Hornsea Project Four: Derogation Information

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Volume B2, Annex 8.5: Compensation measures for FFC SPA: Fish Habitat Enhancement: Ecological Evidence

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Glossary

Term	Definition
Compensation / Compensatory Measures	If an Adverse Effect on the Integrity (AEoI) on a designated site is determined during the Secretary of State's Appropriate Assessment, compensatory measures for the impacted site (and relevant features) will be required. The term compensatory measures is not defined in the Habitats Regulations. Compensatory measures are however, considered to comprise those measures which are independent of the project, including any associated mitigation measures, and are intended to offset the negative effects of the plan or project so that the overall ecological coherence of the national site network is maintained.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for one or more Nationally Significant Infrastructure Projects (NSIP).
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Directive and EIA Regulations, including the publication of an Environmental Impact Assessment (EIA) Report.
Hornsea Project Four Offshore Wind Farm	The term covers all elements of the project (i.e. both the offshore and onshore). Hornsea Four infrastructure will include offshore generating stations (wind turbines), electrical export cables to landfall, and connection to the electricity transmission network. Hereafter referred to as Hornsea Four.
National Site Network	The network of European Sites in the UK. Prior to the UK's exit from the EU and the coming into force of the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019 these sites formed part of the EU ecological network knows as "Natura 2000".
Mitigation	A term used interchangeably with Commitment(s) by Hornsea Four. Mitigation measures (Commitments) are embedded within the assessment at the relevant point in the EIA (e.g. at Scoping, or PEIR or ES).
National Grid Electricity Transmission (NGET) substation	The grid connection location for Hornsea Four.
Orsted Hornsea Project Four Ltd.	The Applicant for the proposed Hornsea Project Four Offshore Wind Farm Development Consent Order (DCO).
Report to Inform Appropriate Assessment (RIAA)	The information that the Competent Authority needs to inform an Appropriate Assessment at Stage 2 of the HRA process, and which has been provided by the Applicant in the RIAA (**Volume 2, Annex 2: Report to Inform Appropriate Assessment**).
Special Area of Conservation (SAC)	Strictly protected sites designated pursuant to Article 3 of the Habitats Directive (via the Habitats Regulations) for habitats listed on Annex I and species listed on Annex II of the directive.
Special Protection Area (SPA)	Strictly protected sites designated pursuant to Article 4 of the Birds Directive (via the Habitats Regulations) for species listed on Annex I of the Directive and for regularly occurring migratory species.

Acronyms

Term	Definition
AEoI	Adverse Effect on Integrity
BQE	Biological Quality Element
DCO	Development Consent Order
EIA	Environmental Impact Assessment
EU	European Union
FFC	Flamborough and Filey Coast
HIWWT	Hampshire and Isle of Wight Wildlife Trust
Hornsea Four	Hornsea Project Four
HRA	Habitats Regulations Assessment
ICES	International Council for the Exploration of the Sea
IHLS	International Herring Larvae Survey
NERC	Natural Environment and Rural Communities
NGET	National Grid Electricity Transmission
NGOs	Non-Governmental Organisations
MCMS	Marine Case Management System
MCZ	Marine Conservation Zone
MMO	Marine Management Organisation
OCT	Ocean Conservation Trust
PIT	Passive Integrated Transponder
RIAA	Report to Inform Appropriate Assessment
ROFI	Regions of Freshwater Influence
SAC	Special Area of Conservation
SAV	Submerged Aquatic Vegetation
SPA	Special Protection Area
UK	United Kingdom
USA	United States of America
WFD	Water Framework Directive
WTG	Wind Turbine Generator
WWF	World Wide Fund for Nature
YWT	Yorkshire Wildlife Trust

1 Introduction

1.1.1.1 Orsted Hornsea Project Four Limited (hereafter the 'Applicant') is proposing to develop Hornsea Project Four Offshore Wind Farm (hereafter 'Hornsea Four') which will be located 69 km offshore from the East Riding of Yorkshire in the Southern North Sea and will be the fourth project to be developed in the former Hornsea Zone.

1.1.1.2 Hornsea Four will include both offshore and onshore infrastructure including an offshore generating station (wind farm) comprising up to 180 wind turbine generators (WTGs), export cables to landfall, and connection to the National Grid Electricity Transmission (NGET) network at Creyke Beck.

1.1.1.3 This document has been prepared to support the identification of compensatory measures for Hornsea Four and its potential impacts on black-legged kittiwake (*Rissa tridactyla*), common guillemot (*Urea aalge*), razorbill (*Alca torda*) and northern gannet (*Morus bassanus*). In light of the conclusions of the Report to Inform the Appropriate Assessment (RIAA) which will support the Hornsea Four Development Consent Order (DCO) application, Hornsea Four's position is that no Adverse Effect on the Integrity (AEoI) of the Flamborough and Filey Coast (FFC) Special Protection Area (SPA) will arise from Hornsea Four alone or in combination with other plans or projects. Nevertheless, in light of the Secretary of State's clear direction in his decision letter for Hornsea Three, Hornsea Four's DCO application will be accompanied by a derogation case (including compensatory measures) which will be provided on a "without prejudice" basis i.e. the derogation case will be provided without prejudice to Hornsea Four's conclusion that no AEoI will arise.

1.1.1.4 The purpose of this document is to explore the evidence base for a resilience measure aimed at supporting a suite of compensatory measures being proposed for seabirds on a without prejudice basis. Where evidence gaps are identified, Hornsea Four is working on a strategy to address those gaps which are to be finalised for DCO submission.

1.2 Document background and purpose

1.2.1.1 The Applicant has been exploring opportunities to restore seagrass to support a range of ecosystems services and associated research as a resilience compensation measure in support of a derogation case for Hornsea Four. Seagrass habitat restoration is being considered as part of a wider suite of projects that will form part of a compensation package to support a without prejudice derogation case in support of Hornsea Four. The Applicant recognises the importance of seagrass as a measure that can provide resilience to support other compensation measures such as predator eradication, bycatch reduction and provision of artificial nesting.

1.2.1.2 Compensation measures are being developed to support the east Atlantic biogenic region seabird populations of:

- black-legged kittiwake;
- common guillemot;
- razorbill; and

- northern gannet (which are included in the derogation case until Natural England confirm no AEoI).

1.2.1.3 Healthy seagrass beds can enhance productivity of fish populations by providing important nursery and feeding resource. This can potentially enhance prey availability for seabird species by increasing fish abundance of key forage fish species. Therefore, the Applicant is currently focusing on opportunities for potential seagrass restoration projects. This document aims to provide an overview of the evidence base of the utilisation of seagrass habitats by key prey fish species associated with the four seabird species of interest listed above and to assess how enhancing forage fish species may increase seabird prey resource.

1.2.1.4 Moreover, this document highlights the importance of seagrass habitat and provides evidence of seagrass meadows functioning as a nursery for juvenile forage fish species, the importance of this habitat for prey fish species for the four seabirds noted above and seagrass habitat restoration.

1.2.1.5 This report will:

- provide evidence of seagrass as a nursery habitat for key fish species;
- acknowledge previously successful seagrass restoration projects and ongoing projects in England and Wales; and
- highlight key evidence gaps in the knowledge base, potential considerations to implementation and next steps to address evidence gaps and inform further project development.

2 Forage Fish Habitat Enhancement

2.1.1.1 Fish habitat enhancement (as a concept) seeks to improve vital habitats for fish species such as those that provide spawning or nursery grounds to increase the productivity of fish populations. Marine habitats that support fish populations such as seagrass, biogenic reef and mudflats have been considered for restoration in the United Kingdom (UK) to increase biodiversity (ABPmer 2017; Marine Management Organisation (MMO) 2019). There is substantial evidence that these types of structured habitats enhance the density, growth, and survival of juvenile fishes and invertebrates (Lefcheck *et al.* 2019).

