (defra.gov.uk)

Mitchell *et al.* (2004) *Seabird Populations of Britain and Ireland*. T & AD Poyser, London.

Moksnes *et al.* (2021) *Handbook for restoration of eelgrass in Sweden - National guideline*. Swedish Agency for Marine and Water Management, Report number 2021, 111

National Trust (Au) (2023) Cape Jaffa Lighthouse Conservation Appeal. Available at: https://www.nationaltrust.org.au/cape-jaffa-lighthouse-conservation-appeal/

NatureScot (2023) Response to the Berwick Bank Offshore Wind Farm derogation case.

Northridge *et al*. (2020) Preliminary estimates of seabird bycatch by UK vessels in UK and adjacent waters. Defra report

Nummi *et al.* (2013) The Red-throated Diver (Gavia stellata) in human-disturbed habitats – building up a local population with the aid of artificial rafts. Ornis Fennica 90:16–22. 2013

Oro & Furness (2002) Influences of food availability and predation on survival of kittiwakes. *Ecology*, **83**, 2516-2528.

Ørsted (2021a) Hornsea Project Four: Derogation Information. Volume B2, Annex 7.1: Compensation measures for FFC SPA offshore artificial nesting ecological evidence. Test (planninginspectorate.gov.uk)

Ørsted (2021b) Hornsea Project Four: Derogation Information. Volume B2, Annex 8.5: Compensation measures for FFC SPA: Fish Habitat Enhancement: Ecological Evidence. Test (planninginspectorate.gov.uk)

Ørsted (2022) Hornsea Project Four: Derogation Information. FFC SPA: Guillemot and razorbill compensation plan EN010098-002038-Hornsea Project Four – Other- B2.8 FFC SPA Guillemot and Razorbill Compensation Plan.pdf (planninginspectorate.gov.uk)

Parker *et al.* (2007) Assessment of social attraction techniques used to restore a common murre colony in central California. *Waterbirds: The International Journal of Waterbird Biology*, **30**, 17-28.

Parrish & Paine (1996) Ecological interactions and habitat modification in nesting common Murres, *Uria aalge*. *Bird Conservation International*, **6**, 261-269

Petalas *et al.* (2021) Foraging niche partitioning in sympatric seabird populations. *Scientific reports*, **11**, 1-12.

Peterson *et al.* (2003) Estimated enhancement of fish production resulting from restoring oyster reef habitat: Quantitative valuation. Marine Ecology Progress Series, **264,** 249–64.

Phillips *et al.* (2011) Summary of birds killed by a harmful algal bloom along the South Washington and North Oregon Coasts during October 2009 1. *Northwestern Naturalist*, **92**, 120–126.

Potouroglou *et al*. (2021) The sediment carbon stocks of intertidal seagrass meadows in Scotland. Estuarine. *Coastal and Shelf Science*, **107442**

Preston *et al.* (eds.) (2020) European Native Oyster Habitat Restoration Handbook. The Zoological Society of London, London.

Raya Rey and Schiavini (2000) Distribution, abundance and associations of seabirds in the Beagle Channel, Tierra del Fuego, Argentina. *Polar Biology*, **23**, 338-345.

ap Rheinallt *et al*. (eds.) (2007) Birds of Argyll. Argyll Bird Club, Lochgilphead

Sawyer *et al.* (2013) Establishment of a new breeding colony of Australasian gannets (*Morus serrator*) at Young Nick's Head Peninsula. *Notornis*, **60**, 180-182.

Searle *et al.* (2023) Effects of a fishery closure and prey abundance on seabird diet and breeding success: Implications for strategic fisheries management and seabird conservation. *Biological Conservation* ,**281.**

Skeate (2022) Berwick Bank Derogation Case. Colony Compensatory Measures Evidence Report.

Smart and Amar (2018) Diversionary feeding as a means of reducing raptor predation at seabird breeding colonies. *Journal for Nature Conservation*, **46**, 48-55

Smith *et al*. (1999) Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. *Environmental pollution*, **100**, 179-196.

Spaans *et al.* (2018) Using a drone to determine the number of breeding pairs and breeding success of Sandwich terns *Sterna sandvicensis*. *Limosa*, **91**, 30-37.

Stanbury *et al.* (2017) Prioritising islands in the UK and crown dependencies for the eradication of invasive alien vertebrates and rodent biosecurity. *European Journal of Wildlife Research*, **63**, 1-13

Steel and Outram (2020) Terns – restoring diversity to the Isle of May's breeding seabirds. *Scottish Birds*, **40**, 206-211.

Sutton and Loram (2021) Diet specialisation in an insular population of coastal peregrine falcons. bioRχiv preprint Diet specialization in an insular population of coastal Peregrine Falcons | bioRxiv

Thomas *et al.* (2022) A Review of the Ecosystem Services Provided by the Native Oyster (*Ostrea edulis*): Implications for Restoration. IOP Conference Series: Materials Science and Engineering, **1245**, 012010.

Thomson *et al.* (2023). Red-throated diver energetics project final report. JNCC Report 736.

Trinder (2016) Population viability analysis of the Sula Sgeir gannet population. Scottish Natural Heritage Commissioned Report.

Votier *et al.* (2011) The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. *Mar Poll Bull* **62**. 168-172

Van der Wal *et al.* (2008) Multiple anthropogenic changes cause biodiversity loss through plant invasion. Global Change Biology **14**, 1428–1436.

Votier *et al.* (2004) Predation by great skuas at a large Shetland seabird colony. *Journal of Applied Ecology*, **41**, 1117-1128

Wanless *et al.* (2018) Community-wide decline in the occurrence of lesser sandeels *Ammodytes marinus* in seabird chick diets at a North Sea colony. *Marine Ecology Progress Series*, **600**, 193-206

Zonfrillo (2002) Puffins return to Ailsa Craig. *Scottish Bird News*, **66**, 1-2

Zonfrillo (2007) Ailsa Craig – rat eradication – history and effects. In: Tackling the problem of invasive alien mammals on seabird colonies – strategic approaches and practical experience. Proceedings of a conference held on 18-19 September 2007, Education Centre, Edinburgh Zoo. National Trust for Scotland, Royal Zoological Society of Scotland and Central Science Laboratory.