2.1.1.2 Forage fish are planktivorous pelagic species (e.g. sandeel *(Ammodytes* species), European sprat (*Sprattus sprattus*) (hereafter sprat), Atlantic herring (*Clupea harengus*) (hereafter herring)) that are often the pathway for converting plankton production into food available to higher trophic levels (Alder *et al.* 2008). Seagrass is considered important fish nursery grounds, crucial for maintaining fish stocks (Bertelli and Unsworth 2014; Dean *et al.* 2000). Seagrass meadows in the UK provide a home to around 50 species of fish and they have particular importance as a nursery ground for juvenile Atlantic cod (*Gadus morhua*) (hereafter cod), pollock (*Pollachius pollachius*), whiting (*Merlangius merlangus*), plaice (*Pleuronectes platessa*), herring and sea bass (*Dicentrarchus labrax*) (Bertelli and Unsworth 2014), meaning their restoration can improve prey availability (Unsworth and Butterworth 2021).

2.1.1.3 Numerous reviews note the importance and value of seagrass meadows globally for supporting high biodiversity and having high ecosystems services in relation to fish habitat, however, there is often limited acceptance of these roles by regulators in England and Wales due to limited regional/local data (Peters *et al.* 2015).

2.2 Seagrass beds as forage fish nursey

2.2.1 Forage fish habitat

2.2.1.1 Seagrass meadows are amongst the most productive marine habitats in the UK. The physical structure of seagrass meadows provide shelter from predators and food for juvenile fish, stabilise the sediment, reduce erosion, improve water quality, absorb excess nutrients and improve nutrient cycling, produce oxygen and store significant amounts of carbon (Heck *et al*. 2003; Lilley and Unsworth 2014; Nordlund *et al.* 2018).

2.2.1.2 Seagrass meadows are renowned for their transformative abilities, turning bare homogenised habitats such as sand or mud into structurally complex, productive ecosystems (Bostrom *et al.* 2006) supporting greater invertebrates (Orth *et al.* 1984; Tu Do *et al.* 2012), fish (Zarco-Perello and Enríquez 2019) and bird (Mosbahi *et al.* 2017) diversity than adjacent sand and mud environments, and a wide range of food resources (Heck and Valentine 2006). These ecological advantages make seagrass beds important nursery and feeding habitats for invertebrates and fish (Heck *et al.* 2003) which support fisheries (Jackson *et al.* 2001; Lefcheck *et al.* 2019) and adjacent habitats (Unsworth *et al.* 2008).

2.2.1.3 Seagrass is known to be rich in fauna, with complex food systems. Birds however are an often-overlooked part of marine ecosystems yet are crucial to their health (Green and Elmberg 2014). Many piscivorous birds feed on species of fish that are known to live within UK seagrass meadows. Seagrass habitats show greater diversity and abundance of fish, particularly juveniles, than unvegetated areas (Bertelli and Unsworth 2014; Jones *et al.* 2008; Lefcheck *et al.* 2019; Lilley and Unsworth 2014) with the large, healthy, well-connected meadows showing the greatest diversity (Henderson *et al.* 2017). Seagrass fish assemblage is composed of mainly demersal and schooling fish (Jones *et al.* 2008).

2.2.1.4 Across the wider Northern Atlantic region, a range of studies has examined the links between seagrass as a nursery ground for specific species such as the herring and cod (Bertelli and Unsworth 2014; Lilley and Unsworth 2014). With a number of studies which have taken place in the UK, Denmark and the Baltic Sea recorded a high abundance of juvenile herring in seagrass habitats (Bertelli and Unsworth 2014; Polte and Asmus 2006; Rönnbäck *et al.* 2007). Reported findings indicate some fish and invertebrate species actively choose seagrass as nursery habitat and gain clear population-level benefits from extended durations using such habitat as a juvenile (Heck *et al.* 2003; Lefcheck *et al.* 2019; Lilley and Unsworth 2014). A study conducted by McCloskey and Unsworth (2015) noted that the size of commercial fish sampled within a seagrass meadow (which included herring, pollock and cod) indicated that the majority were below the age of sexual maturity, supporting the premise that seagrass meadows have a high ecosystem service value as nursery habitats.

2.2.1.5 Available data indicates that seagrass meadows provide a key fish nursery habitat. Balon (1975) identified herring as phytolithophilous (spawning on vegetation and other benthic structures) and therefore seagrass could provide a substrate for herring eggs to be laid upon (Polte and Asmus 2006). This is further evidenced by studies on Pacific herring (*C. pallasii*) in Japan, where most of the eggs recorded were attached to seagrass blades, which were abundant within the spawning area (Hoshikawa *et al.* 2001) and in California, United States of America (USA), where herring were recorded to spawn in seagrass beds even in the presence of predators (Rederer 2020). A study by von Nordheim *et al*. (2018), noted the Atlantic herring population in the Baltic Sea have directed spawning migrations into inner coastal waters and to vegetated spawning beds (e.g. seagrass, *Zostera marina*). Polte and Asmus (2006) also recorded Atlantic herring eggs attached to seagrass beds (*Z. noltii*) in the Wadden Sea. However, to date, no Atlantic herring have been recorded spawning in seagrass meadows in the UK. It is possible to identify specific spawning and nursery (larval) areas in proximity to seagrass meadows through the combined use of historical fish sensitivity maps and the International Council for the Exploration of the Seas (ICES) International Herring Larvae Survey (IHLS). The main herring spawning areas within the North Sea, these include Shetland/Orkney, Buchan, Banks and Downs, with discrete stocks in the Blackwater Thames Estuary (Boyle and New 2018).

2.2.1.6 It is recognised that there are knowledge gaps on the specific linkages between seagrass in the UK and predatory seabirds and the level of the role of seagrass supporting forage fish for seabirds such as razorbill, guillemot, gannet and kittiwake. Whilst the broad understanding of the links between seagrass meadows and fisheries, including some prey fish species for seabirds (e.g. herring) are well understood (Kritzer *et al.* 2016; Unsworth *et al.* 2019c), we still have limited evidence for this role at a UK level, with most data collected from only a handful of sites (Bertelli and Unsworth 2014; Peters *et al.* 2015).

2.2.2 Key fish species for kittiwake, guillemot, razorbill and gannet

2.2.2.1 Key forage fish for seabird species, such as kittiwake, gannet, guillemot and razorbill, are planktivorous pelagic species (e.g., sandeel, sprat, herring). Sandeel are the most important forage fish species in the North Sea and are a key component in the diet of certain seabirds (including kittiwake, guillemot, razorbill, gannet (gannet are included in the derogation case until Natural England confirm no AEoI)), however other species such as herring and sprat are also important.

2.2.2.2 Herring and sprat both belong to the family *Clupeidae*, which also includes shads and sardines, most of whom are forage fish. All clupeoids feed on plankton, are small and spawn a huge number of eggs. Sprat and herring travel in large schools possibly as a mechanism to avoid predation.

2.2.2.3 While many seabirds hunt miles away from any seagrass, the species that they prey on, such as gadoids (a group that includes cod, haddock (*Melanogrammus aeglefinus*) and hake (*Merluccius merluccius*)) and clupeids, often utilise seagrass as nursery habitats (Bertelli and Unsworth 2014; Lefcheck *et al.* 2019; Lilley and Unsworth 2014; McDevitt-Irwin *et al.* 2016). Seagrasses are incredibly important in supporting fish stocks in the wider ocean, with 20% of the world's largest fisheries supported by seagrass meadows through the provision of a nursery function to juvenile fish (Unsworth *et al.* 2019b), including commercially important fish species. There is also evidence of negative effects on pelagic fish stocks following a decline in seagrass meadow habitat (Kritzer *et al.* 2016; Seitz *et al.* 2013). This, in turn, may impact the success of the bird species that feed on them.

2.2.2.4 Many seabird species (e.g. kittiwakes, guillemots) are known to forage in coastal shallow water areas when nesting (Bugge *et al.* 2011; Redfern and Bevan 2014) and consume young fish known to be abundant in seagrass (Bugge *et al.* 2011; Lilley and Unsworth 2014). In addition, several studies noted a high abundance of juvenile herring were found in seagrass in studies that took place off the coast of North Wales, UK, in the Wadden Sea off the coast of Denmark and the Baltic Sea of the coast of Sweden (Bertelli and Unsworth 2014; Polte and Asmus 2006; Rönnbäck *et al.* 2007).

Kittiwake

2.2.2.5 Kittiwakes are surface-feeders and prey predominantly on sandeels, which are thought to be the most important prey forage fish in the North Sea (Engelhard *et al.* 2014), but also on gadoids, clupeids and sprats in some areas of the UK, where sandeels are uncommon (Harris and Wanless 1997; Chivers *et al.* 2012). The diet of kittiwake populations from the coast of eastern England can comprise up to 60% sandeel (Furness and Tasker 2000). FFC SPA, which protects the largest kittiwake colony in the UK, is located in this coastal region. In the absence of sandeel, several studies have also found kittiwake will usually feed on the most abundant prey available to them in surface waters which can include herring and cods (Baird 1994; Shultz 2002; Suryan *et al.* 2002).

2.2.2.6 In addition to kittiwake, sandeel are a key component in the diet of other key seabirds including the common guillemot, razorbill, northern gannet (Anderson *et al.* 2014; Engelhard *et al.* 2014; Nettleship and Sharpe 1996). However, the contribution of sandeel in the diets vary both latitudinally and among marine regions, with the proportion of sandeel significantly higher for a given latitude on the west coast compared to the east (Anderson *et al.* 2014).

Guillemot and razorbill

2.2.2.7 For both guillemot and razorbill in the North Sea, forage fish comprise a large component of their diet (around 70% for both species) (Engelhard *et al.* 2014). Of the forage fish, sandeel represents the highest proportion by mass followed by sprat and herring (ICES 2011).

2.2.2.8 Although guillemot feeds predominately on sandeel, sprats are the main alternative prey source predominantly consumed at southern colonies and juvenile gadoids in the north (Anderson *et al.* 2014). Unlike other seabirds, guillemot makes both benthic and pelagic dives (Chimienti *et al.* 2017) and can take sandeel when they are buried in the seabed by digging or scaring them out of the sediment. Guillemots in general may be more able to switch from a diet of sandeels to a diet of sprats than other seabird species (Wanless *et al.* 2018).

2.2.2.9 Razorbill uses its wings to propel itself underwater in pursuit of small fish prey. They tend to make shallower pelagic dives (Chimienti *et al.* 2017), feed primarily sandeel, however, they are known to feed upon sprat as an alternative to sandeels (Nettleship and Sharpe 1996).

2.2.2.10 Clupeids form a part of the diet of numerous seabirds, notable in the diet of common guillemot chicks and razorbills (Anderson *et al.* 2014; Barrett 2015; Ouwehand *et al.* 2004; Riordan and Birkhead 2018). For adult guillemots, capable of catching and eating larger prey, gadoids were a significant prey item (Anderson *et al.* 2014; Ouwehand *et al.* 2004).

Gannet

2.2.2.11 Northern gannets are known to opportunistically consume any small fish or small pelagic species such as squid. Gannet are plunge divers, observing their prey from well above the water surface and target shoal-forming species including anchovies (*Engraulidae* spp.), haddock, smelt (*Osmerus eperlanus*), cod (Cornell University 2019). A study conducted in Australia recorded inshore foraging behaviour of the Australasian gannet (*Morus serrator*) (which typically forages in continental shelf regions) in a shallow coastal seagrass bed (Wells *et al.* 2016). Anchovies, smelt and juvenile cod and haddock are known to use seagrass habitats as shelter from predators (Lilley and Unsworth 2014; The PEW Charitable Trusts (PEW) 2019). Sandeel also make up a large proportion of their diet, however, when absent other prey species such as mackerel can become the predominant species (Davies 2012).

2.2.3 Fish movements in the vicinity of seagrass

2.2.3.1 Utilising IHLS survey data, which record herring larvae concentrations each year in the North Sea, an indication of larval drift could be captured. As the majority of evidence for herring spawning in the North Sea points to areas of gravel in the marine environment (Boyle and New 2018), herring larvae can drift into estuarine habitats and subsequent nursery areas, where they may have an affinity with seagrass meadows. Such areas include the Northumberland coast and therefore the Humber Estuary, where juvenile herring have been recorded (Ellis *et al.* 2012). **Figure 1** illustrated recorded larval drift from some of the main herring spawning stocks in the North Sea to east coast estuaries on the east coast of the UK.

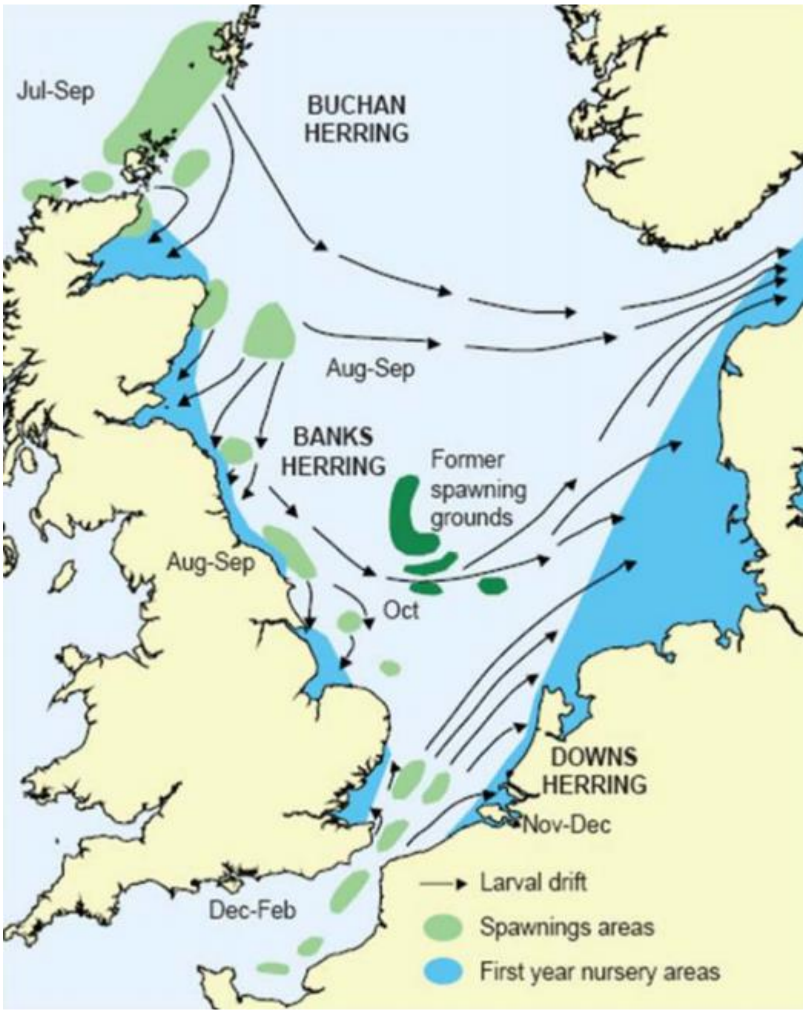


Figure 1: The spawning areas and periods of the autumn spawning North Sea sub-populations showing larval drift to known nursery grounds (taken from Nichols 1999).

Evidence of fish tagging of key species

2.2.3.2 Tagging has often been used in studies to improve the management of fish stocks by studying their movement and behaviour (Prentice and Park 1983; Gibbons and Andrews 2004; Jørgensen *et al.* 2017). The most commonly used tags for these types of fish movement studies are acoustic-, radio- and passive integrated transponder (PIT).

2.2.3.3 Herring tagging experiments have indicated that tagging is possible with studies conducted by Wheeler and Winters (1984) and Kanwit (2006) which noted that herring can be effectively tagged and long-term, long-distance recoveries can be made.

2.2.3.4 Sprat spawning takes place over wide areas and extends through several months. Tagging studies on sprat are limited, however have been used previously to detect spawning migrations into the North Sea from Norway (Bakken 1973).

2.2.3.5 To date tagging evidence on herring and sprat within the North Sea and the wider region are limited. Information from juvenile migration tagging could enable a better understanding of the prey fish migrations to and from the North Sea, and to seagrass habitats. This is therefore an evidence gap that could be explored further (see **Section 4.2**).

2.3 Forage Fish Species Ecology

2.3.1 Important forage fish species in the North Sea

2.3.1.1 There are five species of sandeel in the North Sea, with *A. marinus* considered the most abundant, comprising of 90% of commercial landings (Department of Energy and Climate Change (DECC) 2016). Sandeel are reliant on coarse sandy seabed habitat and are unlikely to move to deeper waters (Holland *et al.* 2005). Sparholt (2015) noted there is little movement recorded between spawning and feeding grounds for sandeel and as a result fishing activity may have a direct effect on spawning. In Scotland, an area on the east coast has been closed to industrial fishing for sandeels since 2000. Although this initially led to an increase in sandeel biomass it has steadily declined since 2001, with 1997-1998 levels (when the fishery was active) seen in 2007 (Marine Scotland 2019). Declining recruitment in the sandeel population of the northern UK is inversely correlated with sea temperature (Heath *et al.* 2012).

2.3.1.2 Herring are widespread throughout the north-east Atlantic, with spawning typically taking place on coarse sand and gravel at depths of between 15-40 m (DECC 2016). This spawning activity can take place in coastal waters or in the open sea (Pörtner and Peck 2010). In inshore waters, young herring occur in dense shoals and can be found with shoals of sprat (Dickey-Collas *et al.* 2015). Important nursery grounds for pelagic herring larvae include the Humber Estuary, Thames Estuary and the Wash (Ellis *et al.* 2012). A report by Boyle and New (2018), noted the main herring spawning areas are separated into four spawning components within the North Sea, these include Shetland/Orkney, Buchan, Banks and Downs, with discrete Stocks in the Blackwater Thames Estuary.

2.3.1.3 Sprats are widespread along the Atlantic coast and are typically found in shallow water around the coastline (DECC 2016), particularly dense schools of juvenile sprat (Dickey-Collas *et al.* 2015). However, they are considered most abundant in the shallow waters of the southern North Sea, with nursery grounds are found around the Southern Bight and Dogger Bank (DECC 2016).

2.3.2 Factor affecting prey resource availability

2.3.2.1 Fish communities are likely to be affected by future climate change, which could influence fish abundance and distribution by potentially affecting behaviour, growth and recruitment rates, survival and responses to changes at other trophic levels (DECC 2016). However, it should be noted that the exact responses are difficult to predict. Habitat requirements are likely to play a significant role in vulnerability to climate change, with species such as herring likely to be vulnerable at different stages in its life cycle, particularly spawning (Petitgas *et al.* 2013) where historic grounds, are no longer optimal.

2.3.2.2 Overfishing can lead to a reduced biomass of commercially valuable fish species and non-target species through bycatch. Fishing can affect the abundance, size and species diversity of fish communities with long-term exploitation resulting in a decrease in body size, age of maturation and productivity (DECC 2016).

2.3.3 Prey fish resource for key seabird species

2.3.3.1 Given the changes that are known to be occurring in many prey populations due to climate change and fisheries impacts, information on predator-prey interactions are considered vital. Seabirds are generally influenced by the abundance of their preferred prey species. A population's vulnerability to changes in prey densities depends on the magnitude of the change itself and the occurrence of alternative prey species resources (Cairns 1988; Burger and Piatt 1990; Zador and Piatt 1999). Moreover, a study by Wohlenberg (1935) documented that the loss of seagrass (*Z. marina*) beds may have caused a drastic decline of spring-spawning herring stocks in the northern Wadden Sea.

2.3.3.2 The influence that fish abundance can have on predators is best illustrated by sandeels, which have declined in abundance dramatically in recent years. Sandeels are the target of what has been the largest single-species fishery in the North Sea over recent decades. There is evidence that the sandeel fishery has contributed to the depletion of sandeel biomass in the North Sea (Lindegren *et al.* 2018), with sandeel landings in the North Sea decreasing by over 50% since 2003 (Frederiksen *et al.* 2006). Breeding success and survival rate of kittiwake are considered to be strongly influenced by sandeel stock size and thus by commercial fisheries on sandeels (Furness and Tasker 2000; Lewis *et al.* 2001; Oro and Furness 2002; Mitchell *et al.* 2004; Frederiksen *et al.* 2004). With evidence that a reduction in the abundance of sandeels can cause a reduction in the breeding success and survival of kittiwakes, and that large reductions in sandeel abundance result in breeding failure of kittiwakes and population decline (Daunt *et al.* 2008; Furness and Tasker 2000; Oro and Furness 2002; Frederiksen *et al.* 2004; Furness 2007; Carroll *et al.* 2017).

2.3.3.3 Reliance on sandeel varies with region and season and the diet of kittiwake populations from the coast of eastern England can comprise up to 60% sandeel (Furness and Tasker 2000). For both guillemot and razorbill in the North Sea, forage fish comprise a large component of their diet (around 70% for both species) (Engelhard *et al.* 2014). Of the forage fish, sandeel represents the highest proportion by mass followed by sprat and herring (ICES 2011). In particular, sprat is a significant component in the diet of razorbill and herring in the diet of guillemot compared to the other species.

2.3.3.4 Food shortage is an evident cause of reduced productivity for both guillemot and razorbill at some colonies in some years (Furness *et al.* 2013). Though both auk species can undoubtedly be impacted by food shortages they are likely much more resilient than kittiwake (Furness and Tasker 2000). In general, guillemot is considered to be better buffered against food shortage as kittiwake can only catch sandeel at the sea surface and at specific times of year (Wanless *et al.* 2005; Monaghan *et al.* 1994). Razorbill may also be able to switch to alternative food sources such as zooplankton if forage fish are scarce.

2.3.3.5 A study by Hjernquist and Hjernquist (2010), recorded the number of breeding pairs of guillemot and razorbills that were found to be positively associated with the abundance of sprat, with the study supporting the belief that the abundance of prey fish is of key importance to the seabird populations. This was further evidenced by Thaxter *et al.* (2013) who found availability, due to relatively small differences in diet and foraging behaviour guillemot and razorbill, vary in sensitivity to different aspects of prey, with guillemot more sensitive to changes in prey distribution.

2.4 Habitat enhancement work for seagrass beds

2.4.1.1 Seagrass meadows are one of the world's most threatened ecosystems and are rapidly declining, with losses occurring at a rate of 110 $km^2 yr^{-1}$ since 1980 (Waycott *et al.* 2009). In the UK, seagrass loss has been catastrophic and is estimated that 39% of seagrass in the UK has been lost since the 1980s and total UK losses could be as high as 92% (Green *et al.* 2021). Factors affecting seagrass meadows contributing to the decline include wasting disease, pollution and physical disturbance. Only 20 of the 155 estuaries in the UK support seagrass and many are in poor condition and facing continued decline (Jones and Unsworth 2016; Unsworth *et al.* 2017a, Unsworth *et al.* 2017b; Unsworth *et al.* 2019a).

2.4.1.2 In the context of seabirds in the North Sea, there is very good evidence that seagrass has mostly disappeared from the coastline between Lindisfarne in the northeast and Scolt Head in Norfolk, a gap in straight line distance of almost 350 km. Seabirds in that area no longer have access to resources within seagrass or are supported by seagrass, with seagrass formerly in the Humber, the Tyne, the Tees and the Wash all but gone (Green *et al.* 2021; Unsworth and Butterworth 2021). Therefore, planting seagrass at sites previously known to support seagrass or known to have appropriate conditions for seagrass would likely result in increased biodiversity and ecosystem service provision (Unsworth and Butterworth 2021). This is widely accepted as providing important biodiversity and ecosystem services as indicated by projects in Europe and in the USA (Moksnes *et al.* 2021; Orth *et al.* 2020; Unsworth *et al.* 2019a). Further information on site suitability and monitoring is noted in **Section 4.2**. The value of the associated ecosystem services is often a significant stimulus for the protection and restoration of threatened habitats with a study by Blandon and zu Ermgassen (2016) identifying the great importance of seagrass as a nursery to a range of commercially important fish species, with commercial fish species enhanced in seagrass by 0.98 kg $m^{-2} yr^{-1}$.

2.4.1.3 Seagrasses perform an essential role by enhancing the productivity of the local marine environment in terms of the seagrass habitat itself and associated flora and fauna (Maxwell *et al.* 2017). Seagrass has been subject to conservation legislation by the UK's Biodiversity Action Plan list of priority habitats, the EU Habitats Directive, and in the designation of Marine Conservation Zones (MCZs) (Peters *et al.* 2015), in the hope of improving the status of these systems to support biodiversity. As seagrasses have declined in coverage, so has the appreciation for why these habitats are of importance. As a result, restoration projects which support these important seagrass habitats are vital, with many projects resulting in a collaboration between Non-Governmental Organisations (NGOs), academia, statutory nature conservation bodies and local councils. Examples of such collaboration in the UK include Seagrass Ocean Rescue project in Wales, which included Project Seagrass Sky Ocean Rescue, University of Swansea, World Wide Fund for Nature (WWF) and Pembrokeshire Coastal Forum (see **paragraph 2.4.3.5** for further project details); and LIFE

Recreation ReMEDIES Project in England which includes Natural England, Ocean Conservation Trust (OCT), Marine Conservation Society, Plymouth City Council and the Royal Yachting Association (with further information on the project provided in **paragraph 2.5.1.3**). Several other seagrass restoration and management projects have a similar collaborative approach in Europe, with ZORRO (ZOsteRa RestOration) project in Sweden and the NOVAGRASS project in Denmark involving several universities, consultancies and government organisations.

2.4.1.4 An important component to protecting seagrass habitat is the knowledge of their associated fish assemblages and their implications on habitat function (Begg *et al.* 1999; Britten *et al*. 2016). In recognition of their ecological and economic importance, seagrass beds are afforded protection by a variety of conservation legislation and policies resulting in their designation as Annex I feature under the EU Habitats Directive, protected features of Marine Protected Areas (including MCZ and Special Conservation Areas (SAC)). Seagrass beds (*Z. marina* and *Z. noltii*) are listed as a Priority Habitat derived from Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006. They also have protection as a habitat in support of seahorses under the Wildlife and Countryside Act 1981. Seagrass beds also qualify as 'higher sensitivity' habitats in the Environment Agency guidance for undertaking Water Framework Directive (WFD) assessments in estuarine and coastal waters and represent a sub-element (along with saltmarsh) of the angiosperm Biological Quality Element (BQE), one of the five BQEs used to classify the ecological status of water bodies.

2.4.1.5 Seagrass restoration and enhancement is a fast-maturing discipline with examples of restoration and enhancement projects being implemented in several locations including the USA, New Zealand, Australia and more recently in Europe (Tan *et al.* 2020; Brode *et al.* 2004; Moksnes *et al.* 2021). With such growing interest, studies have examined the effectiveness of a range of scales and methods of seagrass restoration across the world (van Katwijk *et al.* 2009). Seagrass restoration is a tool that is now expanding globally, and its success rate is growing rapidly. Recent high-profile examples of wide-ranging success have been seen in the USA where over 3000 ha of seagrass have been planted and brought to maturity in the Chesapeake Bay, leading to full ecosystem service recovery (Orth *et al.* 2020).

2.4.1.6 To date, there has been limited seagrass restoration on the ground in the UK. Some studies were conducted in the 1970s using transplantation of seagrass 'sods' in East Anglia (Ranwell *et al.* 1974), however, the long-term success of that work has been considered unsuccessful due to the lack of seagrass recorded at those sites to date (Unsworth and Butterworth 2021).

2.4.1.7 Nevertheless, in recent years the work of Swansea University and Project Seagrass was the first to progress and in 2013 trials were started to develop locally appropriate seagrass restoration methods building on the work of Professor Orth and his team in the Chesapeake Bay, USA. Comparative studies using transplants of shoots, transplants of seagrass 'sods' and seeds were conducted in West Wales alongside widespread trails (over multiple locations) with seeds. Restoration using seeds was found to be the most effective method, however, this was primarily driven by the European green crab (*Carcinus maenas*) tearing apart the transplanted plant material, resulting in a lower success rate. Trials of planting seagrass seeds continued, resulting in a range of studies for which an initial study has been published (Unsworth *et al.* 2019b).

2.4.2 Feasibility

2.4.2.1 A broad overview of the literature illustrates that although a lot is now known about seagrass restoration, there are research gaps and as a result the success rate of restoration projects can be very low, demonstrating that it is vital that studies are undertaken to assess the feasibility and site selection and ensure the efficacy of the measure (Unsworth and Butterworth 2021). Historically the most common restoration techniques include transplanting and seeding seagrass, which has had varying success and has been used concurrently (van Katwijk *et al.* 2016). Moreover, the feasibility of restoration would also need to account for water quality which may be affected by nutrients or diffuse pollution, making restoration unsuccessful without much wider management measures. Poor water quality is one of the main reasons for limited restoration success (van Katwijk *et al.* 2016). Therefore, any water quality issues need to be addressed prior to a future restoration project.

2.4.2.2 Whilst evidence gaps remain, the existing knowledge and experience of restoration projects and associated processes and technology published in the academic literature are considered a major strength for informing future programmes. The increasing levels of understanding about the reproductive biology of seagrasses and their environmental requirements over the last couple of decades have led to a vast improvement in the capacity of scientists to restore seagrass meadows (Unsworth and Butterworth 2021).

2.4.2.3 Swansea University and Project Seagrass are continuing work on method development on seagrass restoration. This includes the aquaria planting of seeds, studies on seed storage and a range of studies on different types of planting methods; this included a failed attempt to utilise biodegradable plastic mesh to support seagrass restoration in West Wales (Temmink *et al.* 2020). Project Seagrass are currently in the early stages of developing a seagrass nursery as a commercial collaboration with Salix Bioengineering to help facilitate seagrass restoration across the wider UK.

2.4.2.4 Although limited planting has yet to be undertaken, the OCT in Plymouth are developing seagrass restoration planting plans under the ReMEDIES programme, but no information has been publicly shared at this time about progress.

2.4.2.5 Other planned seagrass restoration projects are being considered in the Humber and the Tees estuaries (see **Section 3**).

2.4.2.6 Globally, the methodology for seagrass restoration is improving rapidly, increasing the database of successful examples from which to gather information on best practices (van Katwijk *et al.* 2016). This in turn will lead to an increase in the chance of success of future restoration efforts. In addition, there is now a greater understanding and recognition of the need to manage ecological feedbacks in seagrass ecosystems in order to enhance and improve seagrass restoration (Maxwell *et al.* 2017).

2.4.2.7 A consistent finding of all planting initiatives has been the expense due to the large number of resources required to extract donor material and the operational costs (Clifford 2021).

However, these costs can be reduced by working in partnership with organisations, businesses and/or universities that may already have facilities available for seagrass restoration works.

2.4.2.8 Some seagrass restoration projects particularly the trials of small/medium-sized projects have funding secured. The Applicant will seek to identify projects that are not part of normal projects that are part of normal practice and/or are part of a site/habitat management of designated sites such as a SAC or MCZ. The Applicant will instead look to fund additional areas for seagrass restoration that do not currently have funding secured and therefore provide additional benefit. Evidence gathering by the Applicant is ongoing and discussions with stakeholders on restoration projects and techniques are continuing. However, currently, all types of restoration methods are being considered and may be combined using the best techniques at the time of restoration for the greatest success.

2.4.2.9 The Applicant recognises the need for feasibility studies to consider site selection and methodology to increase the likelihood of a successful restoration programme and efficacy of the resilience compensation measure. Factors that will be considered prior to restoration efforts being initiated to ensure the viability of seagrass restoration include looking for sites that are/have:

- historical evidence that the area has previously supported seagrass habitat;
- sheltered from wave action;
- suitable topographical and hydromorphological conditions including sedimentation rates;
- sufficient nutrients and available light; and
- good water quality.

2.4.2.10 Potential seagrass restoration sites which have connectivity to where seabird species forage and where prey fish migrate to after leaving the restoration site; and the connectivity between the species of prey fish the restoration site and the prey fish species that seabirds forage on will be taken into consideration during site selection. In addition, sites with activities that could cause significant physical disturbance and/or have ongoing stressors should be avoided in order to maximise success. The future effects of climate change will also be considered when determining the optimum locations for this resilience measure.

2.4.3 Success

2.4.3.1 Seagrass restoration is considered in its infancy in the UK compared with other nations, such as the USA and several nations in Europe. However, *Z. marina* is extensive throughout the Northern hemisphere and so examples can be sought in multiple continents. Over the past 20-30 years there have been several success stories on the east coast of the USA.

2.4.3.2 Seagrass restoration requires consideration of a range of factors necessary to make it a success. A recent review of the success of restoration projects globally found that success relates to the severity of habitat degradation (van Katwijk *et al.* 2016).

2.4.3.3 The Submerged Aquatic Vegetation (SAV) Program on the Eastern Shore, Virginia, USA, is considered a leading example of how restoration can be conducted. This large-scale project has aligned decades of research on the biology of restoration with active restoration programmes. This has been focused on restoring the seagrass (*Z. marina*) habitat but also monitored the effect of this restoration on the surrounding ecosystem (Orth *et al.* 2020). The program included a large-scale seed restoration effort, where 74.5 million seeds were collected using hand and mechanised methods. These were broadcast into 536 individual restoration plots totalling 213 ha. The areas have expanded since and so far, resulted in a total of 3,612 ha of vegetated bottom, from virtually no coverage before the restoration. The combined efforts by academic, non-profit and citizen groups have led to it being one of the more successful marine restorations for seagrasses and rivals other large-scale marine restorations in terms of scope, rapidity, dedication, and organisation (Orth *et al.* 2020).

2.4.3.4 In 2013, Swansea University commenced a programme of restoration work, studies on laboratory-grown plants, transplantations and the movement of seagrass 'sods' were conducted alongside studies using seeds. This led to a range of trials utilising seagrass seeds planted in small hessian bags, a method that to date has been very successful in further studies in West Wales (Unsworth *et al.* 2019a).

2.4.3.5 Seagrass Ocean Rescue project ran between 2019 and March 2021 and was led by Project Seagrass in partnership with Sky Ocean Rescue, University of Swansea, WWF and Pembrokeshire Coastal Forum in Dale Bay Pembrokeshire, Wales. The project planned to restore seagrass in small experimental 2 ha areas and aimed to inspire future major projects in other regions to restore the UK's seagrass meadows. To date, the project has successfully planted 1.2 million *Z. marina* seeds, with thousands of mature plants recorded throughout the restoration area. Although many aspects of this project have resulted in learning lessons, the overall project is considered a resounding success (Unsworth and Butterworth 2014).

2.4.3.6 Seagrass restoration is known to enhance fish production, as the additional biomass produced per year due to the presence of this habitat, represents a significant ecosystem function that supports valuable commercial and recreational fisheries, both directly and through the provision of forage species (zu Ermgassen *et al.* 2021). This is also supported by the Orth *et al.* (2020) study which recorded a rapid increase in fish biomass associated with the restoration of seagrass over a 20-year period at the seagrass restoration. Restoration of habitat can support increased numbers of juvenile fish and ultimately enhance fish production through increased population sizes (Folpp *et al.* 2020; Sundblad *et al.* 2014). A study by McSkimming *et al.* (2021) noted that the epifaunal richness and abundances, however, were comparable after one year to a natural seagrass meadow.

2.5 Linkage between potential seagrass enhancement locations and qualifying features of National Site Network SPAs

2.5.1.1 The qualifying features associated with this resilience measure and the National Sites Network (including FFC SPA) include kittiwake, guillemot, razorbill and gannet. For these key seabird species' clupeids, gadoids and sandeels are of particular importance as they form the main diets of these seabirds. All of these forage fish species may utilise seagrass meadows at specific periods within their lifecycle with potential to enhance recruitment to the wider stock and therefore prey resource. Herring and sprat in particular are known to show an affinity to seagrass meadows (see **paragraph 2.5.1.2** below) although the nature of this role has not yet been quantified (Unsworth and Butterworth 2021).

2.5.1.2 Since the 1930's seagrass meadows in the Humber Estuary have declined dramatically (Phillip 1936). The Humber Estuary is an important fish spawning area for sandeel and an important nursery area for herring and sprat (Rogers *et al.* 1998). The Humber Estuary has a diverse fish assemblage, comprising of many different ecological types, both resident and migratory. A report on the fish assemblage of the Humber Estuary found the occurrence of sprat and herring with abundances increasing during winter sampling, with sprat being one of the more abundant prey species overall (Marshall 1995). A study by Swig (2009) also identified the occurrence of herring and sprat within the Humber Estuary, particularly associated with the Paull Holme Strays habitat restoration site. Many of these species are prey for seabirds in the North Sea including kittiwake, gannet, guillemot and razorbill. Organisations are undertaking research and trials to expand the last remaining seagrass meadow in the Humber Estuary at Spurn Point Nature Reserve. Yorkshire Wildlife Trust (YWT) are undertaking trials to discover the optimal biotic and abiotic conditions for gathering and germinating seagrass seeds (YWT 2021).

2.5.1.3 In April 2021, the largest seagrass project commenced in the Plymouth Sound and the Solent. This restoration project is a partnership led by OCT and involving Natural England, and numerous other stakeholders and volunteers (OCT 2021). The project aims to plant seagrass bags across a total of 8 ha of seagrass meadows, split equally between the Plymouth Sound and the Solent Maritime SAC. The planting unit (hessian bags) which contain *Z. marina* seeds collected from South Devon and Cornwall, will be dropped into the sea by hand and allowed to naturally sink (Marine Case Management System (MCMS) 2020). By planting seagrass, the project seeks to create more seagrass meadows which in turn will provide habitat for juvenile fish and protected marine life such as seahorses and stalked jellyfish (OCT 2021). The project will restore 40,000 m^2 of sub-tidal seagrass habitat over a 15-month period, this will be over two planting seasons suitable for optimal plant growth, which will be during March to May 2021 where 20,000 m^2 will be planted and again using the same techniques during March to May 2022 when 20,000 m^2 will also be planted (MCMS 2020).

2.5.1.4 Opportunities are currently being explored by the Applicant to expand existing seagrass restoration projects or create new seagrass restoration projects in partnership with the academic community. This potential seagrass restoration effort could form a resilience measure to support the wider compensation measure proposal (further detail is provided in **Section 1.2**).

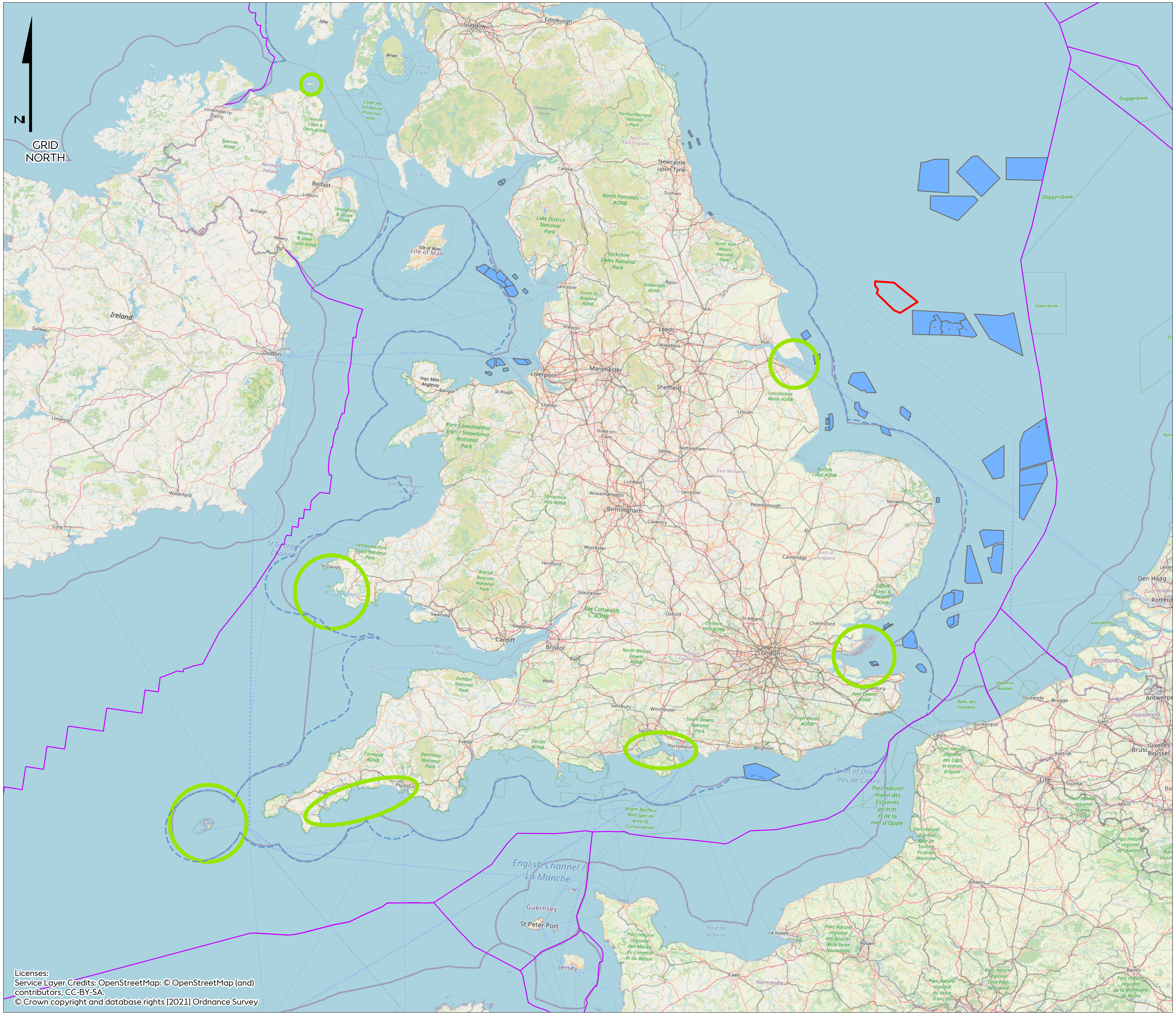
2.5.1.5 The exploration of the potential broad area for seagrass restoration by the Applicant is ongoing. However, the main regions being considered consistently support all four of the target seabird species. As a result, these areas have the potential to not only provide options for seagrass restoration but support other compensation measures proposed by the Applicant.

2.5.1.6 Potential existing seagrass meadows are being considered in locations within proximity to the primary razorbill and guillemot compensation measures i.e. bycatch and predator eradication, with connectivity with east Atlantic biogeographic region populations including the Solent, Bailiwick of Guernsey, Cornwall and Devon, Isles of Scilly, Essex, Rathlin Island and Humber Estuary (see **Figure 2**). All of these locations are being considered for potential feasibility trials and future implementation. Consideration of the location of seagrass restoration will be given due to the relevant connection between where the seabird species forage in relation to the seagrass restoration location and where prey fish species migrate to after leaving the restoration site (see **Section 4.2**). Seagrass restoration locations will also consider the prey fish species recorded in the vicinity of the restoration site to determine if key prey species will be benefited.

2.5.1.7 Kittiwake are migratory following the breeding season with many birds travelling to the western Atlantic via the North Sea or remain in the North Sea at low densities throughout the year. The mean maximum foraging range of kittiwake is 156.1 km (Woodward *et al.* 2019). However, this foraging distance may also be dependent on prey availability and so may vary from year to year, potentially, with shorter foraging ranges in years with more abundant prey (Chivers *et al.* 2012).

2.5.1.8 From April to July (breeding season), both guillemot and razorbill are located tightly around their colonies (around the coasts of the UK except for the Humber to the Isle of Wight). During the non-breeding season, guillemot and razorbill disperse from breeding colonies into the North Sea with a general shift south towards the English Channel. The mean maximum foraging range of 73.2 km for guillemot and a mean maximum foraging range of 88.7 km for razorbill (Woodward *et al.* 2019). As seabird distributions change throughout the year, the composition of their prey can also change, for example, guillemot have a more varied diet in winter (Furness and Tasker 2000). It will therefore be important to evaluate temporal variations when undertaking site selection analysis for the purpose of planning resilience compensation measure locations. The fish habitat enhancement resilience measure will aim to improve prey availability for kittiwake, razorbill and guillemot by enhancing fish nursey habitat.

2.5.1.9 During the non-breeding season, gannets move southward via the North Sea from northern breeding colonies. A study by Miles *et al.* (2020), identified 146,581 breeding pairs of gannets in the greater North Sea region, with Woodward *et al.* (2019) reporting the mean maximum foraging range of 315.2 km for gannet. The wider suite of compensatory measures being proposed for gannet aim to provide benefits to gannet such as increase in survival and/or breeding capacity. The fish habitat enhancement resilience measure will aim to improve prey availability for gannet, by enhancing fish nursey habitat.



Hornsea Four

Compensation Measures Type Overview
Seagrass

- Hornsea Four Array Area
- Economic Exclusion Zone Boundary
- UK Offshore Windfarms

Compensation Measures Areas of Search

- Seagrass

Coordinate system:
Scale@A3: 1:3,000,000

0 40 80 160 Kilometres

0 20 40 80 Nautical Miles

REV	REMARK	DATE
	First issue	28/07/2021

Compensation Measures Type Overview - Seagrass
Document no: HOW040499
Created by: XDAOO
Checked by: JOHLE
Approved by: HUMLA

3 Review of Current Enhancement Projects

3.1.1.1 There is a growing body of evidence to support the development of effective restoration and enhancement seagrass projects, and key advice available in terms of ecological feedbacks and appropriate planning through the use of modelling. Whilst evidence gaps remain, the existing knowledge and experience of restoration projects and associated processes and technology published in the academic literature are considered a major strength for informing future programmes. The Applicant is aware of several seagrass restoration projects and proposals, with some located within or in proximity to where the potential seagrass restoration sites are being considered. These projects and/or proposals are detailed below.

3.1.1.2 The YWT is currently engaged in a restoration project restoring the last remaining seagrass meadow in the Humber Estuary, located within the national nature reserve at Spurn Point (YWT 2021). YWT is currently replanting 4 acres over 18 months, collecting seeds from the remaining meadow fragments and replanting areas to improve coverage and connectivity, where YWT is working with partners to support the long-term restoration of 250 acres of seagrass within a specially managed protected area. The methodology proposed for this piece of work includes direct seeding and planting of seedlings. The YWT are also collecting seagrass fronds between August and September 2021 as part of the second phase of their Humber seagrass restoration project (YWT 2021). The collection of seagrasses within the Humber will reduce biosecurity concerns and genetic variations.

3.1.1.3 In April 2021, the largest seagrass restoration project commenced in the Plymouth Sound and the Solent led by OCT in partnership with Natural England, as part of the LIFE Recreation ReMEDIES Project. The project aims to restore a total of 8 ha of seagrass meadows, split equally between the Plymouth Sound and the Solent Maritime SAC and is the first of its kind to collect seagrass seed and cultivate and replant seagrass at this scale in England. A team of scientists, conservationists and divers handpicked the reproductive seed-bearing shoots for cultivation by OCT in their purpose-built 400 m^2 seagrass cultivation facility and after approximately three months were transplanted at sea using 'small hessian bags' containing the seedlings (Nolan 2020). The aim is to grow tens of thousands of seedlings over the next three years in this way (Nolan 2020). By planting seagrass, the project seeks to create more seagrass meadows which in turn will provide habitat for juvenile fish and protected marine life such as seahorses and stalked jellyfish (OCT 2021). The OCT are monitoring the restoration site in Plymouth Sound, where over 18,000 seeds and seedling bags were transplanted by hand, to determine growth rates and overall success.

3.1.1.4 Although the process of restoration for the Seagrass Ocean Rescue project (see **paragraph 2.4.3.5**) is now complete, having successfully planted 2 ha of seagrass in Dale Bay, Pembrokeshire, Wales. Efforts are ongoing and focus on long-term monitoring of the restored habitat.

3.1.1.5 In July 2021, Hampshire and Isle of Wight Wildlife Trust (HIWWT) in partnership with Boskalis Westminster received funding from the People's Postcode Lottery for their Solent Seagrass Restoration Project. The project will collect seagrass seeds and plants using hessian bags and aims to support increased biodiversity, sustainable fisheries and ecosystem services. The project will also involve long-term monitoring to identify lessons to be learned and allow for replication at scale in the Solent and wider region (HIWWT 2021).

3.1.1.6 Another potential restoration project is located in the Tees Estuary, as part of the IMMERSE project which aims to address the issue of the coastal squeeze on the estuary, by creating intertidal habitat at a pilot site (Tees River Trust 2021). The project is funded by the EU INTERREG Programme, however, to date, no information has been publicly shared about progress.

3.1.1.7 These projects can provide lessons learned on seagrass restoration in England and Wales such as the guidance on site selection, methodology and stakeholder engagement, including the local marine users and community. Information on planning, management and monitoring can also be informed by the above projects, including most appropriate approaches and the way in which long-term monitoring can inform adaptive management measures, as long-term planning at the start should take into account what is realistic and feasible in terms of scale and longevity.

4 Conclusions

4.1.1.1 UK seagrass supports diverse communities of fish, invertebrates, algal epiphytes and birds. It helps keep our coastal waters clean, stripping them of pathogens and stores carbon at rapid rates. The biodiversity in seagrass meadows helps supports productive fisheries and complex food webs.

4.1.1.2 Seagrass meadows in the UK are likely to have an indirect effect on pelagic birds by acting as a nursery habitat for their prey items. Although, there does not appear to be any literature that connects the birds with seagrass directly. Connections can be made between the diets of pelagic bird species (comprising sandeel, herring and sprat) linked to knowledge of how individual fish species utilise seagrass. Further research to identify spawning locations and juvenile forage fish species movements would help to determine the link between seagrass associated fish and locations of key bird species foraging grounds.

4.1.1.3 The location of a seagrass restoration is key to ensuring that the habitat and conditions are suitable for supporting seagrass beds. Areas that have previously supported seagrass beds may have changed to an extent that any habitat enhancement work may be too costly or impractical to reverse to support seagrass beds. The best approach is site selection suitability modelling followed by detailed site assessment and pilot studies.

4.2 Next steps

4.2.1.1 The fish habitat enhancement seeks to improve vital habitats for fish species such as those that provide spawning or nursery grounds to increase the productivity of fish species. The main aim for the proposed seagrass restoration resilience measure is to support other compensation measures such as predator eradication, bycatch reduction and provision of artificial nesting. The restoration of seagrass aims to provide an increased or additional food source for the key seabird species covered by the suite of proposed compensation measures. The fish habitat enhancement work will provide an increased resilience to both compensated individuals and the wider seabird population by supporting the full suite of compensatory measures (predator eradication, bycatch reduction measures and artificial nesting structures) proposed. Additional information on the timeline and proposed scale of restoration is provided in **Volume B2, Annex 8.6: Compensation measures for FFC SPA: Fish Habitat Enhancement: Roadmap**.

4.2.1.2 As detailed in this document there are a number of evidence gaps in the understanding of the level of support seagrass provides to prey species and the links with kittiwake, guillemot, razorbill and gannet. Research that could support our understanding and contribute to this resilience compensatory measure is being considered. Such research will provide important baseline data contributing to knowledge gaps for the ecosystem role that UK seagrass meadows provide. As yet, there does not appear to be any literature that directly connects the key seabirds with seagrass habitats. Connections could be made through improved understanding of the diets of pelagic bird species linked to knowledge of how individual fish species utilise seagrass. Therefore, expert opinion discussions will need to take place to determine the best approach to gathering evidence.

4.2.1.3 Moreover, there have been limited studies on the identified key prey species in seagrass beds in the UK. A site-specific survey will be undertaken to determine the use of seagrass by key prey species. This will require extensive fish surveys in an area of interest and the search area is including Northumbria, Solent and Cornwall. In conjunction with this, and due to limited information on the movement of these key fish species a migratory fish tagging exercise is being considered subject to practical requirements of the specific species. The aim of this research will help to determine connectivity between juvenile forage fish species associated with seagrass meadows and their potential distribution into the wider North Sea region following maturation. The tagging of these fish species could also aid in investigating the value of seagrass for the recruitment of fish stocks. This is primarily to support the limited scientific evidence and associated tagging data (see **paragraphs 2.2.3.2** to **2.2.3.5**). By researching these topics further evidence can be used to support the restoration of seagrass beds in key areas and determine the availability of prey fish resources associated with seagrass for the key seabird species: kittiwake, guillemot, razorbill and gannet.

4.2.1.4 In addition to providing evidence to support the linkages between seagrass, prey fish species and seabirds of interest, areas of interest for seagrass restoration will require further study to determine suitability for restoration efforts. This will include habitat suitability modelling, physical and biological surveys, monitoring and feasibility trials prior to the selection of specific sites in areas such as Northumbria, Solent and Cornwall (see **Figure 2**). During site selection determination the health and nutrient status of the nearest seagrass meadow/bed in the prospective location will be assessed. Unfavourable conditions include continuous sediment resuspension and high turbidity, lack of stable sediments for seedling growth, and strong wave action that damages or uproots plants (Maxwell *et al.* 2017). Therefore, good planning and baseline measurements supported by habitat suitability monitoring is key to this process.

4.2.1.5 There have been many small-scale restoration trials around the globe, that have shown success and knowledge transfer has been considered critical across projects (Orth *et al.* 2020). However, larger projects require long-term commitment and collaboration from stakeholders. To ensure long-term establishment of a restoration site a long-term monitoring strategy to inform adaptive management measures will likely be required. Long-term monitoring of seagrass included recording the rates and patterns of growth/loss in a site, the likely drivers of any losses and general monitoring of successes will aid in future restoration works. As a result, this information can confirm the efficacy of seagrass restoration methods and can also be used to make adaptive management decisions (Maxwell *et al.* 2017). Continuous monitoring throughout the restoration project to determine success is considered key, with Moksnes *et al.* (2021) noting regular monitoring of test planting sites, before planting at greater scales, determined the most suitable biotic and abiotic factors for success at a larger scale.

4.2.1.6 Moreover, stakeholder engagement is considered important for restoration projects and stakeholder engagement could be required throughout the restoration project development. Stakeholders can range from local communities, local and national NGOs, and government bodies. Where stakeholder support is considered helpful for the success of a project, early engagement should aim to ensure that they are willing to engage, assist and contribute.

4.2.1.7 Once a site has been deemed suitable, seed collection will need to be considered. A nearby seagrass meadow/bed will likely be selected in consultation with appropriate stakeholders such as Natural England to avoid genetic or biosecurity risks. The Applicant will likely work in collaboration with an organisation experienced in seagrass restoration, particularly those with previous or ongoing involvement in the potential locations for seagrass restoration, as illustrated in **Figure 2**. The Applicant is also willing to consider contributing to ongoing/existing seagrass restoration project with the proposed areas where appropriate and feasible, to provide a higher likelihood of success.

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